Ontario-Quebec Interconnection Capability

A TECHNICAL REVIEW

Prepared by the
Independent Electricity System Operator
for the Deputy Minister of Energy

May 2017

ieso
Connecting Today.
Powering Tomorrow.

Contents

List of Figures 3
1. Introduction 4
2. Benefits of Interties 6
Economic Efficiency 6
Capacity and Energy 6
Reliability 8
Operability 8
2.1 Interconnections with Quebec and their Historical and Current Usage 10
3. Import Capability from Quebec on Existing Interties 13
3.1 Description of the Eastern Ontario Transmission Network 14
Hawthorne TS Hub and the Transmission System in the Ottawa Area 15
St. Lawrence TS Hub and the Transmission System in South Eastern Ontario 16
3.2 Using Technical Criteria to Determine Import Capability of the Eastern Ontario Transmission Network 17
3.3 Technical Evaluation of Import Capability 18
Case 1: Existing System 18
Case 2: After Replacing the Disconnect Switches at Hawthorne TS 18
Case 3: After Reconductoring the 230 kV Circuits Between Hawthorne TS and Merivale TS 19
Case 4: Operating the Beauharnois Intertie in Bus-Split Mode 20
Case 5: After Reinforcing the Eastern Ontario Network 22
4. Import Capability with New Ontario-Quebec Interties 24
4.1 New Intertie at Outaouais 25
4.2 New Intertie at Beauharnois 26
4.3 New Intertie at Chats Falls 27
5. Capacity and Energy Considerations 28
Using Interties for Importing Firm Capacity 28
Using Interties for Additional Energy 29
Flexible Energy Imports 29
Baseload Imports 30
6. Conclusion 30
Appendix A: Regulatory Context for Ontario's Operational and Planning Criteria 31

List of Figures

Figure 1. Existing Ontario-Quebec Interconnections........ **10**

Figure 2. Summary of Total Yearly Imports and Exports between Ontario and Quebec, 2013-2016........ **11**

Figure 3. 2016 Imports from Quebec by Intertie........ **12**

Figure 4. Eastern Ontario Transmission Network........ **14**

Figure 5. Hawthorne TS Hub and the Transmission System in the Ottawa Area........ **15**

Figure 6. St. Lawrence TS Hub and the Transmission System in South Eastern Ontario........ **16**

Figure 7. 230 kV Circuits between Hawthorne TS and Merivale TS........ **19**

Figure 8. 230 kV Circuits between Hawthorne TS and Merivale TS........ **21**

Figure 9. Rebuild Existing 115 kV circuit L2M to be a Double- Circuit 230 kV Transmission Line........ **22**

Figure 10. New Intertie at Outaouais........ **25**

Figure 11. New Intertie at Beauharnois........ **26**

Figure 12. New Intertie at Chats Falls........ **27**

1. Introduction

In October 2014 the Independent Electricity System Operator (IESO) and the Ontario Power Authority (OPA) (now merged) provided a report in response to a request from the Minister of Energy for a review of the opportunities and constraints that may exist on Ontario's intertie connections to meet demand for electricity and support other reliability requirements of the power system. The report focused on the technical capabilities of the interties and the Ontario transmission system. It also outlined possible infrastructure investments and market factors that could influence decisions on transactions between Ontario and Quebec. Ontario's Deputy Minister of Energy has requested a technical update to the 2014 assessment, and that is the purpose of this document.

Ontario's ability to trade[1] electricity with Quebec is determined by the capability of the interties with Quebec, as well as the capability of Ontario's transmission system to deliver imported electricity from the Ontario-Quebec border to Ontario's consumers. As was the case with the 2014 report, this report focuses on the technical capabilities of the interties and the Ontario transmission system. This report does not consider the commercial aspects of electricity trade.

Intertie transactions are beneficial when they measurably improve the reliable, cost-effective operation of Ontario's power system. Interconnected electricity markets provide a significant opportunity to efficiently utilize the energy generated from a diverse range of resources over a much greater geographic area, thereby lowering the cost of producing and managing electricity for all parties. Interties with neighbouring jurisdictions expand the options available to meet system needs, and Ontario's tielines – including the ones with Quebec – have provided both reliability and economic benefits to the province for over a century.

On an hourly basis, Ontario's wholesale electricity market economically schedules energy transactions to and from Ontario via the interties, providing an important balancing function that helps address the peaks and valleys of electricity demand and ultimately results in lower costs to consumers. Electricity trade provides valuable operational flexibility that helps the IESO manage increased variability as more wind and solar resources are integrated into the system, as more generation is connected at the distribution level which affects demand for grid-supplied energy, and as consumption patterns become less predictable.

Historically, Ontario and Quebec have benefited from trading electricity on a cost-effective basis. Ontario continues to import from and export to Quebec in order to meet reliability needs efficiently. Since 2014, collaboration between Ontario and Quebec has resulted in the completion of two electricity trade agreements. These agreements, which make use of existing intertie and transmission system capability, provide Ontario with cost-effective, clean energy imports from Quebec, and provide Quebec with needed capacity from Ontario.

Building on the 2014 report, but using updated modelling and analysis, this report presents several cases in which expanding the eastern Ontario transmission system could enable Ontario to maximize the firm import capability of the existing tielines with Quebec. The cases presented in this report reflect different options related to technology, complexity, timing and cost.

[1] In this report, 'trade' means the trading of electrical energy, capacity or ancillary services (such as operating reserve, which is standby or backup energy) between neighbouring electrical areas, such as between Ontario and Quebec or between Ontario and New York.

The technical analysis supporting these cases shows that an investment of about $20 million could enable the full 1,250 MW nominal import capability of the Outaouais intertie and a further investment of over $200 million could boost firm import capability to 2,050 MW.[2] The report also describes several conceptual options for new tielines. However, constructing a new tieline and completing the necessary upgrades to Ontario's transmission system would be a major infrastructure project that would require up to 10 years to develop, and cost over $1 billion. These potential investments in transmission capability – plus the cost of the energy from Quebec - would need to be weighed against other alternatives such as domestic supply or equivalent imports from other jurisdictions to ensure they are cost competitive.

This report was prepared to address intertie and transmission expansion considerations. However, transmission capability is only one of several factors in determining whether further energy or capacity transactions would provide value for Ontario consumers. Other relevant factors, such as the characteristics and costs of the capacity and energy resources in each jurisdiction, current and forecast demand/supply conditions, and market-based alternatives are not addressed in this report – but are equally, if not more important to assessing the value of potential transactions. In addition, clarity around the supporting internal transmission in Quebec is necessary to understand and better facilitate trade between the two jurisdictions.

The IESO is also working to enhance its wholesale markets to better meet system needs. Improvements under consideration include enabling the trade of capacity to meet reliability needs as well as the trade of energy and ancillary services, which already happens on an economic basis. A more dynamic market will provide increased opportunities for trading energy, ancillary services and capacity over the interties.

As part of the Market Renewal project the IESO has identified opportunities to lower the cost and risks associated with trading as well as enable trading to occur on a more frequent basis. These initiatives would enhance the value that energy trade (including transactions with Quebec) could provide in meeting Ontario's operational needs as well as lowering costs and emissions in the process.

The IESO has already facilitated capacity exports for Ontario-based generators to New York, and is committed to working closely with stakeholders to further enable capacity trading with our other neighbours, including Quebec. Having competitive market mechanisms that support efficient trading and, in particular, allow imports to help meet system needs in Ontario, will maximize value for Ontario consumers.

[2] In this report, 'capacity' is applied to supply resources (e.g. the 'capacity' of a generator to supply energy) while 'capability' is applied to transmission elements (e.g. the 'capability' of a transmission circuit to transmit energy).

2. Benefits of Interties

Ontario's connections with neighbouring jurisdictions have provided both economic and reliability benefits to Ontario for over a century.

Economic Efficiency

Interties between electricity markets provide a significant opportunity to efficiently utilize the energy generated from a diverse range of resources over a much greater geographic area, thereby lowering the cost for all parties.

Interties benefit Ontario by allowing cheaper power to access Ontario's electricity market when it is available, and enabling our generation to reach other markets across eastern North America whenever it is economic. These real-time economic transactions are a result of the differences in energy prices with power predominantly flowing from low cost energy providers towards the higher cost regions. In recent times Ontario has been a net exporter on an annual basis, reflecting today's strong supply conditions. However, it wasn't long ago that Ontario was a net importer of power when Ontario demand was high and Ontario did not benefit from such a robust supply mix. On an hourly basis power flows to and from Ontario providing an important balancing function that helps smooth the peaks and troughs for domestic producers and ultimately results in lower cost to consumers. Electricity trade provides a revenue opportunity for Ontario's less flexible resources (such as baseload hydroelectric and nuclear) when Ontario demand is low and attracts imports when they are a lower cost option than producing power domestically. Interties are increasingly viewed as playing an important role in efficiently integrating intermittent renewable generation. For example, because the output of renewable resources varies across markets, the use of interties across wider geographic areas helps offset the uncertainty and variability of renewable resources. Additionally, interties can increase system flexibility by allowing the output from resources to be balanced efficiently over a larger geographic footprint.

Capacity and Energy

This report makes reference to capacity and energy – two key attributes of electricity.

Capacity, measured in megawatts (MW), is the maximum instantaneous level of electricity that is consumed and that must be supplied by the power system. Ontario must have adequate capacity resources available, either within the province, or through firm imports, to supply electricity customers during the peak demand periods of the year. In the context of imports, capacity has two essential components, the capability of the interties and related transmission system in both the sending and receiving jurisdictions, as well as the generating capability at peak of the sending jurisdiction, over and above their domestic requirements. This report only focuses on the interties and the related transmission system in Ontario.

Energy, measured in megawatt hours (MWh) or terawatt hours (TWh) is the volume of electricity that is consumed or supplied over some period of time, for example over a day or over the course of a year. Energy has been, and continues to be, economically imported and exported over the interties through Ontario's wholesale energy market. It is important to keep in mind that while a given volume of energy may be supplied over the course of a year, at no time can the profile of this energy exceed the capacity of the equipment that is required to supply or transmit it. However, the difference between energy and capacity is that with energy the exporter would not have to offer their energy in any given hour.

The IESO has traditionally planned to meet Ontario peak demand by only considering domestic resources. The role of interties has been limited to supplying energy when real-time market-to-market transactions are more economic than internal resources. However, going forward the IESO is considering how Ontario's electricity market and transmission assets could facilitate both capacity and energy transactions between regional buyers and sellers, providing the transmission connections are robust enough to support the scheduled quantity of electricity and that the reliability services such as voltage control provided by Ontario resources (and that cannot be provided by imports) are provided by other resources.

Capacity transactions are a well-established feature of many North American markets. Firm capacity imports can be a cost effective alternative to meet domestic reliability needs. Capacity exports can provide an asset owner with an opportunity to earn revenues even if the facility is not required to maintain home market reliability. Enabling capacity transactions improves market efficiency since it allows excess or shortages of capacity to be bought and sold on an as needed basis. Capacity transactions can avoid the need to build an expensive new generation resource that might only be required for a short period of time, and can also provide bridging revenue for a domestic asset that is not needed today, but might be required in the future in its home market.

If a capacity-based firm import arrangement is created, the IESO must ensure that both the interties and the Ontario transmission system have sufficient deliverability (from the intertie to load centres) to meet the maximum energy transfers for this firm import under virtually all system conditions and demand scenarios. Essentially, the IESO must be confident it can rely on the firm import for reliability and that the interties and Ontario transmission network can support the full flow of power under a wide variety of system conditions.

By contrast non-firm imports (i.e., energy-only transactions) do not require such a rigorous assessment since they are an economic transaction and not relied upon for reliability. As such, the interties and the Ontario transmission system are not required to support the full import flow under all system conditions. In addition, these non-firm imports are likely to be curtailed by the source system operator under shortage conditions so that the electricity can be used to meet their internal needs first. By contrast a capacity-backed import (firm energy trade) can only be curtailed under very specific circumstances. This treatment of firmness is the key difference between a capacity-backed trade and non-firm imports.

Reliability

The interties have provided operating flexibility to help the IESO better deal with routine and extreme events on the power system. The interties are also a source of reliability services, such as operating reserve.

Ontario relies on the interties in the seconds and minutes following an event on the Ontario power system (e.g., loss of a large common mode generation resource or transmission asset, such as the western Toronto flash flooding event of July 2013). In such cases, Ontario will temporarily draw on neighbouring systems to assist with maintaining system frequency and partially make up the lost energy, or absorb the extra energy. To manage these events, it is important to maintain a reliability margin on the interties to provide the IESO with additional options for managing the system, especially during those extreme events that rarely occur but that would likely impact reliable operation of the system. In practice, the IESO applies this reliability margin on all of the interties in aggregate and not necessarily on each individual intertie in the province.

From an operational perspective, it is preferable to have this reliability margin on the interties with New York and Michigan rather than Quebec. Ontario, New York and Michigan are all part of the same interconnected, synchronous power system, referred to as the Eastern Interconnection. Following an event in Ontario, the interties with New York and Michigan instantly spread the impact of the event across the entire Eastern Interconnection (i.e., to neighbouring jurisdictions) and, in that way, provide support until replacement resources can be brought online or output is reduced. Quebec is not part of the Eastern Interconnection. The nature of the special transmission and generation connections between Quebec and Ontario prevent Quebec resources from providing the same significant support following events in Ontario. In fact, the power transfers from Quebec usually stay almost constant immediately after an Ontario event.

As such, delivering firm import capacity on the interties with Quebec up to the capability of the intertie (i.e., have no reliability margin on the interties with Quebec) is technically possible, as long as there is sufficient flexibility on the New York and Michigan interties. It may be necessary to reserve some room, specifically, on the Outaouais HVDC tieline with Hydro-Quebec to allow for the provision of reliability services such as operating reserve. For example, today the IESO's electricity market may economically select Quebec resources, across the Outaouais tieline, to supply operating reserve rather than using more costly Ontario resources.

Operability

It is critical that the IESO have the ability to balance supply and demand using a mix of flexible internal resources (which are able to quickly adjust energy output) and by scheduling transactions (imports and exports) through Ontario tielines. The continued growth of wind and solar generation can create significant operability challenges for any system operator as there is a corresponding need for other supply resources to quickly respond to changes in wind and solar generation output. Other markets have sought means to maintain an operable system by developing more frequent intertie scheduling processes with their neighbouring markets. By moving from hourly scheduling of imports and exports to a more frequent 15-minute cycle, other markets such as MISO, PJM, NYISO and ISO-NE have a better mechanism to manage intra-hour fluctuations in intermittent generation output across their regional markets.

These examples are some of the ways that system operators are increasingly turning to interties as a way to help manage the challenges of a changing supply mix and greater supply uncertainty. As part of its Market Renewal project the IESO is also considering what changes can be made to the existing market design to fully optimize the potential that interties can offer in meeting Ontario's operability needs. Opportunities to facilitate greater trading with Quebec need to be considered in light of these broader market reforms to identify any linkages and potential overlaps.

2.1 Interconnections with Quebec and their Historical and Current Usage

There are currently six tielines between the Ontario and Quebec transmission systems at the provincial border. They are shown geographically in Figure 1, below. Table 1 also lists their main characteristics and nominal capabilities. There is a seventh location shown on the map where a hydroelectric generating station owned by Brookfield Power (Masson GS), located in Quebec, can be disconnected from the Quebec system and radially connected to the Ontario system. For practical purposes this is not considered to be an intertie with the Quebec system; however the output of this generator has been reflected in technical studies where relevant.

Figure 1. Existing Ontario-Quebec Interconnections

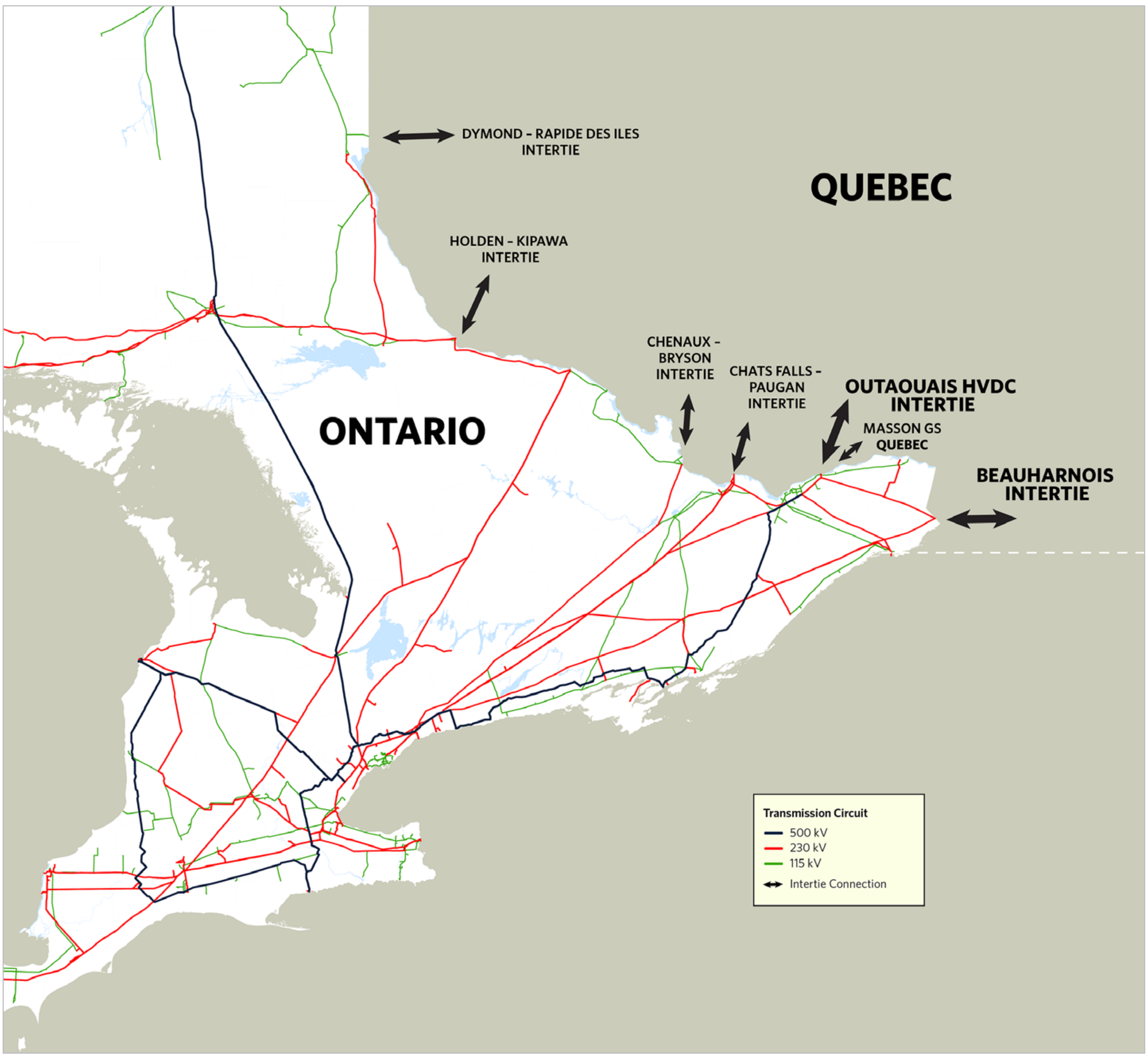
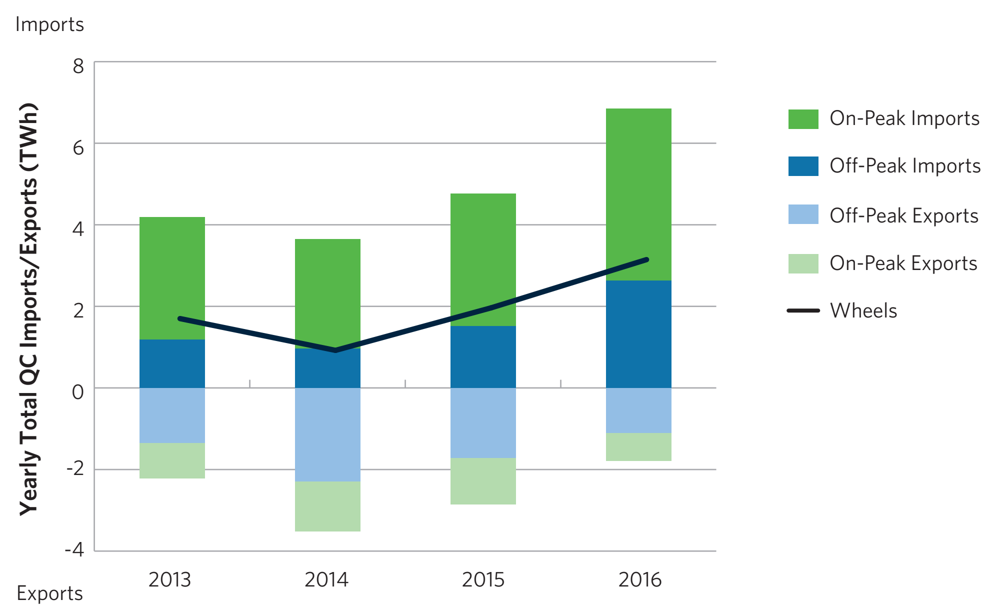


Table 1. Existing Ontario-Quebec Interconnections

Intertie	Geographic Location	Connection Voltage	Nominal Import Capability (unless otherwise noted)
Outaouais HVDC Intertie	East of Ottawa	230 kV	1,250 MW
Beauharnois Intertie	Near Cornwall	230 kV	800 MW
Holden-Kipawa Intertie	East of North Bay	115 kV	~ 100 MW (export only)
Dymond-Rapide Des Iles Intertie	North of Kirkland Lake	115 kV	~ 80 MW
Chats Falls – Paugan Intertie	North of Ottawa	230 kV	~ 350 MW
Chenaux – Bryson Intertie	North of Ottawa	115 kV	65 MW

The six interties described above facilitate economic transactions between Ontario and Quebec through the Ontario electricity market. Figure 2 below summarizes the last four years of exports and imports between Ontario and Quebec. Export activity on the interties with Quebec has been decreasing, with total exports from Ontario to Quebec decreasing from a maximum of about 3.5 TWh to 1.8 TWh over the 2013-2016 period. Import activity on the interties with Quebec is increasing, with imports serving Ontario load growing from about 2.5 to 3.5 TWh over the same period, while total imports including wheel-throughs went from about 4 to 7 TWh. A wheel-through (or wheel) is a type of energy transaction in which power is sent from one jurisdiction, through another jurisdiction (Ontario in this case), and on for consumption in a different regional market. A wheel-through is a market tool that helps to economically transfer energy across jurisdictions. In this case, a wheel-through Ontario from Quebec does not serve any Ontario load, but, rather, serves that of another jurisdiction. Figure 2 shows that as imports from Quebec increase, so too are the wheels, which accounted for about half of all imports of energy from Quebec in 2016.[3]

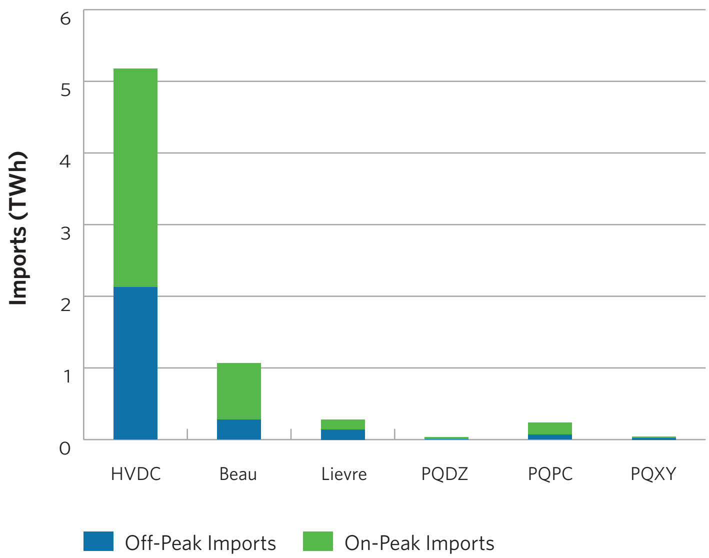
Figure 2. Summary of Total Yearly Imports and Exports between Ontario and Quebec, 2013-2016



[3] This data is based on linked wheel-throughs that are specified by the energy marketer in the market system. When power is wheeled through Ontario, the transaction is charged for the use of Ontario's transmission system.

The breakdown of scheduled imports from Quebec into Ontario over six interconnections is as follows:[4]

Figure 3. 2016 Imports from Quebec by Intertie



Scheduled Import	Intertie for the Import
HVDC	Outaouais HVDC Intertie
Beau	Beauharnois Intertie
Lievre	Masson GS
PQDZ	Dymond-Rapide Des Iles Intertie
PQPC	Chats Falls – Paugan Intertie
PQXY	Chenaux – Bryson Intertie

The bulk of imports from Quebec in 2016 were scheduled on the HVDC intertie. Typically these imports are scheduled during on-peak hours. As described above, material quantities of these imports are wheeled through Ontario to other jurisdictions.

In addition to regular wholesale market trading, Ontario and Quebec have recently collaborated on two agreements. The first agreement, signed in the spring of 2015, took advantage of seasonal differences in the two regions' demand patterns; this was known as the Capacity Swap Agreement. The Capacity Swap Agreement, which covered the period from 2016 to 2025, allowed for Quebec to receive up to 500 MW of firm capacity from Ontario during the winter periods, and Ontario to receive an equal amount of firm capacity from Quebec based on Ontario requirements.

A new agreement was signed at the end of 2016 which refined the original agreement to take better advantage of updated system outlooks. The new agreement provides for:

1. Ongoing sale of 500 MW of firm capacity from Ontario to Quebec during the winter periods of 2016 – 2023;
2. 2.3 TWh of energy from Quebec to Ontario, to be offered into the IESO-administered market with the intention of displacing higher cost/higher emission gas generation;
3. Cycling energy from Ontario to Quebec, to be cycled to Quebec during periods of surplus, stored in Quebec and returned to Ontario with the intention of displacing higher cost/higher emission gas generation;
4. As a result of Ontario having provided 500 MW of capacity to Quebec in winter of 2015/16 as part of the original Capacity Swap Agreement, a commitment from Quebec to deliver 500 MW of firm capacity to Ontario for four months during summer period(s) of the IESO's choosing before 2030.

[4] The Holden-Kipawa interconnection is not used for scheduled imports.

3. Import Capability from Quebec on Existing Interties

Ontario's ability to receive electricity imports from Quebec is determined by the capability of the interties with Quebec, as well as the capability of Ontario's transmission system to deliver imported electricity from the Ontario-Quebec border to Ontario's customers.

This section focuses on the existing and potential import capability of the largest two of the six existing interties that were introduced in Section 2. In this report it is assumed that firm imports would be most readily supplied by the 1,250 MW HVDC intertie at Outaouais, east of Ottawa because it is the largest intertie and the only HVDC intertie, providing a robust connection to Quebec's bulk electricity system. Once the import capability of the HVDC intertie is fully utilized it is assumed that up to 800 MW of additional imports would come from the Beauharnois intertie, east of Cornwall, because it is the second largest intertie and also located in close proximity to major electricity system infrastructure. At this time, the remaining four interties have not been considered for incremental import purposes because of their lower capability and their relative remoteness to Ontario's and/or Quebec's bulk transmission system. For study purposes, it has been assumed that the remaining four interties will continue to operate in a similar manner as they do today.

This Ontario study also did not consider any limitations on the Quebec system in delivering the noted levels of transfers to Ontario. The IESO expects those matters will be addressed in a parallel Quebec study report.

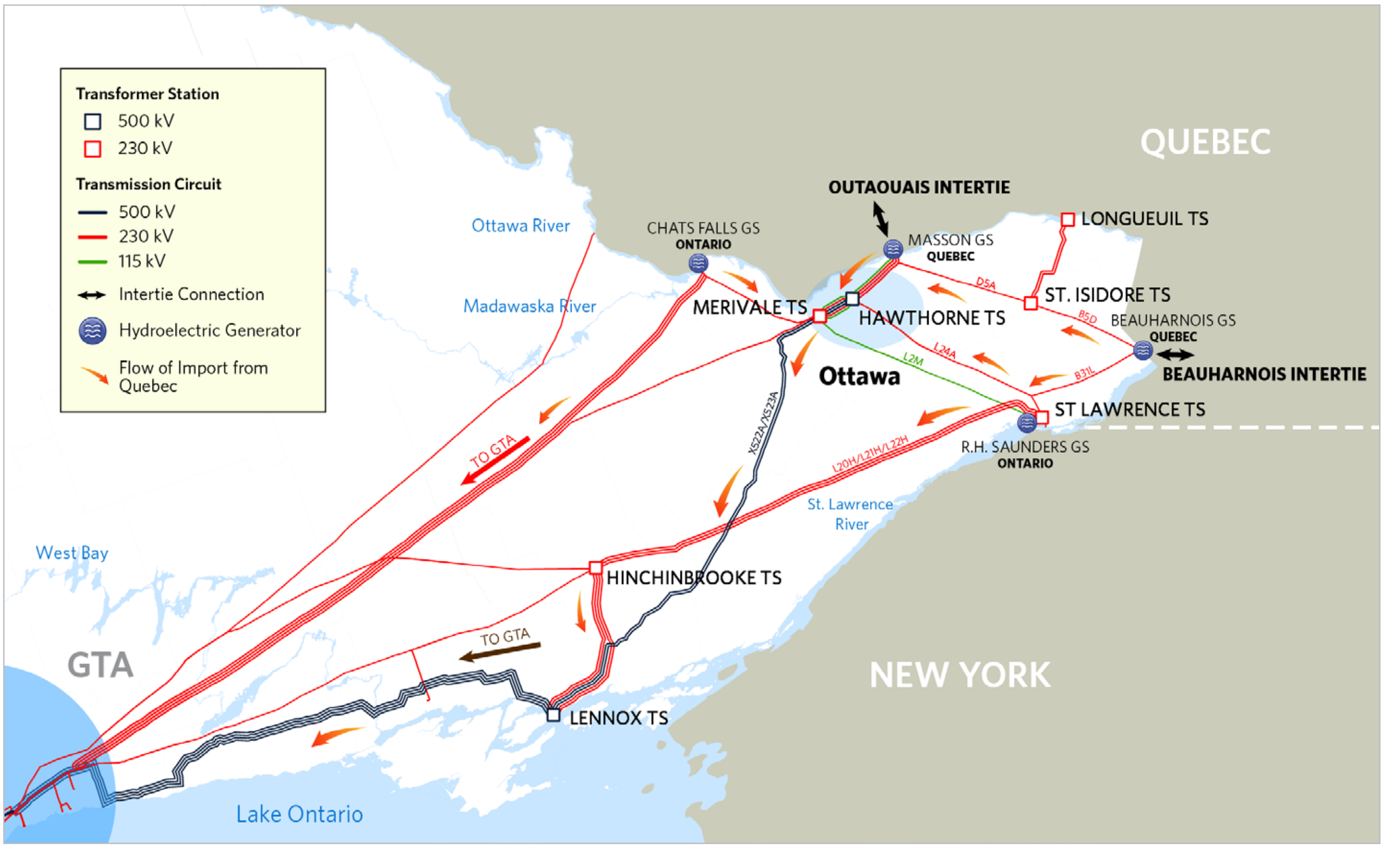
Ontario's bulk transmission network connects the province's larger electricity supply sources, such as hydroelectric generation located on the province's major river systems, or nuclear generation located east and west of the Greater Toronto Area (GTA), with the province's major load centres. The majority of these load centres are located within the GTA and southwestern Ontario. Ottawa is the only major load centre located in eastern Ontario. The 500 kV transmission system level is the backbone of Ontario's transmission system. Ontario's 500 kV system encircles the GTA, and extends radially into eastern Ontario to supply Ottawa, as well as to connect major eastern Ontario generation sources.

The Outaouais intertie injects imports into the Ottawa area while the Beauharnois intertie injects imports into the Ottawa area and the Cornwall area. Ontario's eastern Ontario transmission network transfers imported electricity from these injection points, as well as output from generating stations located in eastern Ontario to customers in eastern Ontario, including Ottawa. Electricity that is not required to supply eastern Ontario customers will result in power flows toward the GTA load centres. The following section describes the eastern Ontario transmission network and the connectivity between the import injection points and Ontario's major load centres.

3.1 Description of the Eastern Ontario Transmission Network

The bulk transmission system between the Ontario-Quebec border and the GTA consists of a network of transmission lines that distribute electricity along several parallel paths based on the physical characteristics of the system. The critical facilities that comprise the eastern Ontario transmission network are in shown in Figure 4, below.

Figure 4. Eastern Ontario Transmission Network



While the eastern Ontario network is complex, for the purpose of this report it is helpful to focus on two key transmission hubs in eastern Ontario: Hawthorne Transformer Station (TS), in eastern Ottawa and St. Lawrence TS, near Cornwall. The Hawthorne hub is located approximately 30 km west of the Outaouais intertie and it is where imports from the Outaouais intertie are integrated onto Ontario's bulk transmission system. The St. Lawrence hub is located approximately 50 km west of the Beauharnois intertie and is relevant to imports from that point. The following sections describe the transmission connections for each of these two hub stations, as well as their roles in integrating imports from Quebec and transferring electricity to Ontario's major load centres.

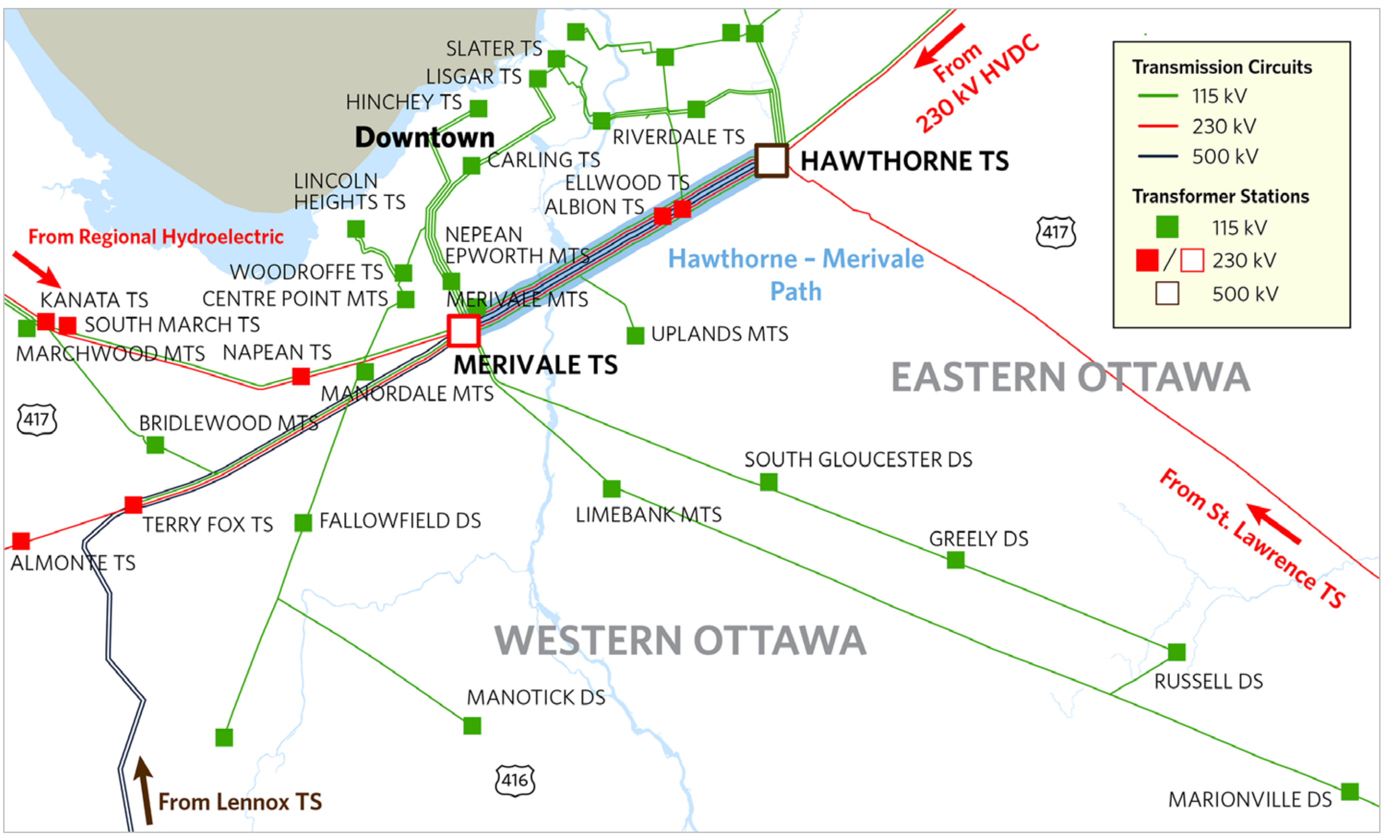
Hawthorne TS Hub and the Transmission System in the Ottawa Area

Hawthorne TS, shown on Figure 5, below, connects the regional 230 kV system to the easternmost point of the province's 500 kV system. The Hawthorne station also contains 230 kV and 115 kV switchyards, and is one of two main supply points for the City of Ottawa. The other main supply point is Merivale TS, located in western Ottawa, which supplies a number of 230 kV and 115 kV supply stations in downtown Ottawa and the western half of the city.

Hawthorne and Merivale are connected by a 12 km supply path consisting of two 230 kV circuits (M30A and M31A) in parallel with two 115 kV circuits (A8M and A3RM). More than half of the city's peak electricity demand is located in western Ottawa, and the majority of this is supplied by the Hawthorne-Merivale transmission path. Together these four circuits, along with other 115 kV and 230 kV circuits west of Merivale, establish a bulk transmission path that connects the Hawthorne hub to the GTA in parallel with the 500 kV system.

The Outaouais intertie is connected to Hawthorne TS via two 230 kV circuits. When imports from the Outaouais HVDC intertie are injected into Hawthorne TS most of the imported energy flows onto the 500 kV system towards the GTA, however approximately 20% flows onto the Hawthorne-Merivale 230 kV path towards western Ottawa.

Figure 5. Hawthorne TS Hub and the Transmission System in the Ottawa Area

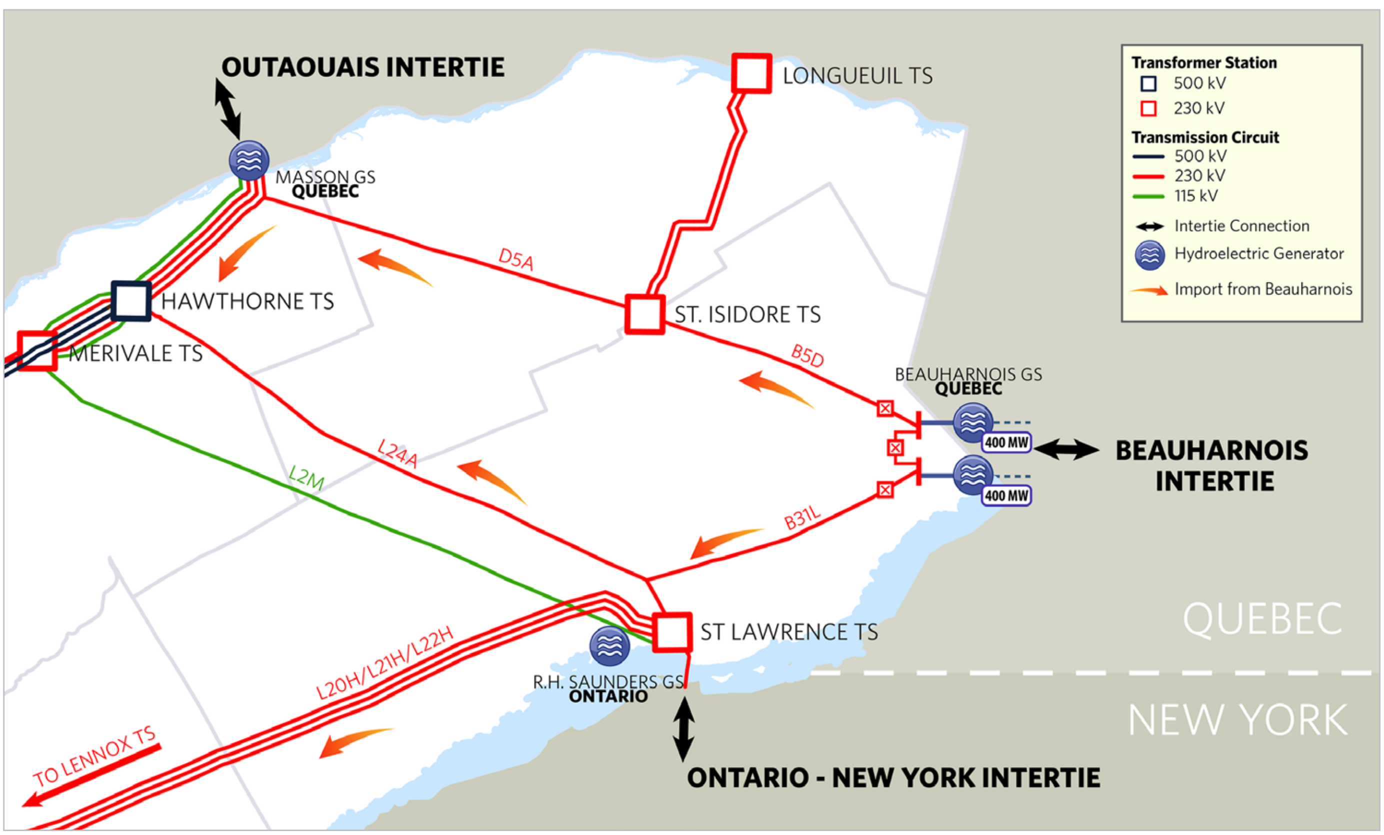


St. Lawrence TS Hub and the Transmission System in South Eastern Ontario

St. Lawrence TS, shown on Figure 6, below, is a 230 kV node that combines a portion of imports from the Beauharnois intertie with up to 1,000 MW of output from the Saunders Generating Station (GS) located near Cornwall, as well as any flows from an interconnection with New York State, also located near Cornwall. Saunders GS is the largest supply source located in eastern Ontario. Today there are three paths connecting the St. Lawrence TS hub to the 500 kV system: westward via 230 kV circuits L20H, L21H and L22H toward Lennox TS located at Napanee, northward directly to Hawthorne TS via 230 kV circuit L24A, and northeastward on an indirect path to Hawthorne via the Beauharnois intertie, through circuits B5D, and D5A.

Several of the 230 kV circuits emanating from St. Lawrence TS, including L24A, reach their thermal limit at times when imports from Beauharnois combine with generator output from Saunders GS and imports from New York on the nearby Ontario-New York intertie. The energy flow through this Ontario-New York intertie can be controlled to some extent by two phase shifter transformers. However, depending on the level of generation, the level of load, and the level of transactions between Ontario and Quebec, and between Quebec and New York, these phase shifters may reach the end of their control range. Possible consequences of this limitation could be a temporary reduction in the transfer capability between Ontario and New York due to limited flexible resources in the area. Full transfers could likely resume once system conditions change (i.e., wind production drops in the region of New York immediately south of that Ontario-New York intertie.)

Figure 6. St. Lawrence TS Hub and the Transmission System in South Eastern Ontario



3.2 Using Technical Criteria to Determine Import Capability of the Eastern Ontario Transmission Network

The capability of the eastern Ontario transmission network to transfer electricity from the Quebec border to Ontario's major load centres is determined by the robustness of the network, the physical capability of the individual lines and stations that make up the network, and the operating criteria that ensure reliable system operation. Ontario has reliability standards and criteria for system planning, called the Ontario Resource and Transmission Assessment Criteria (ORTAC) that must be used to assess the transfer capability of the existing transmission system. When new facilities to expand Ontario's transmission system are being planned, the ORTAC is used to assess the impact of potential system changes. The IESO maintains the ORTAC to be consistent with the applicable standards and criteria established by the Northeast Power Coordinating Council (NPCC) and the North American Electric Reliability Corporation (NERC), the two international organizations that govern the reliability of the bulk power system in Ontario. Unless otherwise noted, the import capability cases described in the next section of this report all meet the ORTAC requirements. Appendix A provides a more detailed discussion of the relevant criteria, standards and technical considerations.

The eastern Ontario transmission system that is the focus of the following sections is restricted by thermal limitations. As power flow increases through the system, it increases the temperature of the system equipment, including circuit conductors, buses, transformers and switches. Each of these elements has a thermal rating, supplied by the manufacturer. If power flow increases above this thermal rating, the equipment may overheat, causing conductors to sag or equipment to be damaged, potentially causing catastrophic failure.

The specific capability of the system is determined by contingency-based assessment. A contingency is a recognized outage that removes one or two system elements from service. For example, a double- circuit contingency removes two circuits that are on the same tower from service. The ORTAC includes contingency criteria consistent with NPCC and NERC standards. These criteria are used to assess the transmission system's ability to operate within reliability standards in an adequate and secure manner. With all transmission facilities in service, bulk system power transfer capability, as described in the ORTAC, is determined for the most limiting contingency. Load flow software is used to model the system and determine post-contingency power transfer capability using multiple demand scenarios and system generation patterns.[6]

[5] At other points in Ontario, system capability may be limited by other phenomena like voltage-related limitations, but these other phenomena are not limiting in eastern Ontario.

[6] PSS/E is an industry standard software package that has been used by the IESO for this purpose.

3.3 Technical Evaluation of Import Capability

This section begins by detailing the import capability of the system as it currently exists (referred to as Case 1), followed by two incremental cases (Cases 2 and 3) of import capability that could be obtained within the next five years as a result of relatively minor upgrades. Cases 4 and 5 are alternatives that build on Case 3.

The import capabilities described in the cases are generally consistent with the import scenarios from the 2014 report. In this report, however, the cases are primarily organized based on system upgrade requirements, whereas in the 2014 report the scenarios were organized by import capability level. The cases described in this section are summarized in table form at the end of this section.

Case 1: Existing System

Section 3.1, above, describes how approximately 20% of imports that flow through the Outaouais intertie are distributed on the Hawthorne-Merivale 230kV circuits toward the GTA. This flow is incremental to the Hawthorne-Merivale flow that is responding to customer demand in western Ottawa. At times when demand in western Ottawa is high, adding a 20% portion of the import from Quebec pushes the Hawthorne-Merivale path to its limit. As a result, the existing Hawthorne-Merivale path is not adequate to ensure Ontario's ability to rely on any firm imports through the Outaouais intertie, for example during the summer months when it would be most beneficial for Ontario consumers. There are, however, significant periods throughout the year when it is feasible to accept non-firm energy imports via the Outaouais intertie such that Ontario will be able to import and achieve the 2.3 TWh target per year that is the subject of the recent agreement. Presently, the most limiting elements of the Hawthorne-Merivale path are the two disconnect switches that connect the two 230 kV Hawthorne-Merivale circuits to Hawthorne TS. These switches have a thermal (current) rating of 1200 A.

In order to accept firm imports through the Outaouais intertie the disconnect switches at Hawthorne TS will need to be replaced, at an anticipated cost of approximately $500,000. This upgrade project is summarized in Table 2, at the end of this section.

Case 2: After Replacing the Disconnect Switches at Hawthorne TS

As described above, the ability to import firm capacity through the Outaouais intertie is limited by the disconnect switches at Hawthorne TS that connect the two 230 kV Hawthorne-Merivale circuits (M30A and M3A). The 1,200 A thermal rating of these switches is significantly lower than the 1,800 A rating of the 230 kV circuits themselves. Replacing the existing disconnect switches with switches rated equal to or higher than 1,800 A would allow use of the full capability of the 230 kV Hawthorne-Merivale circuits.

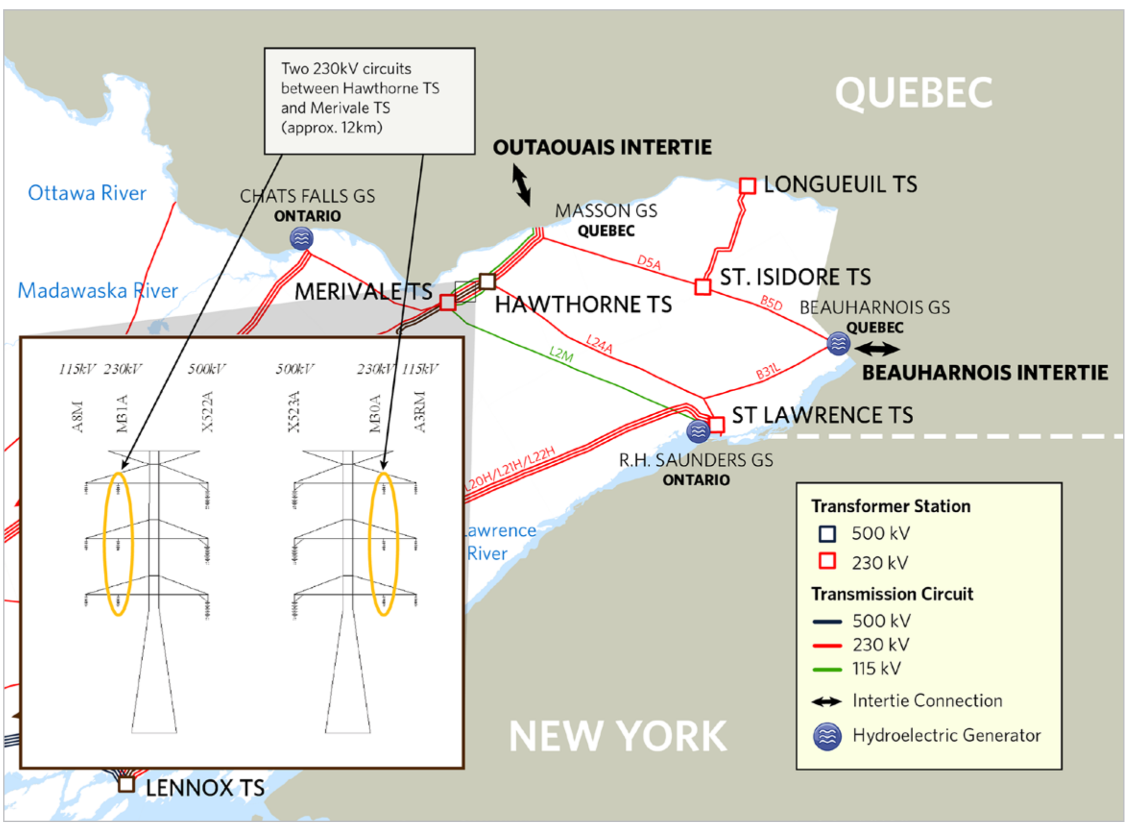
After replacing the disconnect switches, Ontario would be able to import up to 500 MW of firm capacity from the Outaouais intertie, before reaching the thermal limit of the Hawthorne-Merivale 230 kV circuits. However, this capability will decrease over the long-term as demand in the western part of Ottawa grows and uses more of the capability of the Hawthorne-Merivale path. This capability is shown in summary Table 2, at the end of this section.

Case 3: After Reconductoring the 230 kV Circuits Between Hawthorne TS and Merivale TS

As described above, after replacing the existing disconnect switches at Hawthorne TS with higher rated switches the two 230 kV circuits between Hawthorne TS and Merivale TS would be the most limiting elements of the Hawthorne-Merivale path, which in turn limits Ontario's capability to import electricity from Quebec through the Outaouais intertie. Therefore, the next step to increasing import capability would be to replace the conductors that comprise the two 230 kV circuits with higher rated conductors. The circuits are highlighted on Figure 7, below. To accommodate the 1,250 MW import through the Outaouais intertie, these 230 kV circuits would need to be upgraded to around 2,400 A thermal rating. In addition to enabling increased use of the intertie capability, reconductoring the Hawthorne-Merivale circuits would allow Ontario to further optimize the targeting of the 2.3 TWh import agreement. This reconductoring project is expected to cost approximately $20 M.

The required environmental and regulatory approvals processes for this project would take approximately one year to complete. Upgrading the Hawthorne-Merivale corridor is complex because it is comprised of a total of six high voltage circuits, (two 115 kV, two 230 kV and two 500 kV) carried on two parallel transmission tower lines. These circuits are critical for supplying Ottawa, making it challenging to schedule outages for upgrade work. The corridor also spans central Ottawa, eliminating the potential for corridor expansion. Once approved, the engineering design and construction processes would take an additional two years to complete. Therefore, if the approval processes were initiated in mid-2017, the conductor upgrades could be completed as early as 2020.

Figure 7. 230 kV Circuits between Hawthorne TS and Merivale TS



[7] The capability of the Outaouais interconnection is nominally 1,250 MW. The actual operating limit is about 1,230 MW.

The 2014 report stated that increasing the capability of the Hawthorne-Merivale path would cost up to $325 million, and take three to five years to complete. At that time it was thought to be infeasible to upgrade the existing circuits using the existing tower structures, and that additional circuits would need to be constructed underground. Since the 2014 report, Hydro One, the transmitter that owns the Hawthorne-Merivale circuits, has carried out detailed engineering studies of the Hawthorne-Merivale corridor and has concluded that it is possible to upgrade the 230 kV circuits on the existing towers using bundled conductors.

Increasing the capability of the 230 kV Hawthorne-Merivale conductors to a rating of at least 2,400 A would significantly increase the capability of the Hawthorne-Merivale path. After this upgrade Ontario would be able to integrate the full 1,250 MW import capability of the intertie at Outaouais. This capability is shown in summary Table 2, at the end of this section.

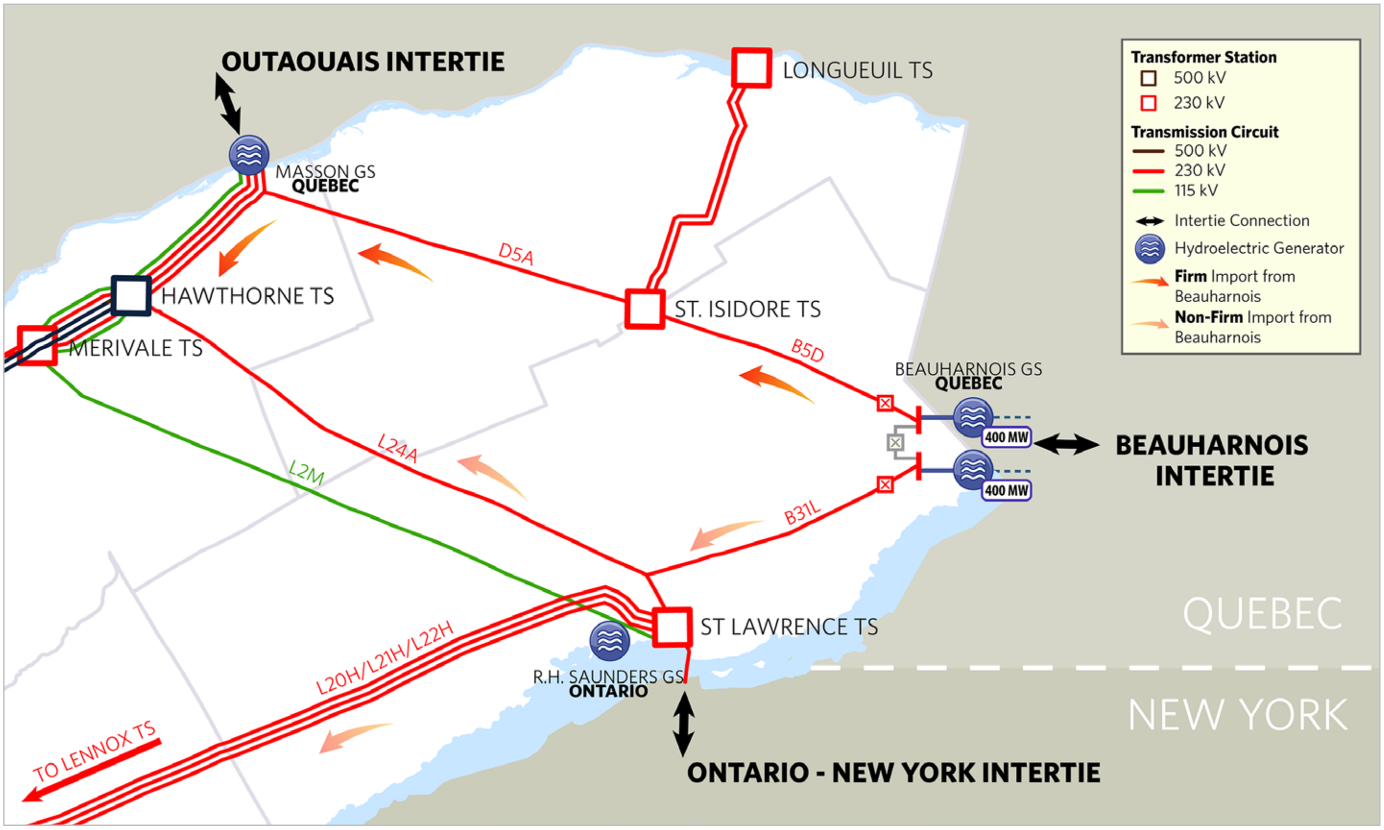
Case 4: Operating the Beauharnois Intertie in Bus-Split Mode

Significant import quantities beyond the 1,250 MW capability of the Outaouais intertie would need to come from the Beauharnois intertie. As described in Section 3.1, the Beauharnois intertie has a total capability of 800 MW. It is important to note that this power is supplied by 800 MW of dedicated generation (as opposed to being supplied by the Quebec grid) that must be physically isolated from the Quebec system and connected to Ontario (and therefore unable to supply Quebec) in order for Ontario to receive energy equal to the capability of this intertie.[8] The electricity system in the vicinity of Beauharnois has two notable modes of operation that provide operational flexibility to enable and optimize bidirectional transactions between Ontario and Quebec, in conjunction with utilizing supply from Saunders GS.

- Four-terminal mode: connect Beauharnois generation station to be part of the path between St. Lawrence TS and Hawthorne TS, which allows transactions from Beauharnois to be distributed between B31L (connecting to St. Lawrence) and B5D/D5A (connecting to Hawthorne). This is the most common mode of today's operation when receiving Beauharnois delivery, as shown in Figure 6 in the previous section.
- Bus-split mode: divide the Beauharnois station in half, including the 800 MW of dedicated generation. This configuration breaks the path between Hawthorne and St. Lawrence, and results in 400 MW of the dedicated generation being radially connected to Hawthorne TS (via B5D/D5A) and the other 400 MW being connected to St. Lawrence TS. This mode of operation is shown in Figure 8 on the next page.

[8] Hydro-Quebec would need to consider the supply reliability impacts for their customers before dedicating this generation to Ontario.

Figure 8. 230 kV Circuits between Hawthorne TS and Merivale TS



The potential for Ontario to integrate electricity imports using the Beauharnois intertie depends on the configuration of Beauharnois. While Hawthorne TS and St. Lawrence TS are both important transmission hubs, one key difference between them is that Hawthorne TS is connected directly to the 500 kV system, while St. Lawrence TS is not. Bulk supply from the St. Lawrence hub must therefore flow through the 230 kV system to integrate with the 500 kV system at either Lennox TS, or Hawthorne TS. Thermal limitations on the 230 kV system emanating from St. Lawrence limit the capability to integrate imports from Beauharnois through the St. Lawrence hub in conjunction with output from the 1,000 MW Saunders GS located at St. Lawrence and flow through the New York interconnection. The 230 kV circuit L24A between St. Lawrence and Hawthorne is most limiting, followed by the three parallel 230 kV circuits between St. Lawrence and Hinchinbrooke TS. As discussed earlier, heavy flow into St. Lawrence may also need to be restricted to respect the control capability of the phase shifters on the New York-St. Lawrence Intertie.

Operating Beauharnois in bus-split mode is a means of maximizing the capability for imports, without major transmission expansion. Operating in this manner enables 400 MW of dedicated generation to be directed toward Hawthorne TS, and removes the flow of firm imports towards St. Lawrence TS, avoiding the 230 kV limitations described above. This capability is described in Table 2, at the end of this section.

Changing the system operating configuration, however, also gives rise to supply considerations in the eastern Ontario system between the New York-Quebec border and Ottawa. Separating the bus at Beauharnois breaks the Beauharnois path between the St. Lawrence hub and the Hawthorne hub that was described in Section 3.1. As a result, the 400 MW of firm capacity import from Beauharnois that could be enabled by the change of configuration would be isolated to a single circuit 230 kV radial connection to Hawthorne TS. Local load supply stations (St. Isidore TS and Longueuil TS) would be supplied by the same single circuit 230 kV radial transmission line between Hawthorne and Beauharnois. While changing these customers to a single circuit radial supply is consistent with the ORTAC requirements, it represents a lower level of supply reliability for these eastern Ontario customers.

Case 5: After Reinforcing the Eastern Ontario Network

Major transmission expansion would be required in order to allow firm Beauharnois imports to flow through the St. Lawrence transmission hub, avoiding the use of bus-split mode of operation and make use of the full 800 MW of intertie capability at Beauharnois, while maintaining dual supply to eastern Ontario customers. A potential upgrade to enable the full import capability of the Beauharnois intertie was described as Scenario 3 of the 2014 report. This upgrade involves replacing an existing 85 km single circuit 115 kV transmission line (L2M) between St. Lawrence TS and Merivale TS (in western Ottawa) with a double circuit 230 kV line, as shown in Figure 9 below. This solution provides an additional 230 kV path emanating from St. Lawrence and hence reduces the flow on the remaining paths. Increasing flow into the Merivale supply hub in this manner would, however, change electricity flows in the greater Ottawa area, and may trigger the need for additional transmission reinforcements in the Ottawa area. This upgrade would require a lead time of 5 to 7 years, have environmental and community impacts, and cost over $200 million. This capability is described in Table 2, at the end of this section.

Figure 9. Rebuild Existing 115 kV circuit L2M to be a Double- Circuit 230 kV Transmission Line

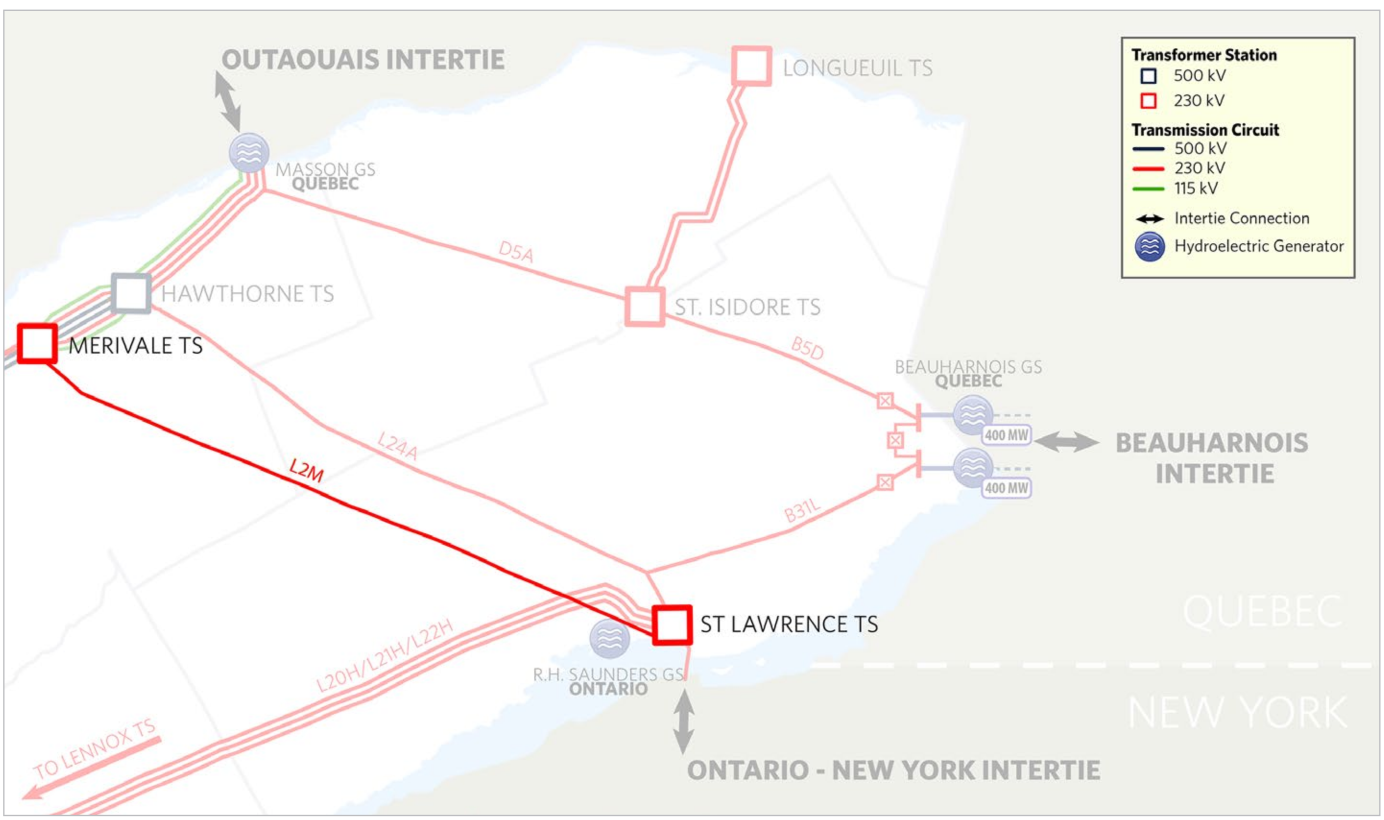


Table 2: Summary of Import Transmission Capability Using Existing Interties

Case	System Change	Total Transmission Cost and Timing Requirements	Total Resulting Firm Import Capability (MW)
1	Existing System		**0 MW firm import** • Non-firm energy imports are feasible, depending on system conditions, such as demand, and eastern Ontario hydroelectric generation levels
2	After replacing two 230 kV line disconnect switches at Hawthorne TS	Approx. $ 500,000; 1-2 years of lead time	**500 MW firm import on HVDC intertie** • In conjunction with Ottawa demand growth up to mid-2020s • Energy import may be able to exceed 500 MW for some hours
3	After replacing two 230 kV line disconnect switches and reconductoring two 230 kV circuits between Hawthorne TS and Merivale TS (approx. 12 km)	Approx. $20 M 3 years of lead time Note: scheduling outages for this work will require significant timing coordination	**1,250 MW firm import – Full capability of HVDC intertie** • Energy import would be limited to approximately 1,250 MW at any given time • In addition to enabling increased use of the intertie capability, reconductoring the Hawthorne-Merivale circuits would allow Ontario to further optimize the targeting of the 2.3 TWh import agreement
Cases 4 and 5 are alternative options that build on Case 3 to enable two levels of incremental import capability from the dedicated generators at the Beauharnois intertie			
4	Operating the Beauharnois intertie in bus-split mode – directing 400 MW of intertie capability to the Hawthorne TS hub	Operational change – no significant incremental cost or timing requirements above the $20 M required for Case 3	**1,650 MW firm import (1,250 MW from HVDC + 400 MW from Beauharnois)** • Energy import would be limited to approximately 1,650 MW at any given time, also dependent on availability of specific Quebec generators • Change of configuration would result in a lower level of supply reliability for some eastern Ontario customers
5	After reinforcing the eastern Ontario network by rebuilding 115 kV circuit L2M between St. Lawrence and Merivale TS as a double-circuit 230 kV transmission line (approx. 86 km)	Approx. $220 M Plus the cost of additional upgrades in the Ottawa area that may be required. 5-7 years of lead time	**2,050 MW firm import (1,250 MW from HVDC + 800 MW from Beauharnois)** • Energy import would be limited to approximately 2,050 MW at any given time, also dependent on availability of specific Quebec generators

4. Import Capability with New Ontario-Quebec Interties

The previous section presented the capability of Ontario's transmission system to import from Quebec using the existing Outaouais HVDC intertie to the Ottawa area, and from isolated generating units at Quebec's Beauharnois generation complex to the Cornwall area. The maximum capability that would be available ranges from 500 MW to about 2,050 MW depending on the transmission improvements made in the Ottawa and Cornwall subsystems. Beyond this level, a new tieline between Ontario and Quebec would be required.

This section describes three illustrative options for a new tieline, and associated expansion of the transmission system in Eastern Ontario. The three options are each related to a potential crossing point for the new tieline. A significant amount of detailed planning work would be required in order to identify the best option(s), as there are a myriad of alternative configurations and associated expansion requirements. All of the options will require greenfield transmission line and/or station development(s). A lead time of up to 10 years – to carry-out planning, approval, procurement, construction and commissioning prior to in-service – is expected to be required and thus, these would be considered options to address needs in the longer term (2025 and after).

In developing the options for a new Ontario to Quebec tieline and associated system expansion in Eastern Ontario, the following are some of the salient considerations and assumptions:

- As discussed earlier, the Quebec system cannot be connected synchronously with Ontario. The new intertie would have to be a DC link, either in a back-to-back (rectifier-inverter) arrangement and connected to each system by AC connections, such as the facilities at Outaouais, or a conventional HVDC line with the rectifier terminal in Quebec and the inverter terminal in Ontario joined by a bipole DC line.

- The new intertie would have a nominal capability of approximately 2,000 MW. Verification by detailed technical studies and acceptance by NPCC would be required to operate at this level. Depending upon the design of the intertie, Ontario would likely have to schedule (and pay for) additional operating reserves to satisfy reliability standard requirements to mitigate the impact should this intertie trip while in operation.

- The new interconnection would be connected to Quebec's main power grid and not via isolation of their generation as with the Beauharnois delivery.

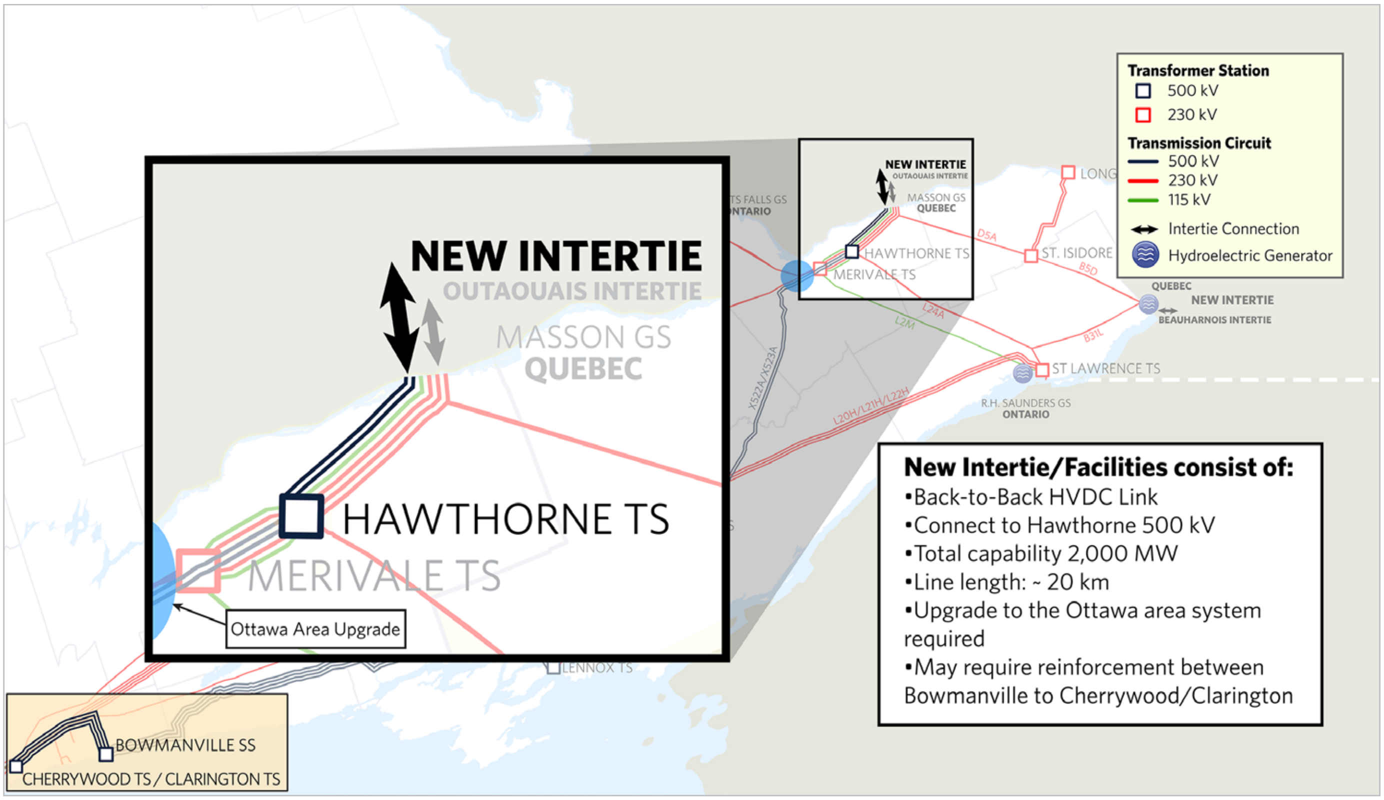
- There are three possible border locations for a new intertie given the existing grids in Ontario and Quebec. They are: (1) a new intertie in parallel with the existing HVDC intertie at Outaouais; (2) a new intertie in parallel with the existing intertie at Beauharnois and; (3) a new intertie in the vicinity of the Chats Falls generation station, located on the Ottawa River, east of Arnprior, Ontario. Future discussions with Quebec could eliminate some of the three possibilities or identify new possibilities.

For each of the new interconnection options, preliminary studies were conducted to identify system expansions required to transmit the higher level of imports to the Greater Toronto Area with due consideration of the local demand in the Ottawa area. The estimated cost for these system expansion options is as high as $1.4 billion, including the cost of the new tieline, as well as required upgrades to the eastern Ontario transmission system.

4.1 New Intertie at Outaouais

A new 2,000 MW interconnection paralleling the existing Outaouais interconnection and its associated system expansion required in Eastern Ontario are shown in Figure 10, below.

Figure 10. New Intertie at Outaouais



The new interconnection comprises an additional back-to-back DC terminal rated 2,000 MW at the Outaouais station in Quebec. From there, a double-circuit 500 kV transmission line (or underground cables) connects the new DC Link at Outaouais to the 500 kV switchyard at Hawthorne TS. A variation of the above is, instead of a back-to-back DC link, the Outaouais to Hawthorne connection would be a conventional HVDC bipole line rated 500 kV and 2,000 MW.

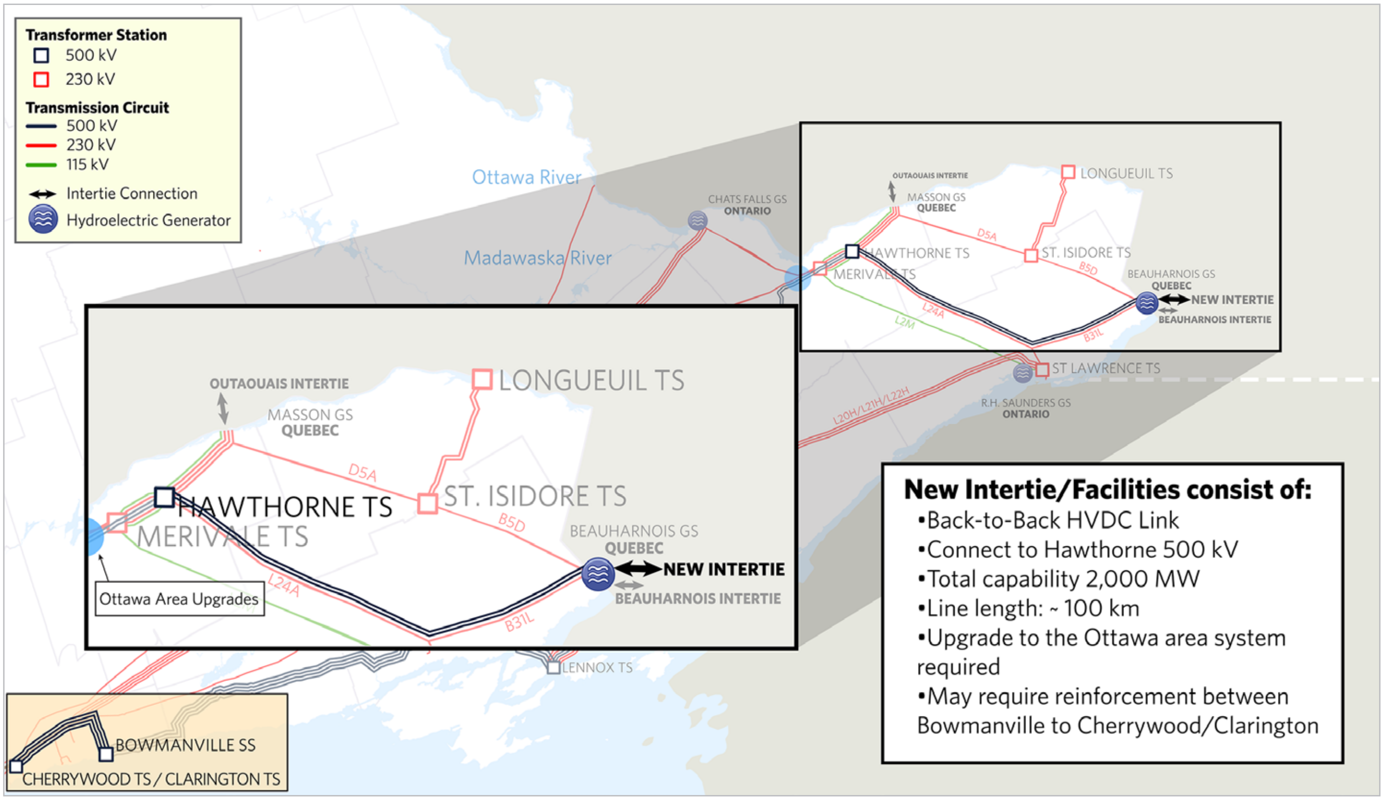
Preliminary technical assessments show that a new interconnection at Outaouais may trigger the need for additional transmission reinforcements in the Ottawa area, in addition to upgrading the Hawthorne-Merivale 230 kV circuits. As the level of imports from Quebec in conjunction with output from the Darlington generating station, located near Bowmanville, increases supply to the GTA from the east it may also be necessary to reinforce the 500 kV path between Bowmanville and Cherrywood/Clarington. A more detailed study would be required to determine the need for upgrades, including consideration of the cost and timeline.

Additional requirements in Quebec were not part of the scope of these studies.

4.2 New Intertie at Beauharnois

A new 2,000 MW interconnection paralleling the existing Beauharnois interconnection and its associated system expansion required in Eastern Ontario are shown in Figure 11.

Figure 11. New Intertie at Beauharnois



The new interconnection comprises a conventional HVDC bipole line rated 500 kV and 2,000 MW with the rectifier terminal at Quebec's Beauharnois station and the inverter at Ontario's Hawthorne 500 kV switchyard. Another feasible configuration is, instead of a conventional HVDC bipole line, a back-to-back DC link located at Quebec's Beauharnois station and from there, a double-circuit 500 kV AC line from Beauharnois to Hawthorne would be constructed.

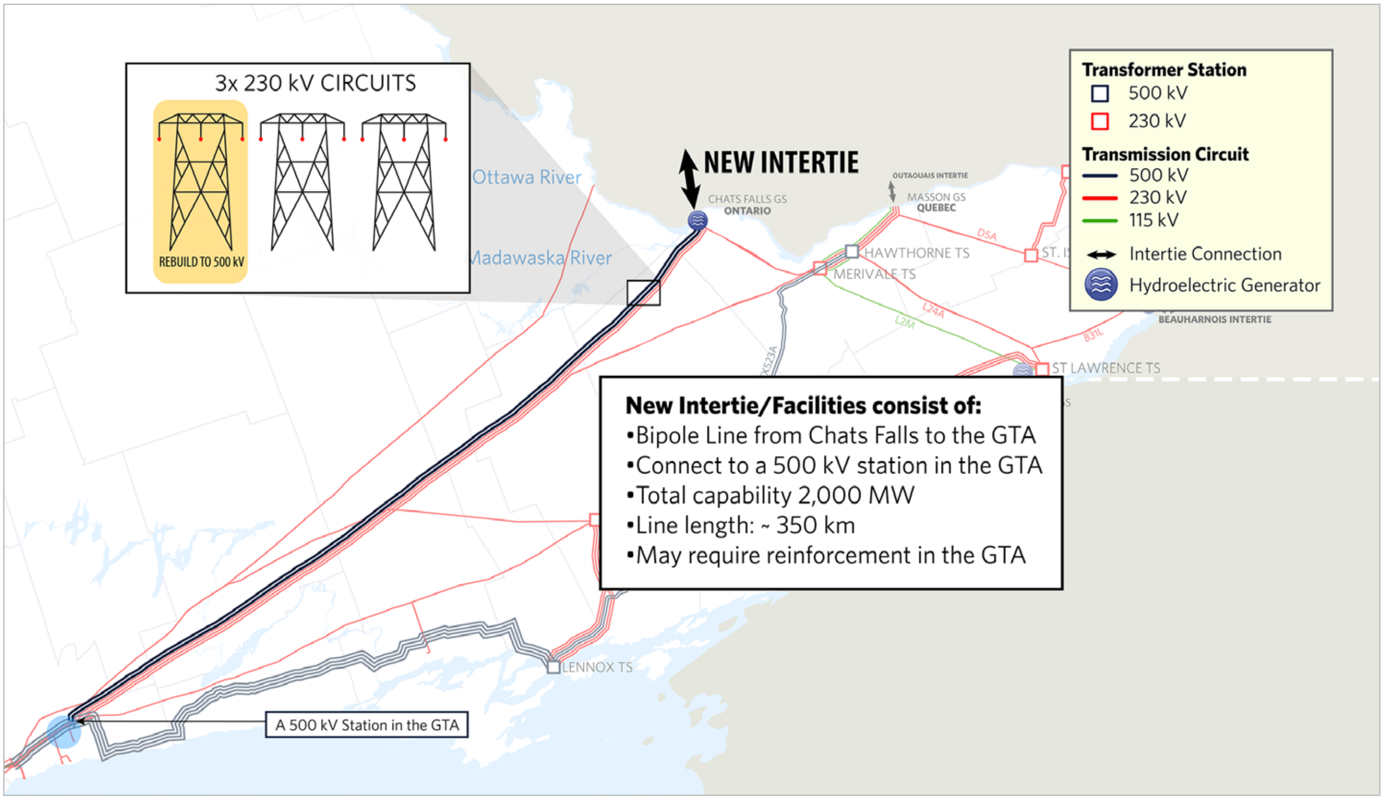
Similar to the above description for a new interconnection at Outaouais, preliminary technical studies show that a new interconnection at Beauharnois may trigger the need for additional transmission reinforcements in the Ottawa area, in addition to upgrading the Hawthorne-Merivale 230 kV circuits. As the level of imports from Quebec in conjunction with output from the Darlington generating station, located near Bowmanville, increases supply to the GTA from the east it may also be necessary to reinforce the 500 kV path between Bowmanville and Cherrywood/Clarington. A more detailed study would be required to determine the need for upgrades, including consideration of the cost and timeline.

Additional requirements in Quebec were not part of the scope of these studies.

4.3 New Intertie at Chats Falls

A new 2,000 MW interconnection paralleling the existing Chats Falls-Paugan interconnection and its associated system expansion required in Eastern Ontario are shown in Figure 12.

Figure 12. New Intertie at Chats Falls



The new interconnection comprises a conventional HVDC bipole line rated 500 kV and 2,000 MW with the rectifier terminal at a new Quebec's station near Chats Falls and the inverter at a major station in the GTA. An alternative to that is to construct two 1,000 MW 230 kV bipole HVDC lines. Most likely, the HVDC line(s) would utilize the existing 230 kV "Gatineau" corridor from Chats Falls to the east GTA.

Depending on where the HVDC line is terminated in the GTA, there may be a requirement to reinforce parts of the GTA system to accept increased imports from Quebec. A more detailed study would be required to confirm that.

Additional requirements in Quebec were not part of the scope of these studies.

5. Capacity and Energy Considerations

This report was prepared to address intertie and transmission expansion considerations. However, transmission capability is only one of several essential factors needed to assess potential import transactions. These assessments must also address the energy and capacity abilities and characteristics of both the importing and exporting systems.

Using Interties for Importing Firm Capacity

As outlined in the 2014 report, purchasing capacity from other jurisdictions is best done through a competitive and transparent market mechanism to ensure the best value for Ontario consumers.

To physically receive additional firm capacity from Quebec, the reinforcements and/or new interties outlined in Sections 3 and 4 would need to be completed.

The IESO has initiated its Market Renewal project, aimed at improving the energy market and introducing capacity auctions in the Ontario market to competitively and efficiently procure resources. The energy market is currently the main platform for matching supply to demand. All energy produced, consumed, imported or exported flows through that market. Improvements to the energy market are intended to increase its efficiency and effectiveness. Capacity auctions are expected to provide a transparent, stable and enduring platform where existing assets, imports, and new entrants can compete on a regular basis for incremental capacity needs. Transparent price signals based on competitive processes are expected to lead to improved investment decisions and the most cost-effective solutions. Enabling capacity imports and exports complements Ontario's existing framework for trading energy and ancillary services.

In addition to the lead-times and costs associated with system reinforcements in Ontario and/or interties, the cost and lead-time of getting capacity delivered to the border would need to be considered. This might include the time and cost for transmission reinforcements and/or additional generation capacity on the Quebec system. In "État d'avancement 2015 du Plan d'approvisionnement 2014-2023"[9] Hydro-Quebec notes that they currently have a need for additional winter peaking capacity in the range of 500 – 1,500 MW in the 2017 – 2023 time-frame. Therefore, to be able to supply Ontario with firm year-round capacity, it is expected that HQ would need to build additional resources above what they have for internal capacity needs.

[9] http://www.regie-energie.qc.ca/audiences/Suivis/SuiviD-2014-205_PlanAppro2014-2023/HQD_EtatAvancement2015_30oct2015.pdf

Using Interties for Additional Energy

When assessing energy imports, consideration needs to be given to the purpose of that energy import as well as how that would fit with any other existing arrangements. Day to day imports and exports cause energy to flow into and out of the province on the interties based on hour to hour economics. Arrangements may be made to deliver fixed quantities of energy under a variety of commitments over longer periods of time such as a year. For example, the commitment could be for a total annual energy quantity to be delivered under a prearranged set of conditions which could range from flexible deliveries based on a formula that targets specific condition in the importing system (e.g. hourly offers for up to a maximum MW level at or above a certain price or aimed at certain resources) or be block loaded at a set MW level for a set number of hours. These would not necessarily have a capacity commitment because they usually allow the exporter relief from delivery in any given hour without penalty as long as the total annual amount is delivered. However capacity arrangements could be bundled with these energy arrangements.

Flexible Energy Imports

The energy associated with the recently signed agreement will be scheduled flexibly and aimed at reducing gas production to meet Ontario domestic load while lowering emissions and costs in Ontario. The combined deals for energy and cycling result in a total commitment of 2.3 TWh per year, and will be offered into the IESO-administered market in the same manner. These offers will be at a price designed to displace gas and at a quantity that is within the capability of the HVDC intertie (nominally up to about 1,250 MW). This intertie and this type of arrangement provide the flexibility required to target the changing need that would have been met by gas being dispatched to address fluctuating net demand. Other interties with Quebec would be more challenged to meet these flexibility arrangements. The 2.3 TWh per year quantity was assessed to be the largest quantity that could be handled by the HVDC intertie and that Ontario could commit to and not displace other baseload resources such as renewables.

This assessment took into account the capability of the HVDC interties and Ontario's need for dispatchable gas production. To illustrate, consider the following.

The absolute maximum capability of the HVDC intertie is approximately 10 TWh per year after accounting for operating buffer and outages. Dispatchable gas generator production is required mainly during on-peak hours which are the 16 hours of the five weekdays of the three summer and three winter months. Even if it were assumed that power would flow at 1,250 MW for every hour during this peak period the total would amount to only about 2.5 TWh (=1,250 MW for 16hours/day x 5 days/week x 4.3 weeks/month x 6 months). However gas generator production levels fluctuate from zero in the early morning hours to several thousand MW at the peak hour of the day and reduce toward zero output at the end of the day. As a result the intertie would be underutilized during some hours while at other hours where gas generation demand is much higher the flow would be limited by the maximum tie capability. Because gas generation production fluctuates this way the practical quantity of imports displacing gas for the on peak period would be less than the 2.5 TWh calculated above. There are also small amounts of dispatchable gas generation needed during shoulder months (for example, to replace the energy supplied by other generators that are removed from service for maintenance during the shoulder months). When these are also considered the current 2.3 TWh annual commitment reflects the practical limits for displacing the dispatchable gas generation on an annual basis.

Thus, although the HVDC tielines may be capable of carrying more energy, increasing the flows from Quebec would not provide value to Ontario under the current outlook.

Baseload Imports

When considering imports of baseload energy it is important to understand that these resources typically have a capacity and an energy component. This means that the intertie would need to be able to deliver capacity and energy for the entire year and the sending jurisdiction would need to have sufficient generation resources to supply both these attributes all year round.

The newly signed agreement to deliver 2.3 TWh to Ontario during peak hours uses most of the HVDC intertie capability during peak hours in order to target the dispatchable gas generation. This is nearly equivalent to full use of the 1,250 MW HVDC tie every peak hour of every weekday during summer and winter (i.e., 2.5 TWh = 1,250 MW x 16 hours/day x 5 days/week x 4.3 weeks per month x 6 months). As a result the only capability on the interties that remains is during off-peak hours at night in the summer and winter and most hours during shoulder months.

Other options for interties, as outlined earlier in this report, would be required to consider additional imports to provide baseload imports and/or to target more natural gas generation.

6. Conclusion

The interties serve an important role for the Ontario power system. Currently they provide operational flexibility and provide economic value to Ontario consumers through hourly trading of energy and ancillary services. In addition to regular wholesale energy trading, long-term agreements provide firm capacity to Quebec to help meet its winter peak needs, and clean energy to Ontario to displace gas generation.

Looking forward, the IESO is enhancing Ontario's electricity market through its Market Renewal project. A more dynamic market would include increased opportunities for trading energy, ancillary services and capacity over the interties. Meeting these needs through competitive market-based mechanisms, as is currently provided for in the IESO's wholesale market, will ensure cost-effective solutions for Ontario consumers. When assessing opportunities to increase Ontario's intertie capability with Quebec, it is important to take a number of different considerations into account beyond the physical capability of the interties. While not addressed in any detail in this report, these include:

- The energy and capacity abilities and characteristics of both systems; and
- Other considerations, such as operating flexibility and the ability to respond to changing circumstances over time.

These should be assessed within the context of the current market structure, as well as the IESO's Market Renewal project to ensure value to Ontario consumers.

This report updates the IESO assessment of Ontario's current and possible transmission capability. However, a clearer understanding of the supporting internal transmission in Quebec is necessary to understand and better facilitate trade between the two jurisdictions.

Appendix A: Regulatory Context for Ontario's Operational and Planning Criteria

This Appendix provides additional details regarding the North American electricity regulatory environment, and how this environment influences the planning and operation of Ontario's electricity system.

To ensure that that support from interties is available for all connected jurisdictions and that one jurisdiction's operation does not put the another jurisdictions at risk, the North American Electric Reliability Corporation (NERC) and Northeast Power Coordinating Council (NPCC) have created standards and criteria applicable to all connected jurisdictions under their authority to address power system planning and operating. From this perspective, NERC standards establish the North American-wide basic requirements while NPCC criteria establish additional requirements that are a result of regional operating history and area characteristics, applicable only to the jurisdictions under their (NPCC) direct authority.

In addition to NERC and NPCC reliability requirements, the IESO developed, via the market rules and including the Ontario Resource and Transmission Assessment Criteria (ORTAC), additional requirements for the IESO-controlled grid. Generally, the NERC standards address the absolute minimum reliability requirements with NPCC setting additional regional requirements, and the market rules further setting additional requirements that are specific to Ontario. The higher NPCC and market rules requirements address the particularities of the regional and provincial grid, respectively.

NERC and NPCC standards and Ontario market rules are intended to maintain the day-to-day reliability of the power system, when situations – known as "planning events" – occur. Planning events generally involve the loss of one or more transmission, generation or load assets as a result of a local incident (equipment failure, lightning strike, vegetation or animal contact, etc.). They can occur at any time and the system must be designed and operated such that following a planning event most consumers continue to receive electricity with no or very short interruptions (seconds, minutes).

The design of the power system is based on industry-defined planning events. These events don't consider the impact of extreme weather (floods, ice storms, hurricanes etc.) that can cause multiple, simultaneous interruptions involving a large number of transmission elements and facilities within a jurisdiction. The IESO monitors and conducts periodic studies to assess the ability of the interties to provide the "first response" emergency assistance should certain critical elements and/or facilities are lost due to extreme weather events.

The planning of the power system assumes, for example, the combined effect of highest expected ambient temperature with no cooling effect of the wind for the thermal stress of the equipment. In real-time the operators can take advantage of the higher equipment capability under lower ambient temperatures and/or the cooling effect of the wind to dispatch higher flows across interties without violating the actual equipment ratings. From this perspective, the planning criteria are generally more restrictive than the operating criteria.

The IESO also follows several North American Energy Standards Board (NAESB) business practices. NAESB provides best practices for coordinating electricity trading across the Eastern Interconnection and Quebec. While we strive to comply with these practices, they are not binding and do not limit our ability to trade with any jurisdiction.

Finally, the US Federal Energy Regulatory Commission (FERC) oversees American markets and inter-state regulation. While FERC has no regulatory oversight in Ontario, they are the major driver for changing NERC reliability standards and market operations in the United States. FERC also mandates open access to transmission systems to facilitate electricity transfers and market sales. FERC does not directly impact Ontario's ability to utilize our interties, but the IESO must be aware of changes in neighbouring markets so that we can remain compatible when facilitating electricity trades with the NYISO, MISO, PJM and other US entities.

Contact Us

IESO Customer Relations:

905.403.6900

Toll-Free:

1.888.448.7777

Email:

customer.relations@ieso.ca

Connecting Today.
Powering Tomorrow.