CIGRE-422
2021 CIGRE Canada Conference & Expo
Toronto, Ontario, October 25-28, 2021

Ontario Electricity Sector Scenario, Technological Advancements and Challenges – a Discussion

Dhaval Patel, Hemant Barot
Hydro One Networks Inc.
Canada

SUMMARY

Ontario's energy supply mix has significantly changed in the last 15 years, mainly due to government polices aiming for increase in clean and renewable energy resources and decommissioning of coal-based power plants to meet the Climate Change Action Plan. These changes along with replacement cost of aging nuclear Generating Stations and integration of renewable energy resources have resulted in an increase in the cost of electricity for rate payers in Ontario.

The connection of emerging technologies in century old electricity sector poses significant challenges; however, at the same time provides the opportunity to meet the long-term need of Ontario's electricity sector cost effectively. This paper discusses recent changes and challenges of Ontario's electricity sector and highlights need for a grid readiness in adopting key technological advancements that can help reform the sector affordably. An illustrative example is presented that highlights the integrated approach to cost effective solution which otherwise could have resulted into costly upgrade.

KEYWORDS

Energy Supply Mix, Distributed Energy Resources, Energy Storage, Electrical Vehicle, Smart Grid

1. Introduction

Ontario's energy supply mix has changed post deregulation, mainly due to government polices aiming for increases in clean and renewable energy sources and decommissioning of coal-based power plants to meet the Climate Change Action Plan. As it stands, Ontario is currently summer peaking at around 24,000MW and has an installed capacity of 38000 MW of mostly transmission-connected generation [1]. In addition, more than 3400 MW of mostly renewable based generation is connected in the distribution system [2].

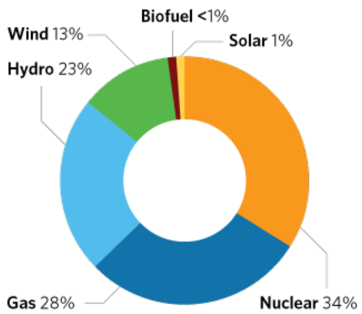
Having been in service for more than half a century, the majority of the nuclear generating plants are due for refurbishment or retiring in coming years. In addition, a number of gas-based generation, demand response (DR) and renewable based generation contracts will expire by mid 2030s leaving mid-term energy supply gap into Ontario's electricity sector [3]. Furthermore, transmission and distribution infrastructure in Ontario needs upgrade due to aging and to meet the technological change into utility industry. The integration of renewable generation technologies, electricity storage (ES) technologies, new and smart electric loads such as electric vehicles (EV) etc., is becoming a challenge for Ontario's mostly passive distribution network. Most critical challenge is the readiness of the grid to transform the electricity delivery and business model in accordance with the upcoming technological changes and customer's desire.

These challenges also provide opportunity to reform Ontario's electricity sector for future. Optimally planned placement of DER including ES can help meet the local demand growth from upcoming EVs, transit electrification, heating electrification etc., in a cost effective manner. Upgrading the aging infrastructure with smart devices enables more behind the meter generation and community energy plans which helps offset the load locally and reduces the stress on upstream grid network. Furthermore, they facilitate mutually benefitting platform for customers as well as utility by enabling upcoming technologies like Vehicle to Grid / Vehicle to Home integration, Internet of Things (IoT) and Energy Management System (EMS).

Section 2 describes recent changes and current challenges of Ontario's electricity sector. Section 3 discusses future opportunities arising from technological advancement to meet the current challenges. Section 4 illustrates an example of challenges associated with the new load connection on a long congested transmission line. It also discusses limitation of DER in solving transmission congestion issues when placement is considered on transmission side. Finally, it proposes a mitigating solution that can be cost effective and mutually benefit to transmitters, distributors and to the customer.

2. Ontario Electricity Sector Changes and Challenges

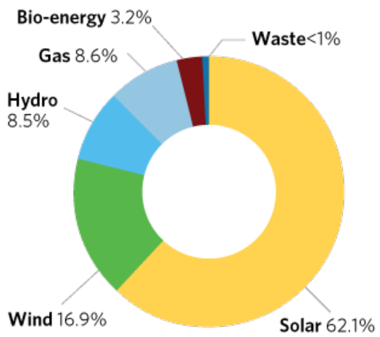
For over a century, electricity in Ontario was supplied from large generating stations to end user load customer. However, Ontario's electricity model has evolved over the years and significant changes have been incorporated to its energy supply mix during recent times. The current energy supply mix relies on nuclear generation and hydroelectric generation as base load generation and gas-based generation as peak meeting generation. Fig. 1 shows current transmission connected energy supply mix of Ontario as of June 2021.



Nuclear	13,089 MW or 34%
Gas/Oil	10,515 MW or 28%
Hydro	8,918 MW or 23%
Wind	4,783 MW or 13%
Biofuel	296 MW or <1%
Solar	478 MW or 1%

Fig. 1 Ontario Transmission Connected Energy Supply Mix (Source: IESO)

The Ontario government made a decision of phasing out coal-based generation as part of Ontario's push for more clean energy in 2007 and issued a directive of cessation of coal-based generation by December 31, 2014. At the time of the directive, the coal-based generation was accounted for 25% of the total generation of the province [4]. The decision of removal of coal-based generation from Ontario's energy supply list provided opportunity of diversifying and adding more renewable resources into Ontario's energy mix. To increase the renewable generation, the Ontario Power Authority (OPA - later to be part of IESO) implemented several fixed price incentive programs starting from year 2004 however, the introduction of Green Energy Act and roll out of Feed-in-Tariff (FIT) and micro-FIT programs in 2009 resulted into significant penetration of renewable generation into Ontario's distribution and transmission network. Due to guaranteed fixed-price incentive over the long term for every kilo-Watt-hour (kWh) generated, more than 3400 MW of Distributed Energy Resources (DERs) were connected to Ontario's distribution grid. More than half the connected DERs are photovoltaic (PV) based solar generation in size ranging from few kW to 10+ MW in capacity. Fig. 2 shows commercially connected energy resources by fuel to distribution system in Ontario as of December 2020.



Solar	2,166 MW or 62.1%
Wind	590 MW or 16.9%
Hydro	297 MW or 8.5%
Gas	299 MW or 8.6%
Bio-energy	110 MW or 3.2%
Waste	24 MW or <1%

Fig. 2 Ontario Distribution Connected Generators (Source: IESO)

Until recently, the electricity pricing in Canada remained low primarily, due to abundant access to large hydroelectric generation. However, aging resources and infrastructure, increased reliance on electricity, push for clean energy and changing paradigm in technology are demanding significant investments into its electricity sector. Ontario is no different and will need significant upgrade / replacements in integrating new technology to its grid network and to meet the various clean energy initiatives.

Having been in service for more than half a century, majority of nuclear generating plants are due for refurbishment or retiring in coming years. The expected shut down of Pickering

Nuclear GS by mid 2020s will result in 3000 MW of baseload generation short fall in Ontario's supply energy mix [3]. The total cost of refurbishment of 4 units Darlington Nuclear GS and 6 units at Bruce Nuclear GS is expected to be $26B and will be completed by 2033 [5]. In addition, the energy supply mix will continue to evolve due to upcoming short term and long term DR, gas based generation and renewable based generation contract expiry [3].

Most of the distribution system was design and built to feed customers in one direction and therefore, integrating renewable based DERs and other technology have posed serious challenges. Furthermore, increasing electrical vehicles and transit electrification initiatives in Ontario are emerging as serious load into already strenuous and passive distribution system network. The IESO forecasts Ontario's EV numbers can reach as high as 2.4 million vehicles by 2035 resulting in total electricity demand of 8.1 TWh by 2035. The public transportation agencies, Metrolinx – Go Transit, is working on electrifying Go Transit rail corridor with expected completion in 2025 [6]. These along with heating electrification will result in need for significant upgrade into transmission and distribution system. The electrification and Ontario's booming agriculture industry may overload certain local/regional transmission pockets.

3. Meeting the Challenges

Despite significant changeover, Ontario's current energy supply mix has sufficient capacity to meet the demand for next few years [3][5]. However, significant reform is required to maintain the current supply level as well as to meet the future demand in the long term. These challenges also provide opportunity to implement cost effective solutions that meet the growing demand and supply issue using emerging technologies and developing mutually benefit platform with end user customers.

Distributed Energy Resources, generally connected directly or indirectly to distribution system, as a market participant can help alleviate capacity issues locally and therefore, helps greater network benefits. Ontario has achieved significant distribution-connected generation in the last decade however, many of the DER will expire by 2030s and onwards leaving significant shortfall in supply capacity as well as distribution network support. In response and for other reasons, IESO has launched a Market Renewal / Capacity Auction initiative in 2021 and is changing how resources bid into the market [7]. This is aimed at reducing the cost of electricity and secure sufficient resources in the upcoming years. Also, with the DER cost approaching close to cost of conventional generation and technological advancements in power conversion allows DER to be operated as a market participant by the ISO/RTO. There are still several barriers remain both from market point of view as well as technical grid code requirement point of view which needs to be addressed to make this successful.

Behind the meter or net-metering generation provides excellent opportunity to meet the supply need with other benefits. The net-metering generation allows the customers to install the renewable generator at site and in return, it lowers the electricity cost by subtracting the energy generated from energy used. The arrangement helps utility to offset the supply need, reduce peak demand and defer or avoid costly upgrades due to congestion. The government in Ontario launched net metering program in 2005 however it got very little attention due to roll out of other popular programs like Renewable Energy Standard Offer Program (RESOP), Feed-In-Tariff (FIT) and micro-FIT. However, in 2013, Ontario's Long-Term Energy Plan

(LTEP) recognized the potential need of expanding and enhancing existing net-metering program and started looking for a transition from an incentive based generation purchasing program to a net-metering program [8]. The government recently started exploring options of single entity and / or multi entity virtual net-metering program and allowed connection of Energy Storage (ES) with the net-metering generation. It is imperative that the greater adoption of behind the meter / net-metering resources will offset the load at transmission and distribution level and thus; will result into revenue shortfall on the transmission and distribution business in the traditional kWh based rate structure. This can have negative impact on utility businesses and also to end user load customers. In response, the utility business models will also have to be transformed to capture the net cost of adopting such technologies and for the survival of the utility business.

Energy Storage can absorb, store and provide the energy when required; thus, provide great flexibility to system operators. Due to this unique characteristic, ESs offer many benefits including but not limited to shifting system peak, ancillary services, regulation support, islanding to name few. Energy Storages are not new to Ontario as large hydro Pumped Storage has been in operation and providing benefits to Ontario grid for more than half a century. In 2014, the Province started procuring Energy Storage through IESO governed Competitive Energy Storage Procurement process as a pilot to gain deeper understanding of the technology. The process targeted to acquire 50 MW of different units to provide regulation and ancillary services. Energy Storages in combination with DERs reduces network congestion at distribution as well as transmission level. Enabling DER along with the Energy Storage allows formation of micro-Grid at community or local level, which can help improve the reliability for the end user load customer. Energy Storage can also relieve congestion on transmission line by shifting peak of the load. Various LDCs are considering ES as a tool to improve reliability through grid edge or even behind the meter installation. For an example, Hydro One Distribution is installing 1.5 MW / 3 MWh Battery Energy Storage System (BESS) to improve reliability to remote community currently being served through very long overhead lines. In this case, the ES helps defer significant capital expenditure otherwise needed to meet the system performance. Despite these benefits and falling prices, market and regulatory barriers are resulting into slow adoption of ES around the world.

Since the deregulation, Ontario has invested heavily into renewing its supply infrastructure and continuing to do so however, little attention has been given to its transmission and distribution infrastructure upgrade need to meet the technological changes. The government of Ontario made a decision to install smart meters for all customers in 2005. The Advanced Metering Infrastructure (AMI), smart meters along with communication and other intelligent components, helped achieve successful roll out of Demand Response (DR) programs and proved to be the key component in roll out of Smart Grid initiatives. The current pricing model in Ontario is called the Regulated Pricing Plan (RPP) and the pricing is set based on Time-of-Use (ToU) to shave the energy during the peak hours. This also helped spread awareness about energy usage among customers and promote conservation efforts. The AMI technology also helps achieve demand response and provides flexibility to the customer. The AMI also helped improve reliability by allowing LDCs to locate and respond outages quicker.

The deployment of smart meter proved to be the first step in modernizing the Ontario grid however; more action is needed at line and transformational level in getting ready for integration of new technology into the system. In 2011, the Government of Ontario launched the Smart Grid Fund to enable renewable based DER into distribution network. Since then, Ontario has implemented several pilot projects aiming for better and smarter grid infrastructure development however; these projects have not been fully materialized into the grid scale roll out. Modernizing the grid with intelligent sensors, hardware automation, communication infrastructure and smart computer and simulation programs can help tackle the issues like reliability improvement, congestion, DER integration, micro-grid formation, supporting community energy plans and integration of Energy Management System (EMS). It can also help achieve maximum potential of emerging technology like Internet of Things (IoT) for the greater benefit.

Electrical Vehicle (EV) and transit electrification are one of the key solutions to meet the Climate Change Action Plan. Although the current sale of EV significantly depends on government policies, the lowering of prices and efficiency improvement in battery systems are resulting in increasing adoption of EVs over the last few years. Furthermore, the federal government's recent announcement of mandatory requirement of zero emission vehicles for all new light-duty cars and passenger trucks sales in Canada likely to push for more EVs across Canada [9]. The City of Toronto acquired 60 zero emission electric buses for public transit in year 2019 alone and announced their green initiative plan of achieving 50% of zero emission transit by 2032 and 100% zero emission by 2040 [10]. EVs and transit electrification can put serious load on distribution network, which may result in a significant upgrade to the system. However, emerging technologies like Vehicle to Grid (V2G) or Vehicle to Home (V2H) can support the grid by reducing the intake power or even sending power back when needed by the grid. These technologies offer much more needed flexibility to utilities without any capital investment. The grid scale roll out of V2G and/or V2H very much depends consumer behavior, similar to other home based DR technology.

4. Transmission Capacity Deferral – An Example

Although Ontario's bulk transmission system has sufficient capacity to meet the Ontario's growing demand, certain regional and local pockets are congested and unable to meet the significant demand growth of the area. Addressing such issues require careful economic assessment of each need in the area / region and most often the solution are very specific to each need which can be wires or non-wires alternatives. It also requires changes in the regulatory framework to allow for investments to be recoverable. For an example as illustrated below, a step increase in a new load connection request results in a major transmission upgrade. However, an integrated planning approach using DERs may effectively utilize the existing asset and can help deferred the costly transmission capacity investments for an small amount of incremental load growth in the area / region. Furthermore, it demonstrates that DERs alone are not the solution, but understanding the transmission system constraints and accordingly placing DERs optimally, an integrated planning approach, serves the need.

As shown in Fig. 3, the Station A and Station B are step down transformer and being fed from long 115 kV lines coming from a HV Station. Station A and B are serving as step down transformer supplying load customers. The Station A peak load is 85 MW and Station B peak load is 125 MW. The customer submits 50 MW of new load application to connect on distribution side of Station A. The new load connection results into Station A being operated beyond transformer's thermal capacity limit, Limited Time Rating (LTR), of 125 MW. In addition, it also results into 115 kV line circuits operating beyond its thermal limit, Long Time Emergency (LTE), rating of 250 MW during single contingency. Addition of this new load is going to result in overloading of the transformers at Station A and the upstream transmission lines by 10 MW which will not be acceptable.

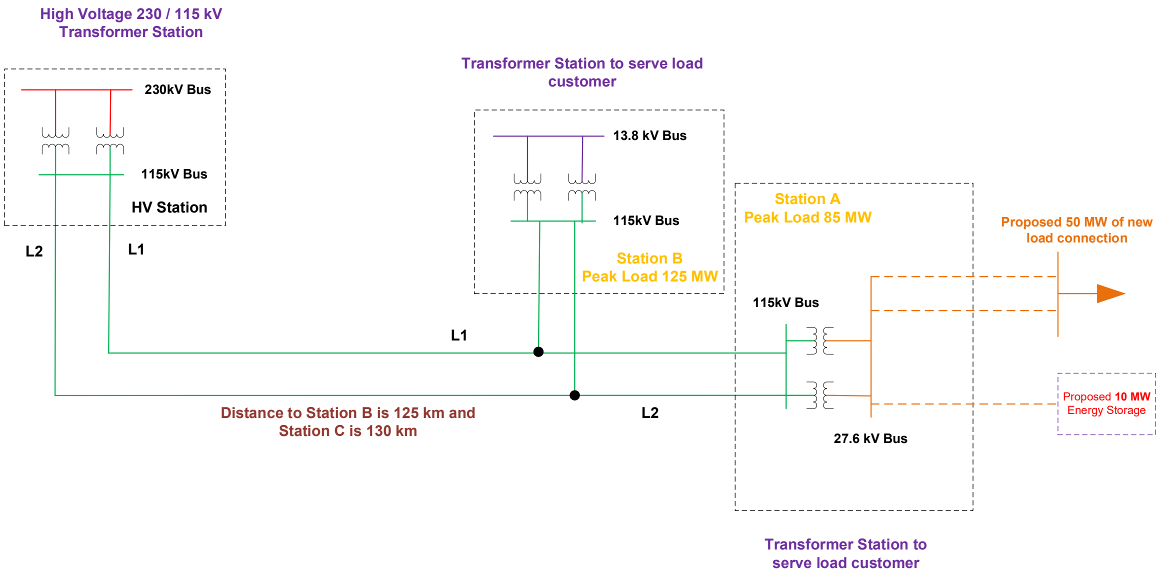


Fig. 3 Schematic diagram of Study Area

The option of upgrading transmission infrastructure to 230 kV can turn down the project due to significant cost to the customer. Installing of a BESS of the appropriate size of the LV side of the transformer can be an economic solution. For example, as illustrated above in Fig.3, installation of a 10 MW Energy Storage device closer to the load customer or at the LV side of Station A can potentially address both station and upstream transmission line capacity issues. . It is worth noting that the energy rating of the BESS needs to be carefully assessed based on the Customer's peak demand duration as well as historical / expected peak duration at the station / line. This mutually benefitting solution requires integrated operation coordination between distributors and transmitters as well as distributors and customers. Addressing this solution in a piece meal manner can significantly increase the connection cost.

5. Conclusion

Post deregulation, push for clean energy and cessation of coal-based generation has resulted into significant change in supply mix for Ontario. Implementation of government policies along with replacement costs for aging resources in the province augmented the electricity costs for load customers. This paper summarizes the recent changes and challenges experienced by Ontario's electricity sector including the need for grid readiness and business model transformation. It identifies future opportunities to meet these challenges in the long term. Furthermore, it is discussed that the success of these opportunities significantly depends on the readiness of the grid at all level and not just in the piece meal solution. Upgrading the grid with modern communication infrastructure and smart devices can benefit both utilities and customers. Increased awareness and participation by customers into various mutually benefitting programs can help achieve better asset utilization and lower rates for ratepayers. Also, the utility business model transformation is required that can capture the net cost of adapting such benefitting programs for the greater success.

BIBLIOGRAPHY

[1] Reliability Outlook – An adequacy assessment of Ontario's electricity system July 2021 to December 2022, available: https://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Reliability-Outlook

[2] A Progress Report on Contracted Electricity Supply - Third Quarter 2020, available: https://www.ieso.ca/-/media/Files/IESO/Document-Library/contracted-electricity-supply/Progress-Report-Contracted-Supply-Q3-2020.ashx

[3] Annual Planning Outlook – A view of Ontario's electricity system needs January 2020, available: http://www.ieso.ca/en/Sector-Participants/Planning-and-Forecasting/Annual Planning-Outlook

[4] Coal Closure in Ontario August 2015, available: https://www.nerc.com/gov/bot/botquarterlyitems/Coal%20Closure%20in%20Ontario%20-%20v6%20clean-6-2.pdf

[5] Ontario's Long-Term Energy Plan 2017 – Delivering Fairness and Choice, available: https://www.ontario.ca/document/2017-long-term-energy-plan

[6] Module 2: Demand Outlook August 2016, available: http://www.ieso.ca/-/media/files/ieso/document-library/planning-forecasts/ontario-planning-outlook/module-2-demand-outlook-20160901-pdf.pdf?la=en

[7] Available:https://www.ieso.ca/en/Sector-Participants/Market-Operations/Markets-and-Related-Programs/Capacity-Auction

[8] Achieving Balance – Ontario's Long-Term Energy Plan, available: https://www.ontario.ca/document/2013-long-term-energy-plan

[9] News Release – June 29 2021, available: https://www.canada.ca/en/transport-canada/news/2021/06/building-a-green-economy-government-of-canada-to-require-100-of-car-and-passenger-truck-sales-be-zero-emission-by-2035-in-canada.html

[10] Available: https://www.ttc.ca/Riding_the_TTC/green_initiatives.jsp