Manitoba Hydro's plans to meet provincial electricity demands and export opportunities

Hilmi Turanli and **Ronald Mazur**[1]
Manitoba Hydro

Manitoba Hydro is experiencing an on-going growth in electricity load in the province as well as increasing export opportunities. This article describes the current power system, and identifies future hydro generation potential along with associated transmission required to deliver this generation to Manitoba load and export customers. Manitoba's hydro power resources offer a very large potential for reliable green clean energy generation for Canada: There are over 5,000 MW of clean hydro electric energy potential to develop; this requires resilient bulk transmission capacity to transfer this power to load centers in the most efficient way. Here we are discussing today's reliability, projects under way and plans for future development of electrical energy and transmission for a smart(er) , highly resilient, electricity grid.

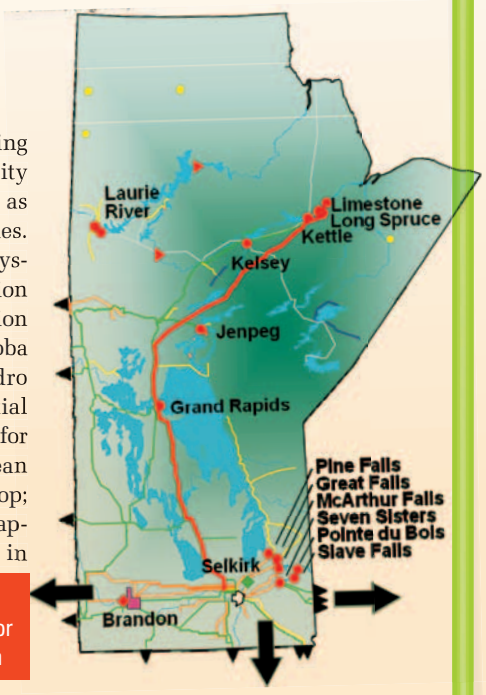

Figure 1: Existing Generation and Major Transmission System

As reported in earlier publications [1, 2, 3], Manitoba Hydro studied the possible development of new hydroelectric generation stations in northern Manitoba. Three sites were under consideration: Gull Rapids on the Nelson River, Notigi on the Rat River and Wuskwatim on the Burntwood River. Manitoba Hydro has recently completed construction of its newest hydroelectric generation station Wuskwatim G.S. (rated 214 MW) on the Burntwood River. New outlet transmission facilities needed for the plant were completed in 2011. The plant was placed into service during the summer/fall of 2012.

Manitoba Hydro has recently studied the possible further development of new hydroelectric generating stations in northern Manitoba. Two sites were under consideration: Keeyask G.S. (formerly called Gull G.S.) and Conawapa G.S., both on the Nelson River. The necessary community consultation, engineering, economic and environmental studies were completed to enable decisions to be made on continuing development. In June 2014, Public Utilities Board (PUB) Need For Alternatives To (NFAT) Panel recommended that the Government of Manitoba authorize Manitoba Hydro to proceed with the construction of the Keeyask Project to achieve a 2019 in-service date.

Existing Generation and Major Transmission System

Manitoba Hydro is a provincial Crown Corporation providing electricity to 548,774 customers throughout Manitoba and natural gas service to 269,786 customers in various communities throughout southern Manitoba [4]. Manitoba Hydro also has formal electricity export sale agreements with a number of electric utilities and marketers in the Midwestern U.S. and the Canadian provinces of Ontario and Saskatchewan.

[1]Mr. Mazur has recently retired from Manitoba Hydro.

Figure 3: Wuskwatim G.S.

The amount of electricity generated from renewable resources amounts to 99% of the total energy generated [5] where the majority is from self-renewing waterpower. On average, about 33.1 billion kilowatt-hours of electricity are generated annually. Seventy-five percent is produced by five hydroelectric generating stations on the Nelson River; the remainder is generated at nine hydroelectric stations on the Winnipeg, Saskatchewan, and Laurie rivers; two thermal stations; and four diesel sites. The electricity is transmitted over nearly 105,000 kilometers of transmission and distribution lines.

Manitoba Hydro has 5725 MW of generation connected to its network. In addition, 116 MW of wind generation at St. Leon and 138 MW of wind generation at St. Joseph are available to Manitoba Hydro under power purchase agreements. In 2012, wind plants in Manitoba produced 875 GW.h, while in 2013 they produced 900 GW.h. Roughly 2.5% of Manitoba's annual energy generation is supplied by wind turbines.

In 2013, the corporation supplied a provincial gross total peak of 4535 MW (weather adjusted 4432 MW) [4]. The provincial peak load is growing at an average rate of about 1.5% per year (energy 1.5% per year).

The transmission system in Manitoba is interconnected to the transmission systems in the provinces of Saskatchewan and Ontario and the states of North Dakota and Minnesota by 12 tie lines. Of these, three 230 kV lines and one 500 kV line interconnect the Manitoba system to the United States, three 230 kV and two 115 kV lines interconnect to Saskatchewan, and two 230 kV lines and one 115 kV line interconnect to Ontario; see Figure 1, page opposite.

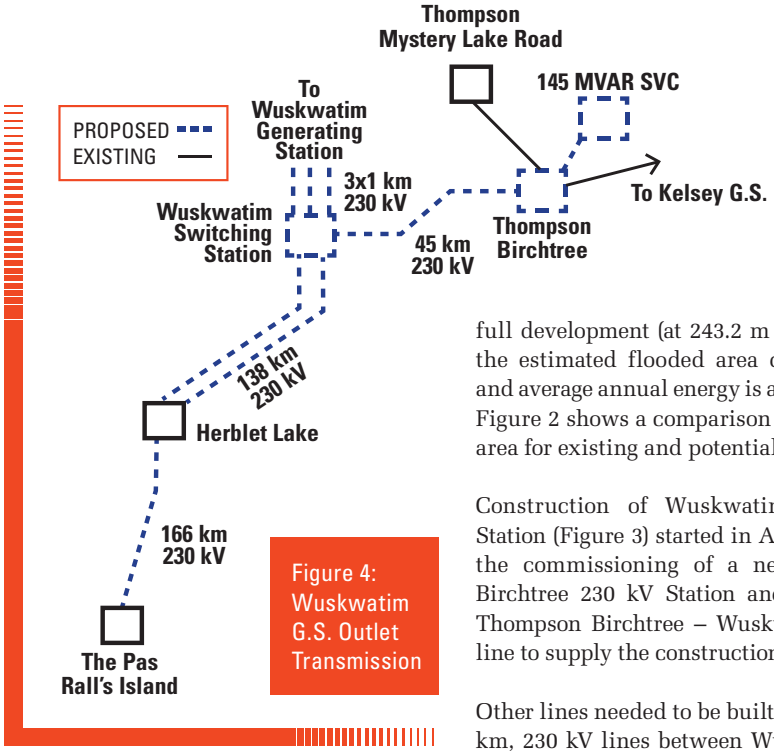

Figure 4: Wuskwatim G.S. Outlet Transmission

The tie lines to the US and Ontario are equipped with a special protection system that reduces the HVDC power (to eliminate the surplus power above tie capability) very rapidly following the loss of a tie in order to prevent cascade tripping of the remaining tie lines.

Wuskwatim Generation and Outlet Transmission Facilities

The initial concept design of Wuskwatim and Gull (now named Keeyask) started in the 1990s. The generation station design was modified to have less effect on the environment, greater public and market acceptability, but at higher cost and lower generation capacity. Flooding was designed to be less than 1-km square at Wuskwatim. When partial development (at 235 m forebay level) of Wuskwatim is compared to full development (at 243.2 m forebay level), the estimated flooded area drops by 90% and average annual energy is about 25% less. Figure 2 shows a comparison of the flooded area for existing and potential hydro plants.

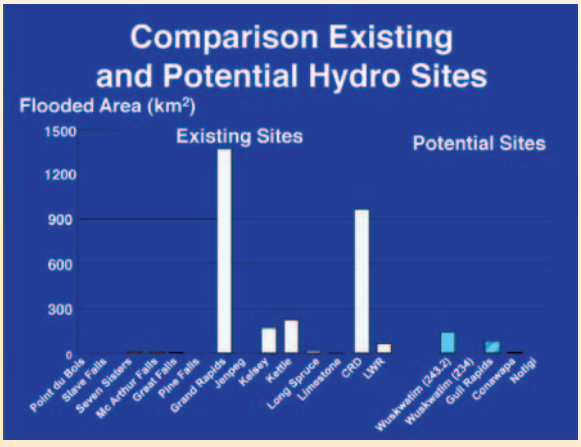

Figure 2: Comparison of flooded area [1,2]

Construction of Wuskwatim Generation Station (Figure 3) started in April 2007 with the commissioning of a new Thompson Birchtree 230 kV Station and 45 km long Thompson Birchtree – Wuskwatim 230 kV line to supply the construction power.

Other lines needed to be built were: two 138 km, 230 kV lines between Wuskwatim and Herblet Lake, and one 166 km, 230 kV line from Herblet Lake to The Pas Ralls Island (Figure 4). A Static Var Compensator, rated -50/95 MVAr continuous, and 145 MVAr for 10 seconds overload rating was installed at the Thompson Birchtree 230 kV Station to provide transient voltage control. In addition to connecting new generation to the system, the new facilities have improved the reliability of the overall transmission system.

Riel Station Reliability Project

D602F, a 500 kV line, connected the Dorsey 500 kV AC Station, north of Winnipeg, to Forbes Station near Duluth, Minnesota in the U.S. A new station, Riel, is to be built just east of Winnipeg adjacent to the right of way of the 500 kV line; see Figure 5 on following page.

The Riel Station is located on the south-east Winnipeg periphery adjacent to major 230 kV and 500 kV transmission corridors, making it an ideal location for a new supply point for Winnipeg load.

The location minimizes the need for new transmission corridors into and out of Riel and reduces the amount of new west to east transmission across Winnipeg as it provides an alternate supply point to Dorsey, which is located on the northwest periphery of Winnipeg.

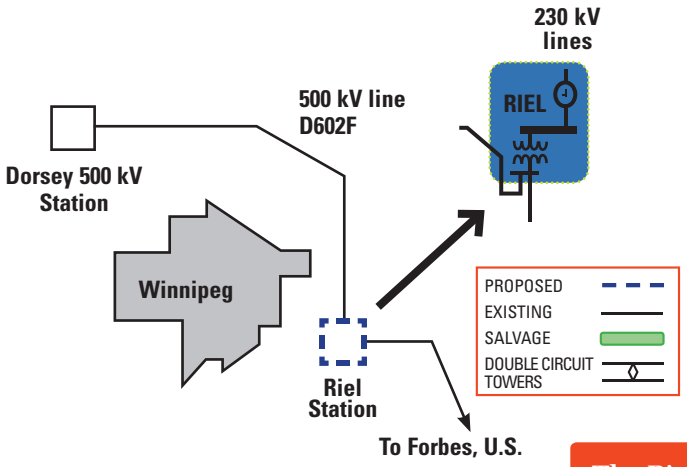

Figure 5: Riel Station Development and Dorsey – Forbes Line Sectionalization[2]

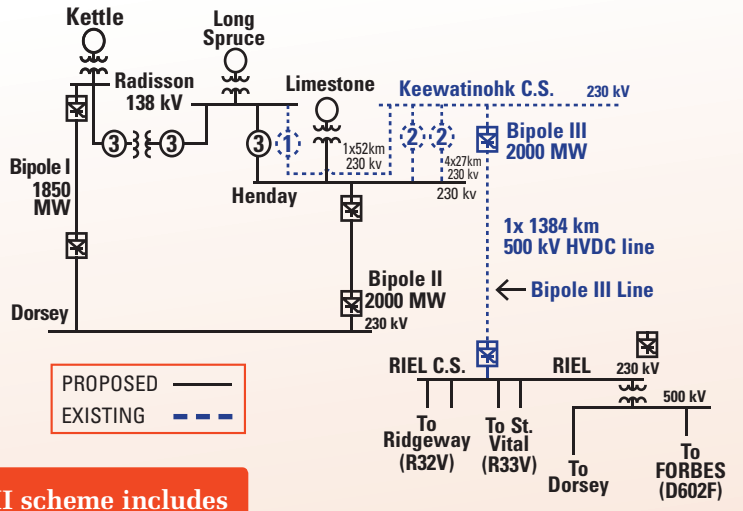

Figure 7: Bipole III Reliability Project

The Bipole III scheme includes (Figure 7):

- A ±500 kV HVDC transmission line, about 1392 km long, from Keewatinohk Converter Station to Riel Converter Station.
- A 2,000 MW converter station in the north (Keewatinohk C.S.).
- One 52 km-long 230 kV transmission line from Long Spruce to Keewatinohk.
- Four 27 km-long 230 kV transmission lines from Henday to Keewatinohk.
- A 2,000 MW converter station at Riel.
- Sectionalizing of the Ridgeway-Richer 230 kV line into the Riel Converter Station.

The project included establishing the Riel Station site, installing 230 kV and 500 kV switch yards, installing a 1,200 MVA, 230 kV to 500 kV transformer bank, sectionalizing the existing Dorsey-Forbes 500 kV line[2], sectionalizing two existing 230 kV lines (Ridgeway-St. Vital lines R32V and R33V), and installing 500 kV line reactors.

The project will improve system reliability by adding an alternate terminal point for the 500 kV transmission line to the U.S., thereby preserving Manitoba Hydro's system import capability if there is a major outage at Dorsey. The station went into service in October 2014.

Bipole III Reliability Initiative

Enhancement of the reliability and security of HVDC transmission lines and the Dorsey Converter Station has been under investigation for some time. The HVDC transmission lines, Bipoles I and II, are located on a common right-of-way corridor referred to as the Interlake corridor (green line in Figure 6), 905 kilometers in length.

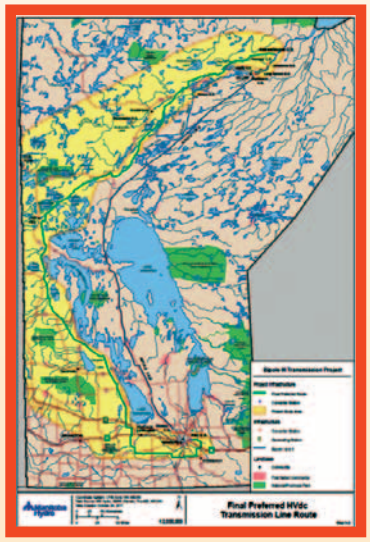

Figure 6: Bipole III Transmission Route

The southern converters of Bipole I and II are both located in the Dorsey Converter Station. The Bipole I & II corridor and the Dorsey Station are vulnerable to rare, but severe weather events such as wind bursts, tornados and ice storms; that could cause extended outages and severe hardship to Manitoba Hydro customers and Manitoba. One such event occurred on September 6, 1996 when straight line winds associated with a microburst resulted in the collapse of 19 HVDC transmission towers north of the Dorsey Converter Station, resulting in the loss of the Bipole I & II lines for about 5 days.

Development of Bipole III will require a Class 3 license under The Environment Act (Manitoba). The environmental impact assessment for the project, including a program of community/public consultation and the identification of potential impacts and mitigative measures, has been documented in an Environmental Impact Statement (EIS). The project EIS was filed with Manitoba Conservation in the fall of 2011 as application for the Environment Act License. The Clean Environment Commission (CEC) began public hearings on Manitoba Hydro's Bipole III transmission project on October 1, 2012. The hearings provided participants with an opportunity to review and comment on the project and its environmental impacts. The hearings were completed in March 2013. An Environmental Act License was received in August 2013.

Bipole III transmission line will run from a new converter station named Keewatinohk in the north located near Conawapa to Riel Converter station south of Winnipeg.

Manitoba Hydro evaluated the converter technology to be used for Bipole III thoroughly [6]. A new technology, referred to as the Voltage Source Converter is available as an alternative to the existing Line Commutated Converter (LCC) technology used for Bipoles I and II, however Manitoba Hydro opted for LCC due to economical considerations

The rating of the Bipole III is planned to be operated at 2,000 MW with a 15% continuous overload. The estimated in-service date for Bipole III is the summer of 2018.

Future Nelson River Generation Development

The planning is underway for two new generating stations, the Keeyask G.S. and the Conawapa G.S., on the Nelson River (Figure 8).

[2]Sectionalizing the existing Dorsey-Forbes line means cutting the line at Riel and terminating it at Riel to form a Dorsey- Riel line and a Riel-Forbes line.

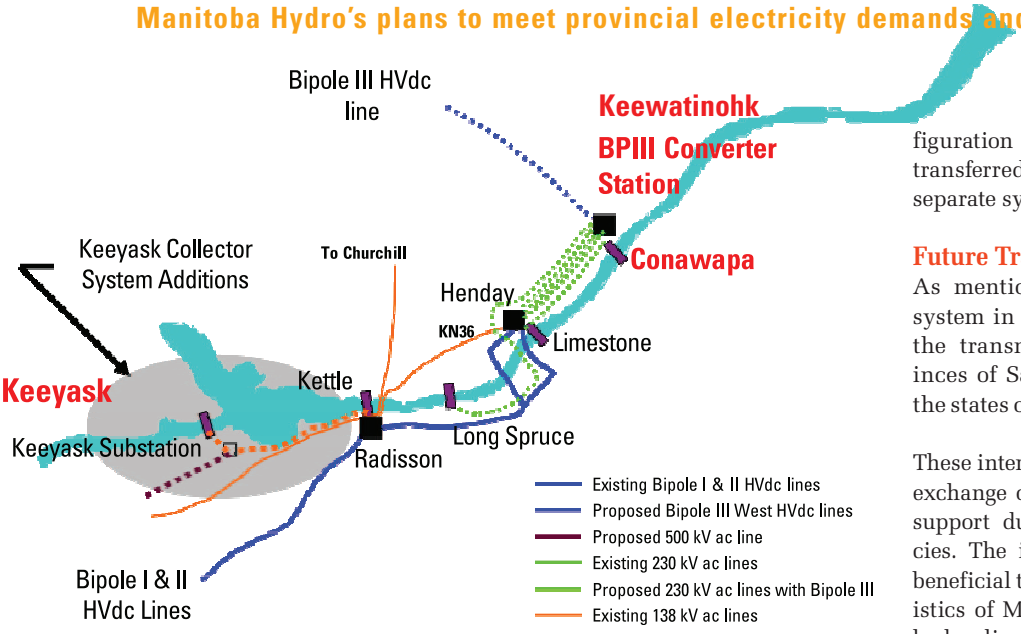

Figure 8: Northern Collector System

The Keeyask G.S. will be located about 61 kilometers upstream from the existing Kettle G.S. (1,224 MW). The Conawapa G.S. will be located about 51 kilometers downstream from the existing Limestone G.S. (1,350 MW).

Future Keeyask and Conawapa Generation and Outlet Transmission Facilities

The 695 MW (630 MW net) Keeyask Generating Station will require new outlet transmission facilities needed to connect the generating station to the Manitoba Hydro grid.

A new Keeyask Switching Station will be established to terminate seven new 138 kV lines including four unit lines (approximately 3 km each) to receive the power from Keeyask Generating Station, and three 138 kV transmission lines (approximately 35 km each) to convey the power to Manitoba Hydro's existing Radisson Converter Station [4]. The 2,000 MW Bipole III, slated to be in-service in 2018, will increase the capacity of the Bipole I, Bipole II and Bipole III HVDC system to accommodate the Keeyask generation.

A construction power station will be built and fed primarily from a 138 kV transmission line with an approximate length of 23 km tapped from existing line KN36. One of the Radisson-Keeyask lines will be constructed earlier than the other two, in order to serve as a back-up source of construction power. Station upgrades at the Radisson station will also be required. In addition to connecting new generation to the system, the new facilities will improve the reliability of the overall transmission system (Figure 9).

The in-service date for the first unit at Keeyask is anticipated to be September 2019. All of the transmission facilities will be in-service on August 2019.

Conawapa Generating Station with a rating of 1,485 MW rating (net 1,395 MW) with an in-service date of 2029/30 at the earliest and subject to further regulatory approvals will be connected into the Northern Collector System (NCS) at Keewatinohk (Figure 9). The only transmission required for Conawapa will be five short lines (7 km each) between the generating station and Keewatinohk. Also NCS will be split into two systems at Radisson to respect the stability limit and associated switching configuration and one Kettle unit will be transferred to the northern ac system (a separate system from NCS).

Future Transmission Interconnections

As mentioned above, the transmission system in Manitoba is interconnected to the transmission systems in the provinces of Saskatchewan and Ontario and the states of North Dakota and Minnesota.

These interconnections allow for economic exchange of electricity as well as provide support during electric system emergencies. The interconnections are especially beneficial to Manitoba due to the characteristics of Manitoba Hydro's predominantly hydraulic generation system. As well as exporting electricity surplus to Manitoba's needs, the interconnections allow Manitoba Hydro to import energy when economical or when river flows are low.

Manitoba Hydro has contracted with Minnesota Power (MP) to provide 250 MW over 15 years starting in 2020. Recently, Manitoba Hydro and Minnesota's Great River Energy have signed a memorandum of understanding to look at the province's energy utility selling up to 600 MW of electricity starting in about 2020. In February of 2014, Manitoba Hydro has inked two major power sales to Green Bay based Wisconsin Public Service (WPS) a subsidiary of Integrys Group Inc. (NYSE: TEG) in the United States. The first sale, running from 2016-2021, is for 108 MW of firm power. The second sale – based on electri-

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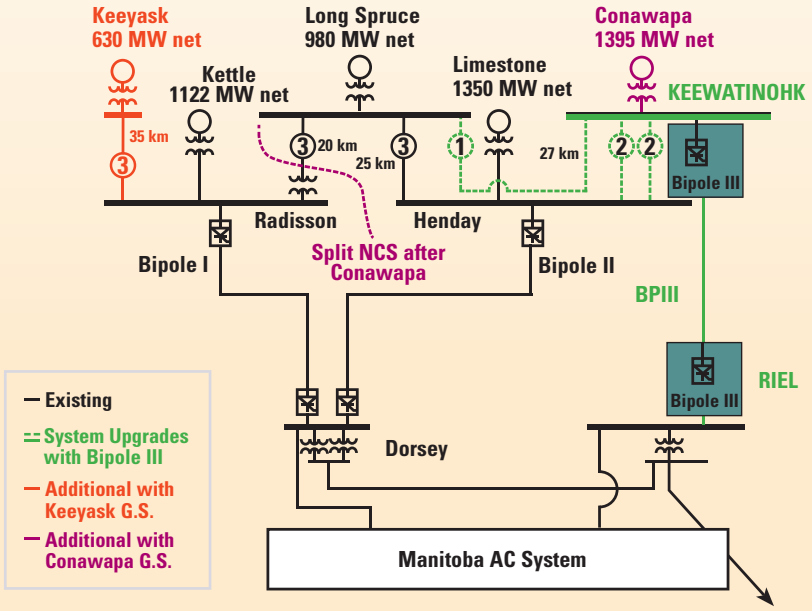
Figure 9: Northern Collector System Development



city produced by the proposed new Conawapa Generating Station on the Nelson River – is for 308 MW of firm power for up to 10 years. The 308 MW sale is scheduled to start in 2027.

The proposed power sales agreements will require new hydroelectric development in northern Manitoba (Keeyask and Conawapa) and a new transmission line between Canada and the United States. Studies are underway to determine the necessary transmission facilities to boost the firm Canada to U.S. export capability.

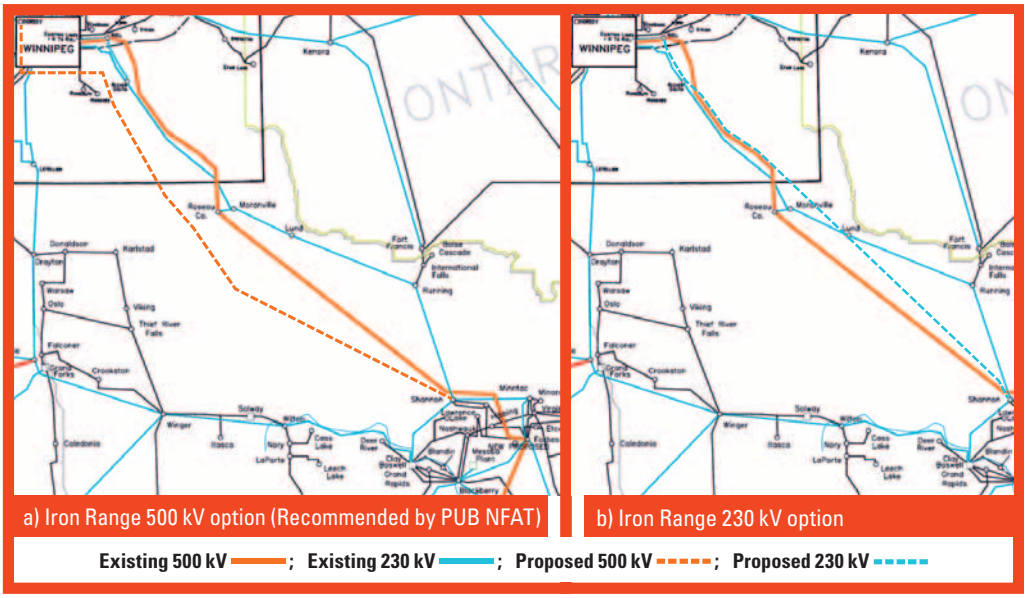


Figure 10: Options for New Transmission Line into Minnesota

There were a number of transmission line options being studied to date. These included a 500 kV line into Fargo, North Dakota area, a 500 kV line into Iron Range area in Minnesota, and a 230 kV line, also into Iron Range, Minnesota. **The Winnipeg (Dorsey)-to-Iron Range line (Option 1 below) has been found at this time as the most beneficial.**

1 Winnipeg (*Dorsey*) to Iron Range (Blackberry, Shannon, or new Iron Range Station); 500 kV line

This 750 MW project consists of a 225-kilometer-long Winnipeg-to-U.S.-border 500 kV line, and a 210-mile-long U.S.-border -to-Iron Range 500 kV line, with a planned in-service of June 2020; see Figure 10(a).

Approval for the project and this in-service date were recommended in June 2014 by Manitoba Hydro's Public Utilty Board through its Needs For and Alternatives To Review (NFAT) Panel. It is now known as the Manitoba-Minnesota Transmission Project. Further provincial and federal regulatory approvals will be required before construction starts. [3]

2 Winnipeg (*Riel*) to Iron Range (Shannon); 230 kV Line

This option (2020) identified as a minimum requirement for MP 250 MW sale consists of a 145-kilometer-long Winnipeg-to-U.S.-border line and 210-mile-long U.S.-border-to-Iron Range line; see Figure 10(b).

Conclusions

Manitoba Hydro has over 5,000 MW of clean hydroelectric energy potential to develop. The past development of its hydroelectric generating plants on the Nelson River in northern Manitoba has allowed Manitobans to enjoy some of the lowest electricity rates in North America. Manitoba Hydro is exploring the feasibility of developing new northern hydroelectric generation sites and new interconnections to meet future load growth and new contracts to ensure that these low rates can be sustained in the future. ■

References

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6. D. Jacobson et al, "Planning the Next Nelson River HVDC Development Phase Considering LCC vs. VSC Technology", Paper B4-103, CIGRE, August 2012.

[3] This U.S. Transmission Interconnection Project has a total line length of about 560 km. It will originate at the Dorsey Converter Station, located near Rosser, northwest of Winnipeg and travel south around Winnipeg. The line will continue south crossing the Manitoba-Minnesota border, and will then connect to the Great Northern Transmission Line that will be constructed by Minnesota Power. The Great Northern Transmission Line will terminate at the Iron Range Station located northwest of Duluth, Minnesota.

Hilmi Turanli *received his B. Sc. and M. Sc. degrees (both in Electrical Engineering) from the Middle East Technical University, Ankara, Turkey in 1976 and 1980. He was granted his Ph. D. degree from the University of Manitoba in 1984, while completing a special research project for Manitoba Hydro. Later, he taught at the University of New Orleans. He also consulted for Louisiana Power and Light Company. With Manitoba Hydro since 1986, he is currently Senior Interconnections Planning Engineer in the System Planning Department. Dr. Turanli is a Senior Member of IEEE, and is registered as a Professional Engineer in Manitoba. He was designated as a Fellow of Engineering Institute of Canada and Fellow of Engineers Canada in 2001 and 2010, respectively.*

Ronald W. Mazur *received his B. Sc. and M. Sc. degrees, both in electrical engineering from the University of Manitoba, Winnipeg, MB in 1971 and 1989, respectively. Following his undergraduate graduation, he worked for Atomic Energy of Canada Limited in Pinawa, MB for a short time. In 1974, he joined Manitoba Hydro and worked on switching station design, system operations and system planning. He was the manager of System Planning Department at the time of his retirement in 2014.*