Enabling Tomorrow's Electricity System

Report of the Ontario Smart Grid Forum

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The Forum gratefully acknowledges the contribution of Joel Singer, of Singer & Watts, Forum Facilitator and Principal Author.

Executive Summary

THE SMART GRID

Source: European Technology Platform SmartGrids

The use and production of electricity are changing. Consumers are becoming more aware of the environmental impacts of the electricity system and are seeking greater ability to manage their electricity use to control costs and help improve the environment. New dispersed energy resources such as solar, wind and storage hold the promise of not only lowering greenhouse gases, but also allowing consumers to produce their own electricity and sell the excess. Widespread use of plug-in electric vehicles will bring even greater change as consumers look to conveniently charge their cars at home or on the road.

These changes will require a paradigm shift in the electricity system. Today, the grid is primarily a vehicle for moving electricity from generators to consumers. Tomorrow, the grid will enable two-way flows of electricity and information as new technologies make possible new forms of electricity production, delivery and use. The smart grid is the name given to the new electricity system that will emerge from this paradigm shift.

A smart grid is a modern electric system. It uses sensors, monitoring, communications, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It increases consumer choice by allowing consumers to better control their electricity use in response to prices or other parameters. A smart grid includes diverse and distributed energy resources and accommodates electric vehicle charging. In short, it brings all elements of the electricity system – production, delivery and consumption – closer together to improve overall system operation for the benefit of consumers and the environment.

Over the past few years, Ontario has undertaken bold initiatives that both underscore the need for a smart grid and help move us toward it. To reduce the environmental footprint of the electricity sector, the Province has:

• Required the shut-down of Ontario's coal-fired generation;

• Worked to create a culture of conservation; and

• Procured renewable generation sources to meet future electricity needs.

These initiatives require the electricity system to accommodate new types of generation in new locations including variable generation sources whose output depends on the wind and sun. The system must also promote increased consumer involvement in electricity consumption decisions and incorporate two-way power flows on lines that have historically been used for delivery alone.

Ontario's leadership in smart meters represents an essential first step in realizing the benefits of a smart grid for consumers. By measuring hourly electricity consumption, these meters allow the provision of prices that vary with time-of-use. Research has shown that providing transparent electricity prices to consumers together with time-of-use rates can lead to consumption reductions that range from five to fifteen per cent. The completion of smart meter installation and implementation of time-of-use rates, along with the information necessary to educate consumers about these changes, will let consumers benefit from in-home energy displays, home energy management systems and related services. These devices and services will help households and small businesses to better manage their electricity use in response to prices or other parameters.

Provincial initiatives on conservation, renewable generation and smart meters begin the move towards a new electricity system, but their full promise will not be realized without the advanced technologies that make the smart grid possible. The challenges that Ontario faces in simultaneously incorporating distributed generation, addressing growth, and replacing aging infrastructure while maintaining reliability and quality of service are daunting. While new grid infrastructure will be necessary to connect generation resources, replace aging assets and address growth, simply adding wires and equipment without intelligence is not a viable option.

While promising, smart grid technologies are not risk free. Many of these technologies are in the early stages of development. Not all of them will advance to commercialization and for some, the cost of implementation on a commercial scale may prove prohibitive. Finally, the challenge of interoperability, enabling new and existing technologies to exchange information and work together is substantial. Overcoming these challenges will require innovation, investment, creativity and hard work, but if Ontario is to realize a sustainable future and continue to grow and prosper, the transformation of its electricity infrastructure is essential. Clearly defining the roles and opportunities for all the potential market players will create an environment that encourages the investment necessary to support this transformation.

Ontario is well positioned to develop smart grid technologies and systems. The Ontario Centres of Excellence (OCE) currently has 14 projects underway or in the pipeline that relate to smart grids. All are collaboratively supported by industrial partners, academic institutions and OCE. The total investment in these projects is currently close to $12 million with almost half of this amount coming from OCE. Sustained funding for research and development is essential if Ontario is to realize the potential benefits from developing and commercializing smart grid applications.

The potential of smart grid technologies will only be realized if they are operated by skilled employees and feed into processes designed to take full advantage of the new technologies. Ontario must continue to educate and train employees who are capable of designing, developing and operating the smart grid. Together, technology, people and processes will permit the realization of a modern electricity system that benefits all Ontarians.

SUMMARY OF THE FORUM'S WORK

This report presents the work of the Ontario Smart Grid Forum (Forum), a group of industry leaders who came together over a seven-month period to learn more about the smart grid, its benefits for consumers, and to develop recommendations for advancing it in Ontario. The Forum did not undertake to analyze in detail the cost of moving to a smart grid or to specify technology requirements as these matters will depend on the investment decisions of individuals and companies, and should be considered in the context of those decisions.

The Forum heard from invited experts on various aspects of the smart grid and then discussed the implications of their presentations for Ontario. The presentations covered the following topics.

- **Smart Grid Vision:** The Forum heard overview presentations describing the vision of a smart grid and smart grid activities in the United States and the European Union. In both jurisdictions, ongoing efforts are underway to establish the technical, legal and institutional frameworks necessary for smart grids to develop. This information helped Forum members to better understand the components and benefits of a smart grid and to develop a vision for an Ontario smart grid.

- **Consumers:** Smart grid technologies, particularly home energy management systems, will change how consumers use electricity by increasing their ability to control household appliances and equipment and thereby manage their electricity cost and contribute to a better environment. Some of these devices can also integrate production from renewable technologies like rooftop solar photovoltaics. A smart grid can change how consumers, utilities, retailers and other service providers interact by offering new ways for them to communicate and expanding the types of service available to consumers. Smart grid technologies will also enable many different types of companies outside the utility sphere to enter the market for home energy management systems and services to help spur innovation.

- **Ontario Status:** Ontario distributors, transmitters and the Independent Electricity System Operator (IESO) are currently undertaking smart grid-related activities, mostly involving the ongoing implementation of smart meters and associated technology. These companies are also developing or exploring smart grid activities beyond smart metering. Examples of these activities include ongoing efforts to increase available communications options and promote the creation of a communications spectrum for use by electric utilities; projects to install distribution transformer monitors and related communications equipment; and increased installation of automated distribution equipment.

The Forum's working group surveyed 12 of Ontario's largest distribution utilities, serving about 78 per cent of the province's customers about their current investments and future investment plans related to a smart grid. This research confirmed that in addition to smart meter deployment and advanced metering infrastructure, distributors are incorporating other smart grid technologies into both current and future investment plans, but not on a comprehensive basis. The research concluded that over the next five years, currently planned investments by the distributors surveyed are insufficient to allow for full smart grid deployment.[1]

- **Distribution:** The use of advanced sensing, automation and communications equipment on the distribution system can improve reliability, equipment performance, restoration times and power quality. This technology also can be used to improve distribution system maintenance and operations, and enhance system planning. The Electricity Distributors Association presented its vision for electricity distributors, which sees them using advanced technology to optimize the operation of their distribution systems and enhance their ability to provide a variety of energy services, including conservation and demand management, and distributed generation, in support of provincial energy policy and community energy plans.

- **Distributed Energy Resources:** Energy resources on the distribution system include generation, storage and demand response. Ontario is in the process of incorporating substantial amounts of renewable generation. Connecting this generation to distribution lines that were designed and built to deliver electricity to consumers poses substantial challenges. Smart grid technology can help maximize the amount of generation that can be connected to the distribution system while maintaining safety and service quality to consumers.

  Energy storage offers many potential benefits such as:

  - delivering energy to meet peak load;
  - providing ancillary services, including regulation and voltage support;
  - allowing for the deferral of distribution investments; and
  - helping to integrate variable generation such as solar and wind, and maximize the value of the energy produced by these technologies.

  While storage can produce many benefits, storage projects can be difficult to fund because the benefits produced typically flow to multiple parties. The returns to the entity investing in the storage facility may be insufficient to justify the investment.

  Demand response is the ability of customers to change their consumption in response to price or other signals. While demand response is currently focused on reducing consumption during peak periods, it is easy to envision future circumstances where demand response also will be used to help balance the variable production of wind and solar generation. Smart grid technologies facilitate demand response by giving customers the ability to see prices and the tools to react to them.

[1] Current Status and Investments Plans: David Curtis, Hydro One; John Mulrooney, PowerStream; Joshua Wong, Toronto Hydro: http://www.ieso.ca/imoweb/pubs/smart_grid/Current_Status_and_Investment_Plans.pdf

- **Micro-Grids:** A micro-grid is envisioned as an integrated solution that meets the energy needs of a group of consumers, such as a neighbourhood or a town, or a single consumer, such as a university. Research is required to address questions regarding the costs and benefits of micro-grids and the appropriate role for them in Ontario.
- **Electric Vehicles:** Plug-in electric vehicles offer the prospect of reduced emissions and lower cost. Their widespread adoption, however, will present challenges and opportunities for the electricity system. At a local level, the major challenge involves enabling vehicles to be charged safely and conveniently without adversely impacting local distribution equipment. For the electricity system as a whole, the challenges involve finding ways to move vehicle charging into off-peak periods so as to avoid increasing peak load and the resulting need for additional peaking resources. The opportunity involves using the energy stored in vehicle batteries to provide peak period energy. A smart grid is essential if Ontario is to address the challenges and embrace the opportunities presented by plug-in electric vehicles.
- **Standards and Security:** Standards and security are vital if the smart grid is to develop efficiently over time. Standards are required to allow devices developed by different companies for different purposes to interact. The notion of interoperability takes the concept further to cover the ability of various devices to actually work together to perform the functions for which they were designed.

  Security is crucial because grid modernization requires installing large numbers of devices that must communicate back into essential computer systems covering core utility functions such as operations, outage management and billing. Many smart grid devices are deployed in physically unsecured locations and thus can be accessed by those seeking to penetrate critical utility systems. Beyond the challenges it poses for cyber security, the smart grid may enhance physical security at substations and other facilities by facilitating remote monitoring via cameras and sensors.
- **Transmission:** Historically the large volume of electricity carried by transmission lines and their relatively small number have justified more extensive monitoring and more automated control of the transmission system in serving large generators and consumers, including distributors. The need to incorporate substantial quantities of variable generation and the development of storage will drive increased application of advanced technologies. Transmission can become smarter through the installation of additional monitoring to allow better assessment of conditions on interconnected systems and through the use of technologies that enhance control of electricity flows over transmission lines.

KEY RECOMMENDATIONS

Presented below are some of the key recommendations that follow in the Forum's Report. They reflect the central belief that Ontario should develop a smart grid to improve the prosperity of its citizens, the performance of its electricity system and the environment. The rapid development of a smart grid to benefit electricity consumers and advance environmental initiatives should be the policy of the Province of Ontario.

- The Ministry of Energy and Infrastructure should facilitate the development of Ontario's smart grid through legislation, regulation or other available means that clarify authorities, establish requirements or create incentives for those entities investing in Ontario's electricity system to accelerate the deployment or enhance the functioning of smart grid technologies.
- Consumers and their designated representatives should have access to timely information on their consumption and the price they are being charged from a smart meter with two-way communication capability or via the internet. Consumers should pay prices that reflect the cost of energy at different times.
- In order to plan and operate the grid reliably and efficiently, distributors, transmitters, the Ontario Energy Board (OEB), Ontario Power Authority (OPA) and the IESO should work together to:
  - develop requirements for and propose sufficient monitoring of distribution connected generation, energy storage, and responsive load;
  - determine the authority necessary to direct the operation of these facilities, the conditions under which their operation could be directed and any compensation that would be provided to the facility;
  - propose contractual and pricing arrangements with distribution connected generation, energy storage, and responsive load that support efficient grid operations and are consistent with the operation of the wholesale electricity market;
  - coordinate the development and implementation of grid control and information systems to facilitate the actions listed above.
- A Task Force led by the Ministry of Economic Development and involving other relevant Ministries should be created consisting of representatives from the auto sector (vehicle manufacturers and suppliers) electricity sector (OEB, IESO, OPA, distributors and generators) and universities to develop a comprehensive plan for enabling plug-in electric vehicles in Ontario. The plan would address policy, financial, and electricity system impacts of substantial electric vehicle penetration and identify what is required to ensure that vehicles can be charged as they develop. The Task Force should link to the ongoing collaborative work by the Electric Power Research Institute (EPRI), the Society of Automotive Engineers (SAE) and standards development organizations to develop electric vehicles standards.
- Utilities, the IESO, the OPA, universities and OCE should conduct research and development related to smart grids to advance Ontario's leadership position in this area, promote innovation and develop green jobs in the province. The OCE should facilitate the development of a task force to produce a framework for smart grid research in Ontario that would include targeted amounts of funding and proposed funding mechanisms.

CONCLUSIONS AND NEXT STEPS

From this diverse body of materials a few common themes emerged. There is tremendous excitement about the potential of the smart grid to provide economic benefits and an improved environment. Balancing this excitement is a recognition that not all smart grid technologies will deliver as promised. Inevitably, there will be false starts and dead ends. Open standards and integrated approaches are the key to minimizing the risk of stranded technologies.

Coordination on several different levels will be a key factor in the successful development of a smart grid. On the technological level, there is the need for standards and interoperatibility to allow devices developed by multiple suppliers to communicate and work together. Coordinated development across the divisions of the electricity system (i.e. customers, distribution, retail service providers, transmission and generation) also will be essential for the smart grid to function as an integrated whole. To deliver on its promise, the smart grid must enable the transparent exchange of operating and price information to efficiently link customer choices with the dispatch of resources and the operation of the electricity grid.

Better coordination will also be required between the electricity industry and other industries. Electric vehicles are a particularly good example of this type of linkage. Vehicle manufactures and the electricity industry must work together to ensure that electric cars can be charged conveniently in multiple locations and that vehicle charging can be accommodated without adversely impacting electric service.

Presentations that described smart grid efforts in Europe and the United States showed that both these jurisdictions are aggressively pursuing smart grid development. While one jurisdiction may be more advanced in adopting certain technologies, overall there is no clear leader in smart grid development. Instead, there is a universal sense of tremendous energy and enthusiasm for modernizing the electricity system to benefit consumers and the environment through improved grid operations and the incorporation of renewable generation. In terms of how to marshal this energy to transform the electricity system, however, the presentations contained more questions than answers. Ontario, like the other jurisdictions, has the opportunity to both lead and learn from the efforts of others as it works to create a smart grid.

The Forum sees value in continuing to champion smart grid progress, monitor ongoing developments and advocate common approaches where they make sense. To this end, the Forum believes that an enduring organization to promote smart grid development with a broader base of representation may be appropriate in the future. The Forum will consider this further based on insights gathered from discussions with Government and industry following the release of this Report.

AN OPPORTUNITY FOR INNOVATION

Ongoing initiatives, growing consumer interest, new technologies, articulated policy direction and economic pressures to increase efficiency and performance are all converging to create an unprecedented opportunity for bold initiatives in Ontario to realize the potential offered by a smart grid. Ontario should seize the chance to become a leader in developing and deploying smart grid technologies to benefit its citizens and enhance its economy. In the pages that follow, Ontario's Smart Grid Forum discusses in detail the opportunities that a smart grid presents and recommends actions to realize them.

Members of the Smart Grid Forum

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Michael Angemeer
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In addition to the members signing above, the Ontario Smart Grid Forum included representation from the Ministry of Energy and Infrastructure and the Ontario Energy Board. These representatives participated in Forum discussions, but they were not participants in the consensus and are not responsible for the recommendations of the Forum. The Forum wishes to acknowledge and thank the following representatives for their contributions:

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* Titles listed were appropriate prior to the final release of the report

Introduction

This document presents the work of the Ontario Smart Grid Forum. The report begins by describing the Forum, what it set out to accomplish, and how it operated. A vision of the smart grid follows which explains the smart grid and the fundamental transformation of the electricity system that it represents. Subsequent sections discuss various aspects of smart grid development and make recommendations in each area. The report concludes with a section on advancing the smart grid.

ONTARIO SMART GRID FORUM

The Forum was convened by Ontario's IESO in collaboration with Burlington Hydro, Hydro One, Hydro Ottawa and Toronto Hydro for the purpose of bringing industry leaders together to learn about the smart grid, explore its potential benefits for Ontario, and recommend appropriate actions to policymakers and the industry at large that will promote smart grid development.[2] Over the period from June through December 2008, the Forum heard experts from Ontario and around the world present on various aspects of the smart grid and engaged in far ranging discussions on these topics. A list of the presentations to the Forum and a link to them can be found in Appendix A.

In the process of developing this report, the Forum reflected on what it had heard from the various presenters and the implications of this information for Ontario. The Forum operated by consensus and the recommendations presented in this report are endorsed by all of the signatories to this document.

The Forum also formed the Ontario Smart Grid Working Group (Working Group) to support its work and undertake research. The Working Group helped the presenters to focus their presentations, investigated specific topics, provided more detailed background on the smart grid and contributed to the Forum's discussions. The Working Group produced a number of research papers, which are referenced in Appendix A.

- Consumer Positions and Attitudes about Electricity
- Value Proposition for a Smart Grid
- Distributor Smart Grid Investments – Current Status and Investment Plans
- Survey of Smart Grid Technologies

[2] Ontario Smart Grid Forum Terms of Reference: http://www.ieso.ca/imoweb/pubs/smart_grid/TOR-SGF.pdf

ACKNOWLEDGEMENTS

The Forum wishes to acknowledge the assistance it received in completing its work. All the individuals who presented, as listed in Appendix A, gave generously of their time and expertise. The Forum wishes to thank them sincerely for their help and willingness to share their knowledge.

The support provided by the Working Group contributed significantly to the work of the Forum. Their efforts are appreciated. The Working Group consisted of:

Raed Abdullah
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Lisa Dignard-Bailey, Ph.D
Natural Resources Canada

John Mulrooney
PowerStream Inc.

Joshua Wong
Toronto Hydro Electric System Ltd.

The Forum also could not have completed its work without the efforts of certain key individuals. We wish to thank the following people for their contributions. Don Tench of the IESO served as the key liaison with the Forum members, chaired the Working Group and contributed his knowledge, creativity and enthusiasm to the Forum's discussions. Derek Beamer of the IESO located expert presenters, worked with them to shape their presentations and kept the Forum on track and on schedule. Melinda Rankin of the IESO provided administrative support to Derek and Don, and the Forum as a whole.

Smart Grid Vision

Smart grid is the term applied to tomorrow's electricity system. It encompasses a variety of changes that will transform the way electricity is used, delivered and produced, and result in a cleaner more efficient and more interactive electricity system. It represents a paradigm shift for electricity much in the way that cell phones transformed communications. The concept is broad; it stretches beyond modernization of the transmission and distribution grid to include devices that allow consumers to better manage their electricity use, new ways of creating and storing electricity, and the widespread adoption of electric vehicles.

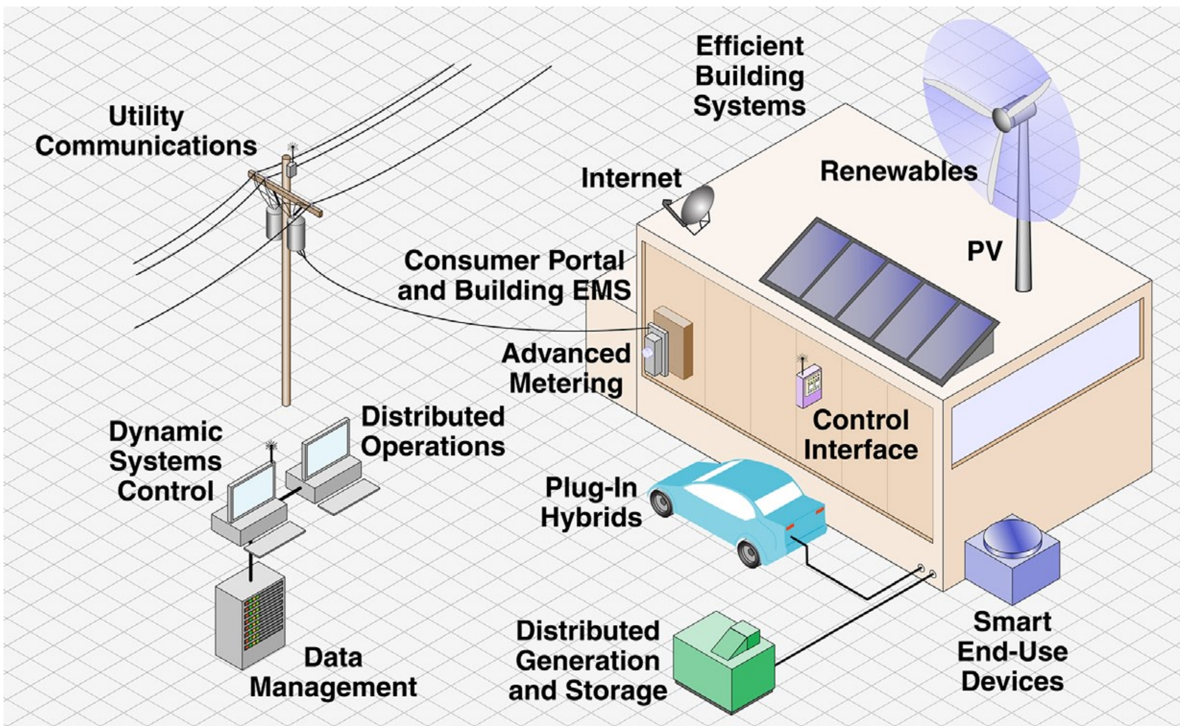
Ontario's move to a culture of conservation and its substantial commitment to renewable energy will also be supported by the smart grid. Smart meters, a major smart grid component, can give consumers timely information on price and consumption. Emerging devices will empower consumers to act on this information automatically while at the same time improving their energy efficiency, comfort and convenience. New sensing, monitoring, protection and control technologies will enhance the ability of the grid to incorporate renewable generation.

The institutional structure of the electricity industry makes it easy to look at how the smart grid will impact each piece of the system in isolation, but the most profound impact of a smart grid may be its ability to link these pieces more closely together. In Ontario we have numerous distribution utilities, one large transmission company and a few smaller ones; one large generating company and many smaller ones. The province has a system/market operator and a corporation responsible for longer-term system planning, and procuring electricity supply and demand resources. While the smart grid will affect each of these segments in different ways, it will affect all of them by increasing their ability to work together to better serve consumers.

SMART GRID DEFINITION

A smart grid is a modern electric system. It uses communications, sensors, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It offers consumers increased choice by facilitating opportunities to control their electricity use and respond to electricity price changes by adjusting their consumption. A smart grid includes diverse and dispersed energy resources and accommodates electric vehicle charging. It facilitates connection and integrated operation. In short, it brings all elements of the electricity system – production, delivery and consumption closer together to improve overall system operation for the benefit of consumers and the environment.

A smart grid is not only information rich, but also has the analytic infrastructure, processes and trained individuals necessary to integrate and act on information in the very short time frames required by the electricity system. It is characterized by clear standards, security protection and open architecture that allow for continued innovation through the development and deployment of new technologies and applications by multiple suppliers.



Source: Electric Power Research Institute

DRIVERS FOR A SMART GRID

The Province's commitment to establishing a culture of conservation and the desire to reduce the environmental footprint of the electricity sector are major drivers for creating a modern grid. The culture of conservation requires the continual search for new ways to encourage all Ontarians to use energy more efficiently and lower consumption during peak periods. The comprehensive provision of smart meters creates the opportunity for all Ontarians to better understand and manage their electricity usage and, for those who wish, to become active providers of demand response.

The prominence of renewable energy in Ontario's resource portfolio requires an increased ability to accommodate variable generation from wind and solar. Where today the grid serves primarily as a vehicle to move electricity generated in large central facilities to consumers, in the very near future, the grid will need to do much more. As the number and distribution of smaller generators grows, the operational challenge of incorporating these energy resources, while maintaining safety and reliability, will also grow. Meeting this challenge will require a smart grid.

Other features of Ontario also drive development of a smart grid. Like most jurisdictions in North America that saw substantial growth after World War II, Ontario is facing the need to replace a significant amount of its electricity infrastructure. This need creates an opportunity to use smart grid technology both to maximize the use of existing equipment and to improve the efficiency of the grid as it is replaced. Growth and redevelopment also present opportunities to introduce smart grid technologies in newly developed and reconstructed areas. Demands by industry and consumers for increased reliability and power quality technology are also pushing toward a smarter grid.

PROMISE, COST AND TIMING OF A SMART GRID

The Forum's research has uncovered many potential benefits from a smart grid in the areas of economics, environment and operating performance. The ability of consumers to increasingly participate in the electricity market by adjusting their demand in response to price or other signals will help to defer the need for peaking resources and incorporate additional generation from variable sources. Improved system economics will come from reduced losses during electricity delivery (line losses) and better use of station equipment. Potential reductions in congestion will also allow greater use of the most cost effective generation and improve the capacity to move generation throughout the province. Greater ability to integrate generation and load can also reduce the cost of operating reserve and some ancillary services. Finally, improved analytics and the ability for the grid to automatically restore itself from faults can reduce the scope and duration of outages, lower operations and maintenance costs, and improve service to customers.

Many of the identified economic benefits also have associated environmental benefits. Reduced losses not only reduce cost, they allow more of the electricity generated to reach consumers thereby lowering the environmental impacts from generation. Increased ability to incorporate distributed energy resources, including both renewable generation and demand response, will allow Ontario to move more quickly to a cleaner resource mix. Using existing assets more efficiently can defer the need to expand the grid to accommodate growth.

The smart grid offers enhanced operational performance. Greater awareness of system conditions can help anticipate and address problems before they lead to outages, minimize the scope of outages that do occur, and enable more rapid restoration of power. With a smart grid, these fixes may increasingly occur automatically so that the grid becomes self healing.[3] The ability to remotely monitor equipment condition and performance can also enhance security, help better target maintenance and improve the accuracy of replacement decisions. The information provided by a smart grid also can be used to improve power quality, which is increasingly important in operating today's sophisticated equipment controlled by digital electronics.

By automating functions that are controlled manually today, the smart grid will increase productivity, which will be essential in managing the more complex grid of tomorrow and helpful in addressing the demographic issues facing the electric system as the baby boomers retire and new workers need to be hired and trained. Finally, the smart grid can provide significant operational advantages through its ability to improve both public and worker safety by increasing the amount of system information available for protection and control and by enabling remote operation and automation of equipment.

The costs of the smart grid are difficult to quantify. They will depend on investment decisions and the pace of implementation by numerous companies and individuals undertaking smart grid expenditures. It is through the analysis underlying these decisions that the benefits and costs of specific smart grid investments will be evaluated. Certain cost elements that support the smart grid have already been incurred. Ontario's investment in smart meters and advanced metering infrastructure provide an important connection with customers and the beginning of the communications infrastructure necessary for a smart grid. Additional communications, with greater bandwidth, speed and reliability will be needed, for full smart grid implementation. Moreover, much of the distribution infrastructure replaced over the last few years is already smart grid compatible.

Preliminary cost projections prepared by Forum members and extrapolated to cover Ontario's entire grid sector (distribution, transmission and the IESO) estimate that incremental annual capital spending on a smart grid would average about $320 million over the initial five years.[4]

This investment, which is in addition to the spending currently planned on smart meters, grid expansion to incorporate generation and grid refurbishment, would only occur based on a clear Provincial commitment to smart grid implementation with supporting legislation and regulations. Customer support also would be a key factor in evaluating smart grid investment and customer education would be necessary to inform consumers on this issue. Investment at this level would require increased availability of demonstrated smart grid technology and the human resources to install and integrate it. Finally, the costs and benefits of proposed incremental smart grid investments would be evaluated through appropriate regulatory processes.

The timing of smart grid development also will depend on individual investment decisions, which in turn will be influenced by external policy drivers. The investment plans by grid owners, operators and consumers that will largely determine the pace of adoption for smart grid technologies will be based on their individual needs and circumstances, and their available capital. Government policy, implemented through incentives, mandates or regulatory initiatives will be a major factor in influencing the timing of investments.

In short, because the smart grid is not a single project, but rather a series of actions by a variety of entities to modernize the electricity system, it is difficult to produce a definitive timeline for smart grid development. Instead, the paragraphs below set out some likely features of smart grid development in

[3] Characteristics of a Modern Grid: U.S. National Energy Technology Laboratory: http://www.netl.doe.gov/moderngrid/docs/Self%20Heals_Final_v2_0.pdf?7982b8d0

[4] Comparisons between this estimate and the smart grid spending estimates for other jurisdictions are not meaningful because of the different spending categories included in various figures and the different starting point for each jurisdiction. For example, the above cost estimate does not include the cost of renewable energy resources or any smart meter costs.

different time periods based on current issues and anticipated developments. They are predicated on Provincial support for smart grid development, continued advances in technology, and the workforce training and process development necessary to use this technology effectively.

By 2011, the most visible elements of smart grid deployment will be the completion of smart meter installation and the introduction of residential time-of-use rates with the customer communications necessary to support them. Time-of-use rates should lead consumers to begin installing simple in-home energy displays showing prices and consumption. Utilities will be demonstrating smart grid technologies in operations and planning. Additional work to demonstrate the use of smart grid technologies to help integrate distributed energy resources will be underway. Work should also be ongoing regarding the incorporation of plug-in electric vehicles into the grid.

By 2015, consumers will have had several years of experience with time-of-use rates and the penetration of home energy management systems and smart appliances to control energy use is expected to increase substantially, particularly if there are programs that promote their installation. Results from utility demonstration projects should be widely available, leading to decisions on greater deployment of feeder and substation automation technologies. This deployment is likely to focus initially on new construction, areas undergoing significant refurbishment, and locations with load growth or reliability issues that are amenable to smart grid solutions. Utilities should also be engaged in the process of enterprise integration so that the information produced by the smart grid can be used effectively in operations, planning and customer service. Ontario will be well on its way to incorporating the substantial amounts of renewable generation currently anticipated in its supply mix. Projects involving the use of storage and demand response to address variability in renewable production should also be underway. Coordination among the various divisions of the electricity system should be enhanced to take full advantage of available information across the entire system. The penetration of plug-in electric vehicles should be accelerating and the infrastructure necessary to incorporate safe and convenient charging and reliable billing should be largely in place.

By 2020, smart appliances and other equipment, and home energy management systems should be standard in new installations and for replacement purchases. For utilities, build-out of the smart grid should be accelerating as significant retrofit of existing equipment will allow them to maximize value of the investments they will have already made in communications, computers systems and enterprise integration. Micro-grids may begin to emerge in niche applications. Coordination across the sector should be fully addressed. Plug-in electric vehicle sales should be substantial with convenient charging and billing readily available. New technologies and approaches, as yet undeveloped, are likely to be the focus of smart grid activities.

OVERALL RECOMMENDATION

This recommendation reflects the Forum's central belief that Ontario should develop a smart grid to improve the prosperity of its citizens, the performance of its electricity system and the environment. The rapid development of a smart grid to benefit electricity consumers and further environmental initiatives should be the policy of the Province of Ontario.

- The Ministry of Energy and Infrastructure should facilitate the development of Ontario's smart grid through legislation, regulation or other available means that clarify authorities, establish requirements or create incentives for those entities investing in Ontario's electricity system to accelerate the deployment or enhance the functioning of smart grid technologies.

Consumer Technologies

INTRODUCTION

While all aspects of smart grid development will ultimately impact consumers, this section discusses smart grid technologies that directly touch residential and small business consumers. The Forum believes that a smart grid must enable devices that will allow these consumers to gain greater control over their electricity usage to lower costs, improve convenience and support growing environmental awareness. A smart grid must also facilitate consumer installation of small-scale self-generation through renewable technologies and help them sell any excess generation back to the grid.

OPPORTUNITIES AND BARRIERS

The Forum received several presentations showing various conceptions of how residential consumers will manage their electric equipment and thus their electricity use in the near future using home energy management systems.[5] These in-home devices already exist, but are not yet widely deployed. The presentations also envision new ways for utilities and consumers to work together on matters such as service connections, billing inquiries, and service restoration after an outage.

Using home energy management systems, or smart appliances that are capable of receiving communications directly, consumers can automatically control the timing and amount of their electricity consumption to manage their energy bills. With home energy management systems, they can see the cost of running equipment and how changes in electricity use impact their electricity bills and environmental footprint, and track consumption over time. Some home energy management systems will also be able to control

[5] Smart meters team with home automation networks to spare grid: Bob Gohn: http://www.digitalhomedesignline.com/howto/212200388

and integrate customer-owned resources such as photovoltaic generation or storage. Finally, these systems and smart appliances can enable automatic demand response when they are programmed to react directly to prices or other signals to reduce load provided by utilities, retailers or other service providers.

These devices support Ontario's goals for conservation and demand response. In addition, by allowing consumers to more easily respond to time-differentiated prices, home energy management systems may also help make the implementation of time-of-use pricing, including critical peak period pricing, more acceptable to consumers.

Home energy management systems also can benefit consumers in other ways. Consumers can set them to match their schedules, embody environmental or conservation values, maximize convenience and enhance security through linkages with intrusion, smoke and heat detectors and emergency notification devices. They can be linked to messaging systems whereby utilities can inform customers or individuals that they designate of impending system emergencies, planned activation of demand response programs, and restoration efforts during power outages.

Numerous companies are developing these systems using different equipment and approaches. Some systems envision direct communication of price and other signals to smart appliances while others rely on a home energy management device as a central controller. Some of the controllers are internet based and work off home computers, while others use a dedicated unit (like a multi-function remote control). All the systems embody communications that allow them to access information delivered through the smart meter or via the internet.

Taken together, technologies that exist today can create an "automatic house" that a few short years ago would have been seen as something from a futuristic movie. These systems offer consumers choice. They can actively monitor their energy use or "set it and forget it." They also offer the prospect of more efficient homes leading to significant reductions in residential energy use and peak demand.

The keys to consumers fully realizing the opportunities offered by home energy management systems are:

- universal availability of timely information on consumption and prices through a smart meter with two-way communications capability or via the internet
- prices that reflect the cost of energy at different times
- widespread availability of in-home devices that allow consumers to manage their energy use
- recognition that these devices are easier and cheaper to install as part of new construction and that increased interaction with the home building community is necessary to facilitate installation in new residences
- widespread availability of smart appliances and equipment that can be controlled directly or by home energy management systems
- education about what these devices do and how their use can benefit both consumers and the environment

The Forum identified several barriers to wide spread implementation of home energy management systems and smart appliances and equipment. As with many smart grid technologies, home energy management systems can produce benefits that are only captured in part by the consumer that invests in these systems.

These benefits include:

- lower peak demand on distribution and transmission systems
- reduced generation investment and cost from controlling peak energy use
- improved environmental performance from peak reduction and overall energy conservation

However, despite the fact that consumers may not capture the full value of the benefits that their investment creates, research presented to the Forum supports the view that consumers do consider how their actions contribute to a better environment when making energy choices.[6]

With respect to the development of home energy management systems, there is uncertainty regarding how these devices will be provided to utility consumers and under what conditions. Specifically, will these devices be provided by distribution utilities, by competitive third party suppliers, or by both? If distributors provide them, how will the costs be recovered and what conditions are necessary to avoid unfair competition? If third parties provide them, how can consumers be assured that the device they purchase can work with their meter or receive price and consumption information through some alternative means? Irrespective of who provides these systems, how can the confidentiality of consumer information continue to be protected?

The Forum believes that consumers are best served when they have the maximum opportunity to procure innovative products. In this way, consumers can decide for themselves which devices and service offerings best meet their needs. To that end, the OEB should clarify the terms and conditions under which consumers can obtain these systems from their local utilities. One potential approach is to allow distribution utilities to provide these devices as part of their conservation efforts in the same way they currently provide direct load control devices on air conditioners, water heaters and swimming pool pumps.

RECOMMENDATIONS

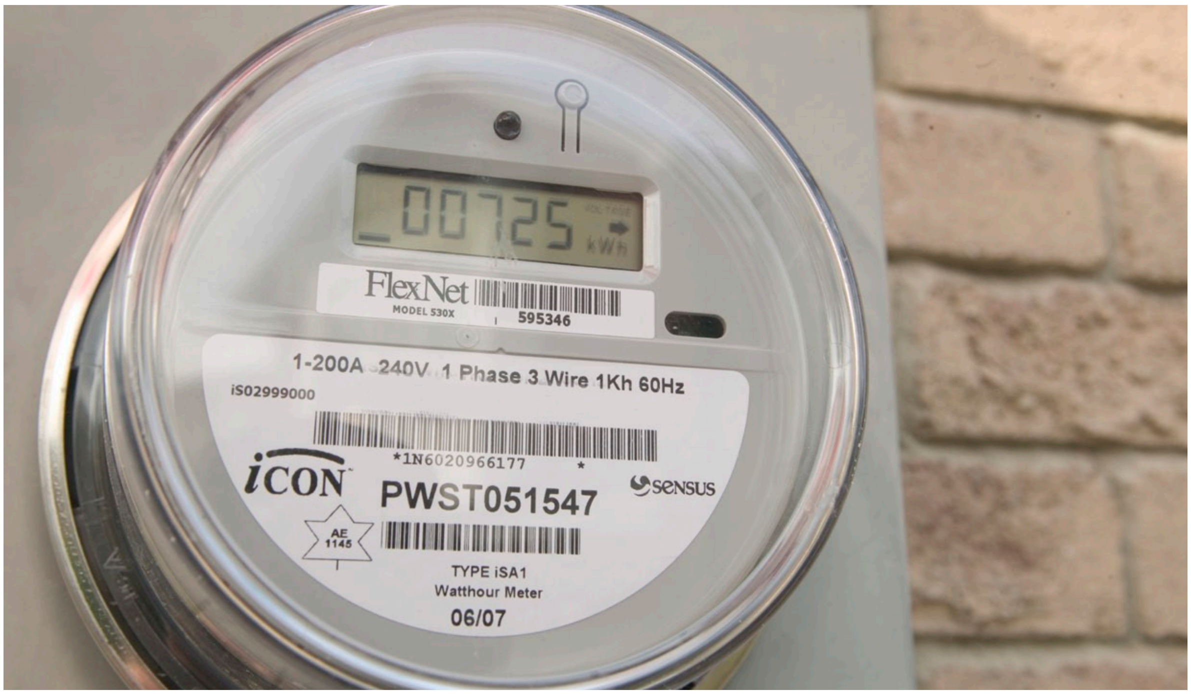
Consumer recommendations are intended to assist consumers in making informed choices on electricity consumption and enabling them to manage their consumption in response to prices or to reflect other values.

- Consumers and their designated representatives should have access to timely information on their consumption and the price they are being charged from a smart meter with two-way communication capability or via the internet. Consumers should pay prices that reflect the cost of energy at different times.
- Consumers should have the ability to obtain in-home energy management devices and services from their distribution utility, retailers or other providers of their choosing.
- The impact of home energy management systems should be tested through research and demonstration undertaken by those providing these systems. The non-proprietary results of these efforts should be widely shared.
- The Ministry of Energy and Infrastructure in consultation with distributors, retailers and other providers of in-home devices and services should develop consumer education materials designed to explain how such devices and services can help manage electricity costs, improve comfort, help the environment and promote the reliability of the electricity system.

[6] Plugging in the Consumer – Innovating Utility Business Models for the Future: Michael Valocchi, IBM Global Services: http://www.ieso.ca/imoweb/pubs/smart_grid/Plugging_in_the_Consumer-IBM.pdf

Distribution

Ontario's distribution system brings electricity to the vast majority of homes and businesses in the province. Historically, the principal job of distributors has been to deliver electricity to consumers reliably and affordably. Today, this job is rapidly expanding to include the provision of smart meters, the integration of distributed generation and assisting communities and consumers in meeting their energy needs on a sustainable basis. Distributors are being challenged to perform these new functions and continue performing existing functions, all while managing costs. Smart grid development is essential if the distribution system is to meet this challenge.



OPPORTUNITIES AND BARRIERS

Smart Meters

Ontario has made an impressive start toward empowering consumers through its decision to mandate that all utilities equip their residential and small business customers with a smart meter by 2010. By creating a potential two-way communication path between consumers and utilities, this decision provides a cornerstone for future smart grid development.

To leverage the potential of smart meters, additional steps are needed. The current approach of setting the minimum functionality of meters through regulation is cumbersome in light of the rapid evolution of smart meter technology. If this approach is retained, however, the minimum functionality should be expanded to include two-way communications, and the ability to detect outages and transmit this information back to distributors (known as "last gasp" functionality).[7] Two-way communications will allow utilities and other service providers to easily provide price information and, if critical peak pricing is implemented, to notify consumers of critical peak pricing events. "Last gasp" functionality will allow smart meters to help pinpoint outage locations and improve service restoration by ensuring that no consumers are missed because of a secondary outage condition when service is restored to an area. Utilities should continue to be able to seek cost recovery for additional functionality that benefits customers in applications before the OEB.

The consumption and price data or other signals provided through smart meters can provide important information for home energy management networks. Customers or their authorized service providers should be able to access this information from the consumer's smart meter for use by home energy management systems.

More work should be done to extend the benefits of smart meters to those customers who live in multi-unit buildings that are bulk metered. In this arrangement, building residents do not pay for their own usage directly, but instead the electricity costs for the building as a whole are paid by all occupants through rental rates or common area charges. Under current regulations, smart sub-meters may be voluntarily installed in condominiums at the discretion of the individual condominium board or the condominium developer for new buildings. Smart sub-metering activities in condominiums are overseen by the OEB, who in consultation with stakeholders, has developed a Smart Sub-Metering Code to ensure the protection of these consumers. The regulations dealing with condominium corporations are an important first step in the rollout of smart sub-meters in the multi-unit residential sector and further regulations should be considered for multi-unit rental buildings.

While smart sub-meters may not be appropriate for some multi-unit buildings because of centralized provision of heating and cooling or wiring arrangements, additional work is necessary to promote installation of smart meters whereever they can provide residents with meaningful ability to control their electricity use. Smart sub-metering will help empower Ontarians with the tools to control their energy use so that they are able to become full participants in the culture of conservation.

[7] Two way communications capability is already present in virtually all the smart meters being installed in Ontario and "last gasp" is available on some of the smart meters being installed.

Distribution Automation

The smart grid will impact virtually every aspect of the distribution system by making system conditions more visible right down to the customer level. This visibility will promote reliability, faster service restoration, enhanced maintenance practices and improved planning. When system visibility is combined with computer analytics and intelligent controls, the result will be to increasingly automate operation of the distribution system. In the future, the smart grid will enable distribution systems that can use sensors and computer analysis to predict system disturbances, take action to avoid their occurrence, and automatically reconfigure the grid to minimize the impacts of faults that do occur.[8]

Starting with the customer, smart meters will let system operators know whether a home or business is without power even if it is unoccupied. With additional sensing capability installed, smart meters could also indicate the voltage and power quality at the customer's meter. This will allow utilities to better understand conditions throughout their distribution networks. Ultimately, consumers with unique needs for power quality, such as manufacturers with sensitive electronic equipment, will be able to be served by equipment that is designed to provide the power quality that they are willing to purchase. Functionality available for smart meters can also permit automatic initiation and disconnection of service.

Moving up into the distribution system, sensors can communicate the operating state of distribution transformers and lines. This information will improve utilities' ability to operate the distribution system as it grows increasingly complex. Advanced transformer energy monitoring combined with information from smart meters at customer locations also will provide information on the loss or theft of energy throughout the system. "Flexible AC transmission systems" (FACTS), a technology that is being used more widely on the transmission system to control power flows is also being introduced for distribution lines. Fault detectors and grid automation in some circumstances will allow electrical faults to be automatically located, isolated and the grid restored without operator intervention and within minutes of the fault occurring.

At distribution substations, sensors will provide information on loading and operating conditions, station security and physical condition. Communicating this information back to the utility and applying computer analytics to it will allow distribution operators to better understand and control these components, including determining their maintenance needs and risk of failure. This information can also feed into systems that automatically control voltage and reactive power to help maintain delivery voltage and reduce line losses. In summary, this information will assist in optimizing the use of the distribution system and scheduling maintenance work.

[8] Smart Grid to Provide Capacity Relief to Distribution Utilities: Jim Blackman and M.L. Chan, Quanta Technology: http://www.ieso.ca/imoweb/pubs/smart_grid/Quanta_Technology.pdf and CURRENT Smart Grid Overview: Daniel Ripchensky, Current Group LLC: http://www.ieso.ca/imoweb/pubs/smart_grid/CURRENT_Group_Presentation.pdf

Sensing and communications equipment will be particularly helpful in managing outages and restoring power. Sensors can communicate outage information directly into a utility's Outage Management System. This system can begin automatically notifying consumers through cell phones or text messages that the utility is aware of the outage and is working on restoration. Subsequent communications can provide consumers with estimated restoration times. Linking service crews directly into the Outage Management System through mobile communications and equipping crew vehicles with Global Positioning System (GPS) capability and access to the utility's Geographic Information System will allow crews to better understand the nature of outages, see the equipment involved, and go directly to the outage location.

An issue for distributors implementing smart grid technologies is the need to collect, cull, manage, store, retrieve and integrate the large amount of data that smart devices will produce. The presentations highlighted the challenge inherent in managing this vast amount of data securely and efficiently and turning it into actionable information. There is a risk of collecting data "for data's sake" and by so doing overwhelming the ability of people and processes to use the data collected effectively.

Data produced will need to be accessible to and usable by a variety of distribution utility computer systems including those that control the system, map and locate system equipment, manage outages, handle meter data and billing, and maintain customer information. Enterprise integration, which allows these systems to access the data they need from a common source, using a common format and integrating them through a common service architecture, will be necessary for distributors to achieve the full functionality of a smart grid.[9]

The challenge of moving to a smart gird is significant from both a technological and human resources perspective. Many of the technologies that will be used to collect, manage and analyze smart grid information are currently being developed. As with all "leading edge" technologies, there is a substantial risk of false starts and dead ends, and a virtual certainty that integration with existing technologies and systems will prove to be more difficult than advertised. From a human resource perspective, learning to understand and

[9] Implementing the Smart Grid: Enterprise Information Integration: Ali Ipakchi, Pages 4-6: http://www.gridwiseac.org/pdfs/forum_papers/121_122_paper_final.pdf

use the full capabilities of smart grid technologies will require a substantial training effort and opportunities to practice using the new tools in a simulated environment. Current business processes will also need to be modified in light of the new information available and the capabilities of smart grid technologies.

In addition to impacting operations, the smart grid will also enable much more detailed planning as utilities gain more precise information on the loading of their equipment down to the individual customer level. By deploying sensors on feeders, lines and substations, utilities will be able to more accurately determine the need for additional infrastructure and to better analyze which capital additions will provide the greatest system benefit.[10] Better analysis of the timing and configuration of needed capital additions will promote efficient capital spending.

As discussed below in the Distributed Resources section, a smart grid is essential if the province is to maximize the generation, storage and demand response resources connected to distribution lines. The distribution grid was originally developed to deliver power to consumers. The sensing and communications that the smart grid will bring are necessary, but not sufficient, to meet the distribution system's expanded role of incorporating substantial amounts of generation safely and efficiently.

Micro-Grids

A micro-grid is an integrated energy solution that serves a group of consumers, such as a neighbourhood or a town, or a single large consumer, such as a university. Micro-grids use a variety of energy, communications and computer technologies to allow the consumers served by them to meet all, or a large portion, of their total energy needs (electric and thermal) with devices that form part of the micro-grid. While a micro grid can be designed to allow those it serves to achieve energy self-sufficiency, it is generally not independent of the larger electricity system.[11] Instead, it buys and sells electricity from the grid to take advantage of price differentials and when necessary to address surpluses or deficits in micro-grid production. For participants, micro-grids can deliver local control of energy production, more efficient use of combined heat and power, greater reliability and improved power quality, and the ability to better tailor their energy supply to their energy needs and environmental values.

Substantial technical, legal, regulatory and institutional issues arise in developing and operating micro-grids, particularly those created by a third party aggregating multiple consumers currently served by an existing distributor. In this context, interconnection of micro-grids to the existing distribution system will raise technical issues related to worker and public safety, equipment protection, and impacts on service to other consumers.

Legal and regulatory questions involve the status of the micro-grid operator as a regulated distributor, the ability of the micro-grid to use existing distribution facilities and at what cost, the ability to construct new distribution facilities that duplicate existing ones, and the nature of an existing distributor's continuing responsibility to serve consumers on the micro-grid. Even if the micro-grid were to be created and operated by the incumbent utility, issues would arise with respect to allocation and recovery of costs associated with the micro-grid's development, operation and maintenance. To the extent that a micro-grid served a single large customer rather than multiple consumers, these issues are likely to be less complex.

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[10] Smart Grid to Provide Capacity Relief to Distribution Utilities: Jim Blackman and M.L. Chan, Quanta Technology: http://www.ieso.ca/imoweb/pubs/smart_grid/Quanta_Technology.pdf

[11] Micro-grids can also be developed in remote areas where connection to the larger grid is uneconomic. Introduction to Distributed Generation: European Commission: http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_dg/article_1158_en.htm

RECOMMENDATIONS

Distribution recommendations are intended to encourage actions in the distribution sector that will accelerate development of a smart grid.

Smart Meters

- Utilities should continue to propose smart meter functionality consistent with the best interests of their customers and apply for OEB approval to recover the costs of this functionality in rates.
- If smart meter minimum functionality continues to be prescribed by regulation, then the minimum should be revised to include two-way communications and "last gasp" capability.
- The Ministry of Energy and Infrastructure should undertake further consultation with the goal of ensuring that smart meters or smart sub-meters are installed in all multi-unit residential buildings where it makes sense to do so.

Distribution Automation

- Utilities should develop their proposed smart grid investments as part of their capital plans.
- Utilities that wish to investigate and test smart grid technologies on their systems should be encouraged to propose demonstration projects that will assist them in testing the performance of available smart grid technologies and quantifying their costs and benefits. The non-proprietary results of these projects should be made widely available.

Micro-Grids

- The Ministry of Energy and Infrastructure in consultation with industry and consumers should undertake research to detail and clarify the technical, legal, regulatory and institutional issues associated with micro-grids to better assess their future applicability in Ontario.

Distributed Energy Resources

Distributed energy resources are generation, storage and demand response connected to the distribution system. These resources may be located at customer premises or a dedicated site. Distributed energy resources offer many potential advantages to the electricity system. They are small scale, can be located close to load, and many use renewable technologies. They can be used by distributors to support grid operations and can be considered as a resource in integrated distribution grid planning. They can also support transmission operations and planning. The challenge lies in using these resources effectively and in connecting them to a distribution grid that historically has been designed and operated to deliver electricity to consumers.[12]

OPPORTUNITIES AND BARRIERS

Distributed Generation

Distributed generation is small scale generation that feeds into the distribution grid. Much of this generation uses renewable technologies, which are a cornerstone of Ontario's future energy supply. Through the work of the OPA, Ontario has been very successful in contracting for renewable generation. The OPA estimates that there are almost 5,000 megawatts (MW) of renewable distributed generation projects that either have a Renewable Energy Standard Offer Program (RESOP) contract or are in the connection process.[13]

[12] For information on work underway in Canada: http://canmetenergy.nrcan.gc.ca/eng/renewables/integration_der.html

[13] Distributed Energy: Paul Shervill and Kevin Devitt, Ontario Power Authority: http://www.ieso.ca/imoweb/pubs/smart_grid/OPA-Distributed_Generation.pdf

Most of these projects are seeking to connect to the distribution system in rural areas served by Hydro One. The electricity being injected into the distribution system by distributed generation may impact on upstream transmission reliability, the operation and maintenance of distribution equipment, and the quality and availability of service to consumers served by that equipment. Because distributors currently have little ability to monitor the output of distributed generators and no means of controlling this production, they must find ways to ensure that the presence of generation does not endanger worker or public safety, interfere with the operation of protective equipment or impair service to consumers. Currently these solutions can significantly increase the cost of connecting renewable generation, making some smaller projects uneconomic. Smart grid technology can help address the technical issues by allowing distribution lines to accommodate more generation without compromising service to consumers on those lines, overall grid reliability (including upstream impacts on the transmission system) and safety.[14]

Distributors are investigating cost-effective technical solutions that will increase the amount of distributed generation that they can safely connect to distribution lines. Some of these solutions will involve increased monitoring of generation and equipment condition, and may involve the ability to control the output of certain generators on occasion to ensure that overall, the maximum amount of generation can be connected. Others will use innovative new approaches to meet utility safety requirements, avoid islanding and maintain voltage and frequency. These technical issues are not insoluble, but further research is necessary to develop and test cost-effective solutions.

As more distributed generation comes on-line, the need to control its output will grow. Controlling this output will require clear rules concerning the responsibilities of the generator, the authority of the controller, the purposes for which control can be exercised, and any compensation provisions.

The current connection process can adversely impact the installation of distributed generation by allowing developers to retain priority in the connection queue without demonstrating continued progress toward completing their projects or the project's continued viability. As a result, in many parts of Ontario, projects that are sized at, or just below the 10 MW RESOP cut-off have occupied all the available connection capacity at distribution substations simply by applying for Connection Impact Assessments and paying the fee, typically $5,000. The OEB, OPA and Hydro One are currently investigating approaches to address the economic and regulatory issues associated with connecting the existing list of proposed distributed generation projects by considering ways to develop a mechanism to link continued maintenance of queue priority to obtaining a contract and meeting contract milestones.

Connection limits have had the effect of holding up some projects that are ready to proceed, particularly very small farm biogas projects (less than 500 kilowatts (kW)). Under current rules, connection priority is established based on the impact assessment application and there is little requirement to actually move the project forward to completion in advance of the three-year in-service window for RESOP. The OEB has issued draft rules generally allowing for the connection of very small generation projects outside the connection queue.[15]

[14] DG Integration Key to Smart Grid: Ravi Seethapathy, Hydro One: http://www.ieso.ca/imoweb/pubs/smart_grid/HydroOne-DG.pdf

[15] Notice of Proposed Revised Amendments to the Distribution System Code: Ontario Energy Board: http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0102/Notice_ProposedRevisedAmendments_DSC_20081209.pdf

Storage

Electricity storage offers a number of potential benefits to the electricity system. For variable renewable generation (wind and solar) and at times of surplus baseload generation (from nuclear and hydroelectric generation), storage can be used to capture energy that would otherwise go unused and make it available to meet peak demand. Storage can also be used to firm up the capacity of intermittent generation so that a greater percentage of this capacity can be counted toward meeting peak load for planning purposes. Finally, storage can be used to moderate price differentials by storing off-peak energy and providing it on-peak.

Source: Planetary Engineering Group Earth

Beyond providing peak period energy, storage can provide ancillary services such as load following, area regulation and black start capability, and may also be used for grid stabilization and grid operations support. On the distribution system, storage can be used to defer investment in substations by shaving peak load and can also be used to improve local area reliability. The Forum was shown how American Electric Power (AEP) is using storage for these purposes and how, by configuring storage equipment in transportable units, AEP can reuse this equipment at different locations as local needs change. Storage sited at customer facilities can be used for load shifting and backup power.

Several technologies have the potential to provide storage including: conventional lead acid batteries, advanced batteries (e.g. sodium/sulphur, zinc/bromide and metal/air), flow batteries, flywheels, pumped generation storage (PGS), compressed air storage and superconducting magnetic energy storage (SMES). These technologies all have advantages and limitations. Some technologies, such as PGS and, to a large extent, compressed air, depend on the availability of sites with particular geological characteristics.[16]

[16] Discussion Paper 4: Supply Resources (IPSP Application, Exhibit C, Tab 8, Schedule 1, pages 93-100), OPA: http://www.powerauthority.on.ca/Storage/50/4552_C-8-1.pdf

Storage is subject to the same issue of diffuse benefits that impacts many other smart grid technologies. While storage can offer demonstrable benefits in terms of both the electricity system and the environment, it is difficult for a single entity to capture all of the electric system benefits, and the environmental benefits may not be monetized. As a result, storage typically has been confined to niche applications and sites with very favourable characteristics.

Regulatory uncertainty is an impediment to the implementation of storage. While a storage facility is never a net generator of electricity, it does discharge electricity when being drawn down. At the same time it can also function like a capacitor bank or a back-up power supply. These multiple functions create uncertainty as to the categorization of storage under the OEB Act and, consequently, uncertainty about how it can be deployed and by whom. For example, can a distributor install a storage device where it is a cost-effective means of providing voltage support or deferring a substation upgrade by helping to reduce peak load?

The lack of differentiation between peak and off-peak in the pricing offered to intermittent renewable generators undercuts the value to those generators of incorporating storage into their projects to increase on-peak availability. Similarly, because the cost of addressing the variable nature of wind and solar is currently borne by the electricity system as whole, there is little, if any, incentive for developers of these projects to consider storage.

Demand Response

Demand Response (DR) is a change in consumption in reaction to prices or other signals. DR can provide significant benefits to the electricity system by avoiding the need for additional facilities to meet extreme peak demand that occurs a few hours each year, reducing the use of expensive peak generation and making better use of variable generation sources when they are available. With the growing penetration of variable resources, DR can increase the systems' ability to use load to address supply variations. DR can be achieved through behavioural changes, changes in processes or equipment, the use of customer-owned generation or through direct control of appliances and equipment.

The OPA offers several DR programs for large commercial and industrial consumers and has entered into a DR contracts that pay for demand reductions against a baseline.[17] Many distribution utilities offer residential/small business direct load control programs under contract with the OPA that reduce demand by controlling the consumption of devices such as central air conditioners, electric water heaters and swimming pool pumps during peak periods in exchange for a one-time payment to participants.

While the reasons that individuals and companies participate in DR are varied and complex, the fundamental intent of DR is simple, reduce the cost of producing and delivering electricity by making consumption more responsive to production cost. To the extent that this cost is visible to consumers through prices, DR will be facilitated. DR will also be facilitated as smaller volume consumers come to understand the difference between peak and off-peak consumption and prices through education about smart meters and time-of-use rates.

RECOMMENDATIONS

The Distributed Energy Resources recommendations are intended to further Ontario's ability to incorporate renewable generation, expand opportunities for consumers to produce their own power, and increase the use of storage and demand response.

Distributed Generation

- Distributors should be required to offer to connect renewable generation just as they are currently required to offer to connect consumers.
- Distributors and the OPA should develop and propose mechanisms whereby dispatchable renewable generation projects and storage can be operated to maximize the total amount of generation that can connect to the distribution system.
- In order to plan and operate the grid reliably and efficiently, distributors, transmitters, the OEB, OPA and the IESO should work together to:
  - develop requirements for and propose sufficient monitoring of distribution connected generation, energy storage, and responsive load;
  - determine the authority necessary to direct the operation of these facilities, the conditions under which their operation could be directed and any compensation that would be provided to the facility;
  - propose contractual and pricing arrangements with distribution connected generation, energy storage, and responsive load that support efficient grid operations and are consistent with the operation of the wholesale electricity market;
  - coordinate the development and implementation of grid control and information systems to facilitate the actions listed above.
- The OEB, the OPA, Hydro One and all other affected distributors should continue working together to unblock the distribution connection queue and assure that projects can retain their queue positions only if they demonstrate progress toward completion in a timely manner against established milestones.

[17] Demand Response Programs, OPA: http://www.powerauthority.on.ca/Page.asp?PageID=1212&SiteNodeID=147

Storage

- To encourage the cost-effective use of storage, the OPA should investigate structuring payments to variable generators that reflect the value of production in different time periods.
- Through legislation, regulation, or other appropriate means, the Ministry of Energy and Infrastructure should clarify that distributors are permitted to own, provide and operate storage devices where such devices can promote the cost-effective provision of distribution services.
- Distributors should develop storage demonstration projects aimed at gaining a better understanding of how various storage technologies can be used and the technical and institutional barriers associated with these technologies. The non-proprietary results of these projects should be made widely available.

Demand Response

- Distributors should continue to develop innovative demand response programs that will facilitate the cost-effective provision of distribution service or the deferral of distribution system investment.
- The OPA, distributors and aggregators should strive to expand the range of demand response products available to maximize opportunities for all customer types to participate in demand response.

Transmission

INTRODUCTION

Ontario's transmission lines are the highways of the province's electricity system, designed to efficiently move large volumes of electricity from generators to load. Ontario's transmission system directly serves large generation facilities, large electricity consumers and the distribution system. Historically, Ontario's transmission system was primarily constructed to link remote generators to the load centres within the province in a cost effective manner. To achieve this goal, Ontario was at the forefront of developing technological solutions that maximized the ability to move electricity over distances efficiently and while maintaining system stability. The result is that today, Ontario's transmission grid is relatively sophisticated in its provision of reliable and affordable service to its customers.

Like all other parts of the electricity system, however, the transmission grid is facing the need for refurbishment and reinvestment. This renewal will involve the increased incorporation of smart grid technologies as old equipment is replaced. In addition, the transmission system must continue to evolve in response to changes in Ontario's resource mix including the development of renewable resources, integration of storage technologies, increased reliance on demand response, the refurbishment of existing and the development of new nuclear generators and the shutdown of coal-fired generation. To meet these challenges, the transmission system must become even more sophisticated, reliable, efficient and flexible through the implementation of additional smart grid technology.

OPPORTUNITIES AND BARRIERS

Historically, the transmission system and the connections to it have been much more visible to grid operators than the distribution system. The length of transmission lines, their relatively small number compared to the number of distribution lines, and the large volumes of energy that they transfer have justified investment in communications, control, sensing and imaging equipment that historically has been uneconomic for distribution. With the development of new technologies and the emergence of new challenges, however, the transmission system has both the ability and the need to become even more technologically advanced.

Technologies such as phasor measurement units and advanced phasor visualization and decision support tools will allow for greater visibility over a wider area than is currently possible.[18] Beyond visibility, however, the focus of smart grid investment will be on technologies that allow for more efficient use and greater control of the transmission system. These investments will enable the transmission system to accommodate increasing amounts of generation from more numerous and less predictable sources that are widely dispersed throughout the province.

Technology will also facilitate increased coordination between transmission and distribution operations. This coordination will be enabled by the implementation of the smart grid within the distribution sector and necessitated by the changing role of the distribution system and Ontario's evolving generation mix. Increasingly, distribution will be feeding energy into the transmission grid, not just withdrawing energy from it. Greater ability to monitor the operation of generation connected to the distribution system and enhanced control of how electricity flows over the transmission system will permit both transmission and distribution grid assets to be used more efficiently. Appendix B illustrates the major information flows necessary for coordination among transmission, distribution and other elements of the electricity system.

The large amounts of wind and solar generation being developed and connected to the transmission system require increased flexibility to enable rapid response to the changes in the availability of these variable resources. Beyond addressing the variability of currently planned resources, the need for flexibility will only increase because the grid must be able to accept new types of generation and storage technologies, each with its own operating characteristics, as they are developed. The electricity market must evolve along with the grid to ensure that developing resources are enabled.

Addressing transmission congestion is another important function of smart grid technology. The more congestion can be reduced, the greater the province's ability to move generation to load. Increased implementation and use of large scale demand response, storage and technologies such as FACTS will allow operators to make more intensive use of the transmission grid. More aggressive fault management, isolation and restoration will also be possible, thereby reducing the number of transmission system disturbances that impact service to consumers and the availability of generation.

Monitoring technology will increase the visibility of conditions on interconnected systems beyond Ontario. This will enhance security and reliability by giving Ontario operators more advance notice of problems developing elsewhere and more tools to prevent these problems from impacting Ontario. Greater ability to control the transmission grid and software developments that improve market integration between jurisdictions will improve the efficiency of trade with Ontario's neighbours. This will allow the province to take greater advantage of regional diversity in generation and load.

[18] Context and Candidate Outcomes to Shape North American Electric System Transformation: Carl Imhoff, Pacific Northwest National Laboratory: http://www.ieso.ca/imoweb/pubs/smart_grid/PNWL-Carl_Imhoff.pdf

RECOMMENDATIONS

The Transmission recommendations are intended to improve coordination and monitoring of the electricity system and market integration.

- Using established forums, the IESO, Hydro One and other transmitters should work with interconnected systems to investigate using smart grid technology to provide additional wide area monitoring of the grid.
- The IESO should continue exploring ways in which the market can evolve to take advantage of benefits enabled by the smart grid.
- The IESO should explore using additional smart grid technology to improve market integration and performance with neighbouring markets.

Communications

INTRODUCTION

Communications technology is at the core of the smart grid. Communication brings the data generated by meters, sensors, voltage controllers, mobile work units and a host of other devices on the grid to the computer systems and other equipment necessary to turn this data into actionable information. To serve the emerging needs of the smart grid, communication must be pervasive, rapid, robust even in emergency conditions, scalable (but with high initial capacity), and most of all, secure. To be effective, communications must be governed by clear standards and support the interoperability of the many devices that will connect to the smart grid.

OPPORTUNITIES AND BARRIERS

Ontario consists of a large and geographically diverse area. No single communication technology will meet the needs of the smart grid throughout the province. Instead, individual utilities will select the communications choices that are appropriate in light of available options, geography, customer mix, equipment being served, load and generation. These choices will rely on a variety of technologies including cellular spectrum, fibre optics, power line carrier (including broadband over power line), microwave, radio (licensed and unlicensed), WiMax, WiFi and others. These technologies may be utility-owned and operated, or provided under contract with a communications company. Irrespective of the technology chosen or the provider, certain characteristics are required for the smart grid to succeed.

Grid communications must be highly reliable because they carry critical data necessary for operations, billing and the safe and efficient restoration of service during outages. Getting the electricity system back into service as quickly as possible provides essential support to the work of police, fire and ambulance services in responding to natural disasters and other crises. Moving to a smart grid will only increase the importance of reliable communications because it will increase the amount of operational data that is being communicated and the reliance on that data in managing the grid. Using multiple communication paths and backup power supplies are two ways of addressing the need for reliable communications.

As part of their deployment of smart meters, utilities are installing various two-way communication systems throughout the province. Unlike mobile devices such as cell phones, which can tolerate “dead zones” as they move between towers, stationary devices such as smart meters require a communication system that reaches every customer.

Even with the requirement to communicate with all consumers, however the communication systems that the utilities are developing for smart meters will not be adequate to support full smart grid development. The communications needs associated with the collection of meter data are different from those of grid operations. Additional bandwidth and redundant service will be needed for grid operations because of the quantity of operational data, the speed required to use it and its criticality. The latter factor will become particularly important over time as the smart grid advances from monitoring the state of grid equipment to automatically controlling and restoring the grid with limited human intervention. Thus there is not a single smart grid communications solution. Instead, a variety of communications technologies are required to perform different functions and support various aspects of the smart grid.

A number of utilities across Canada are working with Industry Canada to achieve a dedicated spectrum for electric utility communications. As a result of these efforts, Industry Canada has proposed making a 30 megahertz (MHz) sub-band at 1800–1830 MHz available for the management and operation of the electricity system.[19] This proposal, when finally approved, will allow electric utilities and their service providers access to this communications spectrum to help communicate throughout their service territories, which will facilitate the development of a smart grid. This development will be particularly important in those rural and remote areas where telecommunications options are limited. A final decision by Industry Canada to dedicate this spectrum for electric utility use will place Canada in the forefront of countries seeking to create the pervasive and affordable telecommunications options necessary for smart grid development.

The developing nature of smart grid technology has three significant implications for communications. First, smart grid communications development must match smart grid development. While the initial communications deployment can be configured and sized to accommodate the first generation of smart grid equipment, such as smart meters; ultimately the communications infrastructure must be capable of servicing the full range of smart grid equipment installed. Given the uncertain pace at which smart grid technologies will be implemented, communications system should be scalable to allow for the addition of new devices as they are developed. Communications systems also will need to be in place for the anticipated service lives of smart grid equipment, which can range from years to decades.

Second, smart grid communications must be developed based on open standards so that the widest possible range of devices can be employed and the development of new devices and entry by new vendors is encouraged. The communications protocols, the methods of addressing various devices and techniques for organizing the data produced by these devices all must be standardized. To the extent that utilities have already implemented proprietary technologies in their smart meter deployments, additional bandwidth and addressing techniques may be necessary to enable translation between proprietary and open communications standards.

[19] Connectivity: the Key to the Smart Network: Richard Bertolo and Leonard Gross, Hydro One: http://www.ieso.ca/imoweb/pubs/smart_grid/HydroOne-Connectivity.pdf

Third, communications must be designed with interoperability as a requirement.[20] While standards allow many different devices to interact over a given communications technology, interoperability allows a variety of technologies to work together. That is, the devices can exchange actionable information and then use that information to perform the functions for which they are designed. This characteristic is essential given the many different types of equipment that make up the smart grid. It also supports the ability to contract with different vendors for different types of equipment and recognizes the likelihood that the many different companies that collectively own and operate the electricity grid will select different technologies and providers that will all need to work together.

Cyber Security

Moving to a smart grid poses opportunities and risks with respect to cyber security.[21] The opportunities arise because the sensors, communications and computer analytics that comprise the smart grid will allow a much more sophisticated view and analysis of system operations. The risks, which are always more prominent in any security discussion, arise because smart grid development will entail placing millions of devices on poles, lines and the sides of houses throughout the province, all of which can communicate back into utility computer systems.

The installation of smart meters has already created millions of potential access points in Ontario. Smart grid deployment will involve additional potential access points through monitors and sensors that connect into core utility operating systems. The multiplicity of physically unsecured entry points by itself creates a substantial security risk. The need to deploy devices in unsecured locations places the smart grid in stark contrast to a typical computer network where limiting physical access to network devices is an important element in enhancing cyber security.

Additional risks occur because of the need to make some devices accessible to third parties. For example, non-utility generators may need to access sensors that provide line data to automate their disconnection and reconnection. Third parties also may access meter data in conjunction with home energy management systems.

Recognizing that it will not be possible to secure every potential access point, utilities and equipment vendors must develop and deploy security measures that make their systems resistant to penetration, able to detect intrusions, and capable of isolating specific areas to limit the damage that an intruder can accomplish. Hardening communications and computer systems against cyber intrusions will add cost, but must be done to assure the security of critical utility infrastructure.

[20] The U.S. Department of Energy has formed the GridWise® Architecture Council "to promote and enable interoperability among the many entities that interact with the nation's electric power system." The U.S. 2007 Energy Independence and Energy Security Act (EISA) required the National Institute of Standards and Technology (NIST) to coordinate the development of a framework to advance interoperability in the smart grid. For information on interoperability see, http://www.gridwiseac.org/about/mission.aspx and http://www.nist.gov/smartgrid/

[21] Cyber Security and the Smart Grid: Doug Westlund and Peter Vickery, N-Dimension Solutions Inc.: http://www.ieso.ca/imoweb/pubs/smart_grid/N-Dimension.pdf

RECOMMENDATIONS

These recommendations are intended to ensure that utilities plan for and develop the standards, security and communications infrastructure necessary for the realization of a smart grid.

- The OEB should require distributors, transmitters and the IESO to address the communications needed to accomplish the full range of their intended smart grid activities into their capital investment plans. This should include as appropriate for each entity:
  - Immediate communications needs associated with smart meters;
  - Longer-term communication needs associated with other smart grid applications;
  - Efforts to make communications scalable so that they can accommodate additional smart grid functionality as it develops;
  - The need for cyber security and defence in depth;
  - Reliance on open standards and interoperability principles to maximize future technology options.
- To ensure the widest range of technological choices, entities investing in Ontario's electricity system and those developing home energy management systems should continue to work with standards organizations, such as IEC, IEEE, Zigbee and Home Plug, to develop and promote open communications standards.

Electric Vehicles

INTRODUCTION

Electric vehicles hold tremendous promise for Ontario. They can help clean up our air, reduce our dependence on petroleum and create new green jobs for the province. Building on its established automotive base and its commitment to a greener future, Ontario has an opportunity to become a leader in the development and deployment of electric vehicles. The smart grid is necessary to facilitate the large scale adoption of electric vehicles by enabling them to be charged in ways that are convenient and reduce the potential for adverse impacts on electricity infrastructure and customer service. The smart grid may also allow the energy stored in batteries to become a source of energy to help meet peak demand.

OPPORTUNITIES AND BARRIERS

Several different models of vehicles and different vehicle charging arrangements are currently being developed. Production vehicles that are available commercially today are generally partially driven by electricity and partially by fuel (HEVs – hybrid electric vehicles), and rely on refuelling at the pump and an onboard motor to generate electricity. HEVs provide a driving range like that of a conventional fuel-burning vehicle. Some hybrids currently permit plug-in charging (PHEVs) and more are on the way.

Electric vehicles (EVs) are also being developed that will be fuelled solely by the electricity stored in their batteries. EVs need a method of recharging when their batteries are depleted. Historically EVs have been suitable only for niche applications because of their limited performance and range due to battery size and weight limitations. The EVs currently being developed are expected to have greater range, longer-live batteries and performance similar to current vehicles.

Several approaches are being investigated for recharging EVs. One approach proposes dedicated charging stations in drivers' homes, parking lots and retail locations to charge batteries when they are parked and battery exchange stations that will allow depleted batteries to be replaced quickly with fully charged ones for longer trips. This model relies on a dedicated mobile communications and billing system to recover charging costs. Another approach envisions plug-in charging at home, at work or in parking lots. Consumers would either be charged a fee to plug-in away from home or sensors would be used to link each vehicle to its home electricity account for billing.

Research is also underway on the use of electric vehicle batteries as a source of widely dispersed storage. Vehicle batteries can potentially provide the types of benefits described above with respect to storage, but the mobile nature of vehicles and the expectation that their owners will want their batteries fully charged and available for use, provide additional challenges to using these batteries as storage. Intelligent grid technologies will be key in addressing these challenges.

As is readily apparent, widespread EV adoption will require the electricity system to develop innovative and cost-effective ways to provide consumers with the electricity they demand for charging. With different vehicle types and charging techniques come different battery sizes and charging durations, which in turn will produce different electrical loads.[22] Impacts from vehicle charging will start at the point of connection. Prior to charging vehicles at home or work, the adequacy of a building's wiring to provide safe charging may need to be addressed depending on characteristics the charging devices. Chargers currently being investigated by the Electric Power Research Institute (EPRI) have associated peak loads of between 1.5 kW and 7 kW with charging durations of between three and eight hours.[23] With significant penetration of electric vehicles, loads at the upper end of this range can have the potential to significantly impact building wiring in some instances. This could occur, for example, in suburban office parks where a high percentage of employees commute by car.

At the distribution level, the adequacy of existing local infrastructure to support a high penetration of electric vehicles is currently being reviewed in a joint study by EPRI and a number of North American utilities. This study is evaluating impacts on transformers, lines and substation equipment. Again, depending on the degree of electric vehicle penetration, innovative charging methods, such as staged charging through the use of smart grid technologies, may be needed to accommodate significant penetration of electric vehicles without adversely impacting local distribution equipment and, as a result, service to customers.

At the transmission level, both the impacts on regional transmission infrastructure from the concentrated penetration of electric vehicles in specific geographic areas and the overall impact of a different provincial load shape due to vehicle charging will need to be assessed.

In terms of energy supply, widespread adoption of electric vehicles represents a potentially significant new load. Methods must be developed so that charging is accomplished in ways that maximize the use of available generation resources and minimize peak demand increases which, were they to occur, would require development of additional peaking generation resources. The extent to which charging can be managed solely through prices or if other controls will be needed remains an open question.

[22] Electric Vehicles and the Grid: Arindam Maitra, Electric Power Research Institute: http://www.ieso.ca/imoweb/pubs/smart_grid/ArindamMaitre-EPRI.pdf

[23] Ibid

The connection between electric vehicles and a smart grid is fundamental. With smart technology, the grid can be an enabler of electric vehicles by maximizing charging flexibility; without it, the grid may be a barrier to the widespread adoption of electric vehicles. The sensing, communications and computer analytics that constitute smart grid technology will be required to ensure that electric vehicle charging is accomplished efficiently and that any impacts on the electricity system are addressed. This same sensing technology can potentially be applied to recover the cost of charging a vehicle away from its home base and include that cost on a customer's utility bill. Finally, a smart grid also is necessary to enable the large-scale use of electricity stored in vehicle batteries as a resource to meet peak demand.

RECOMMENDATIONS

The Electric Vehicle recommendations are intended to facilitate the widespread deployment of plug-in electric vehicles and the development of an electric car industry in Ontario.

- A Task Force led by the Ministry of Economic Development and involving other relevant Ministries should be created consisting of representatives from the auto sector (vehicle manufacturers and suppliers) electricity sector (OEB, IESO, OPA, distributors and generators) and universities to develop a comprehensive plan for enabling plug-in electric vehicles in Ontario. The plan would address policy, financial, and electricity system impacts of substantial electric vehicle penetration and identify what is required to ensure that vehicles can be charged as they develop. The Task Force should link to the ongoing collaborative work by the EPRI, the Society of Automotive Engineers (SAE) and standards development organizations to develop electric vehicles standards.
- The OCE working together with the automotive and electricity sectors and Ontario's universities should continue to undertake projects aimed at developing electric vehicles and the products and infrastructure necessary to support them in Ontario.

Innovation and the Economy

INTRODUCTION

The Forum heard from speakers describing the European Union's smart grid efforts and those of the United States. Through research, the Forum received additional documentation of these smart grid efforts. The smart grid is already worldwide phenomenon and will only grow as it moves from planning and demonstration projects to full implementation. Hearing these presentations and examining the research led the Forum to ask "How can Ontario enhance its position as a leader in the development and production of smart grid technologies?"

Ontario is currently home to a strong base of innovative companies that are offering products and services that help further the Provincial policy of creating a culture of conservation. For example, to support Ontario's smart meter initiative, smart meter suppliers have established a presence in the province. The smart meter initiative has also created jobs for the installation of smart meters in Ontario as well as drawing on Ontario's skilled labour force for the computer work necessary to store, validate smart meter data and integrate it into utility computer systems and the provincial data repository.

Ontario companies are also at the forefront of the emerging market for home energy management systems that consumers can use to control their electricity use and automate various functions in their homes. A recent showcase hosted by the Ministry of Energy and Infrastructure highlighted a number of these home energy management systems, some of which are currently being developed in Ontario. These devices are an important complement to Ontario's smart meter program. In addition to in-home device vendors, Ontario is also home to several energy management companies who are involved in smart grid pilots currently being undertaken by U.S. utilities.

OPPORTUNITIES AND BARRIERS

To realize the smart grid vision, new technology will need to be developed, designed and built. Where it occurs, research and development, and ultimately manufacturing, will spur innovation, economic development and job creation. The Forum believes that Ontario is well positioned to be a leader in smart grid technology because of its universities and other academic institutions, progressive companies and entities like the OCE and the OPA's Technology Development Fund.

Established by the Ontario government in 1987, the OCE drives the commercialization of cutting-edge research across key market sectors to build Ontario's economy and secure its global competitiveness. OCE's Centre of Excellence for Energy (OCEE) was established in January 2005.[24] It currently has eight projects underway or in the pipeline that relate to smart grid. All are collaboratively supported by industrial partners, academic institutions and OCE. The total investment of these projects is currently almost $12 million with about half this amount coming from OCE.

The OCE currently funds a number of projects in areas related to the smart grid. These areas include: small scale solar photovoltaic plant impacts on the distribution system and integrating large-scale photovoltaic plants into the grid; developing tools for the competitive provision of reactive power in electricity markets; working to establish a communications protocol for home energy management systems; developing a web-based tool to control energy use; and technology to improve the detection and isolation of system faults. The OCEE also has begun a process to search for new smart grid projects involving large capacity energy storage, large scale penetration of PHEVs, consumer information and methods of increasing grid capacity.

The OPA's Technology Development Fund was established in 2006 to fund projects that promote the development and commercialization of technologies or applications that have the potential to improve electricity supply, conservation or demand management.[25] The projects funded are technologies or applications that are pre-commercial or are facing barriers to commercialization. Funding is provided for further study, development, demonstration, or performance verification. OPA typically partners with the OCEE, academic institutions and research organizations.

Apart from its participation in projects with the OCEE, the OPA has helped to fund projects with the Centre for Energy Advancement through Technological Innovation (CEATI).[26] These projects involve: battery storage demonstration in a rural distribution system; developing an assessment methodology for the impact of a large deployment of PHEVs; and research on utility load control devices.

RECOMMENDATION

The Innovation recommendation is intended to advance Ontario as a leader in the development, implementation and production of smart grid technologies.

- Utilities, the IESO, the OPA, universities and OCE should conduct research and development related to smart grids to advance Ontario's leadership position in this area, promote innovation and develop green jobs in the province. The OCE should facilitate the development of a task force to produce a framework for smart grid research in Ontario that would include targeted amounts of funding and proposed funding mechanisms.

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[24] Ontario Centres of Excellence: http://www.oce-ontario.org/Pages/COEEnergy.aspx?COE=EN

[25] OPA Technology Development Fund: http://www.powerauthority.on.ca/tdfund/

[26] CEATI is a global research organization aimed at developing and providing technology solutions for utilities: http://www.ceati.com/about.php

Conclusions and Next Steps

CONCLUSIONS

The diverse body of materials reviewed by the Forum highlighted a few common themes. There is tremendous excitement about the potential of the smart grid. Balancing this excitement is a recognition that not all smart grid technologies will deliver as promised. Inevitably, there will be false starts and dead ends. Open standards and integrated approaches are the keys to minimizing the risk of stranded technologies. Demonstrations and pilots are appropriate tools to test technologies to see how they perform under real world conditions.

Coordination on several different levels will be a key success factor in developing a smart grid. On the technological level, there is the need for standards and interoperatibility to allow devices to be developed by multiple suppliers. Integrating the development of workforce training and appropriate processes with the deployment of technology is also necessary. Coordinated development across the divisions of the electricity system (i.e. customers, distribution, retail service providers, transmission and generation) also will be essential for the smart grid to function as an integrated whole. To deliver on its promise, the smart grid must enable the transparent exchange of operating and price information to efficiently link customer choices with the dispatch of resources and the operation of the grid.

Better coordination will also be required between the electricity industry and other industries. Electric vehicles are a particularly good example of this type of linkage. Vehicle manufactures and the electricity industry must work together to ensure that electric cars can be charged conveniently in multiple locations and that vehicle charging can be accommodated without adversely impacting electric service.

The Forum's review of activities in Europe and the United States showed that both these jurisdictions are aggressively pursuing smart grid development. The drivers for grid modernization are somewhat different in each area depending on their existing resource base and the emerging issues for each grid. While one jurisdiction may be more advanced in adopting certain technologies, overall there is no clear leader in smart grid development. Instead, there is a universal sense of tremendous energy and enthusiasm for modernizing the electricity system to serve the digital age. In terms of how to marshal this energy to transform the electricity system, however, the presentations contained more questions than answers. Ontario, like the other jurisdictions, has the opportunity to both lead and learn from the efforts of others as it works to create a smart grid that will benefit Ontario's people, economy and environment.

ADVANCING THE SMART GRID

The recommendations above envision action by numerous parties to develop a smart grid in Ontario. The Forum sees value in continuing to champion smart grid progress, monitor ongoing developments and advocate common approaches where they make sense. To this end, the Forum believes that an enduring organization to promote smart grid development with a broader base of representation may be appropriate in the future. The Forum will consider this further based on insights gathered from discussions with Government and industry following the release of our report. As part of this consideration, the Forum welcomes feedback and ideas on how to move forward.

Appendix A – Presentations with Links and Additional Information Resources

1.0 VISION

Overview of SmartGrids – European Technology Platform: Dr. Christian Sasse, Tavrida Electric North America Inc.: http://www.ieso.ca/imoweb/pubs/smart_grid/SmartGrids_Ontario_CSasse.pdf

Ontario Smart Grid Forum: Peter A. Landauer, Capgemini North America: http://www.ieso.ca/imoweb/pubs/smart_grid/IESO_Smart_Grid%20_PLandauer.pdf

2.0 CONSUMER FOCUS

Plugging in the Consumer – Innovating Utility Business Models for the Future: Michael Valocchi, IBM Global Services: http://www.ieso.ca/imoweb/pubs/smart_grid/Plugging_in_the_Consumer-IBM.pdf

Day In The Life Of a Utility Customer: Tom Brunetto, Distributed Energy Financial Group (DEFG LLC): http://www.ieso.ca/imoweb/pubs/smart_grid/Day_in_the_Life-DEFG.pdf

Bell Canada Home Energy Management: Tom Hewitt, Bell Canada: CONFIDENTIAL PRESENTATION AND DEMONSTRATION

A Smart Energy Ecosystem: Scott Stewart, Direct Energy: http://www.ieso.ca/imoweb/pubs/smart_grid/Direct_Energy-Smart_Grid_Forum.pdf

Consumer Positions and Attitudes: Raed Abdullah, Hydro Ottawa: http://www.ieso.ca/imoweb/pubs/smart_grid/HydroOttawa-Consumer_Focus.pdf

3.0 ONTARIO STATUS UPDATE

Connectivity: the Key to the Smart Network: Richard Bertolo and Leonard Gross, Hydro One Networks: http://www.ieso.ca/imoweb/pubs/smart_grid/HydroOne-Connectivity.pdf

Toronto Hydro and the Emerging Smart Grid Infrastructure: Joshua Wong, Toronto Hydro: http://www.ieso.ca/imoweb/pubs/smart_grid/THESL-Infrastructure.pdf

MDM/R Status Update and Plans: Bill Limbrick, IESO: http://www.ieso.ca/imoweb/pubs/smart_grid/IESO-MDMR-Update.pdf

Smart Grid... Realizing the Promise: Edward Chatten, PowerStream Inc.: http://www.ieso.ca/imoweb/pubs/smart_grid/PowerStream.pdf

Current Status and Investment Plans: David Curtis, Hydro One Networks; John Mulrooney, PowerStream; Joshua Wong, Toronto Hydro: http://www.ieso.ca/imoweb/pubs/smart_grid/Current_Status_and_Investment_Plans.pdf

Status of Hydro Ottawa's Smart Grid Programs and its Implications for the Smart Grid: Raed Abdullah, Hydro Ottawa: http://www.ieso.ca/imoweb/pubs/smart_grid/HydroOttawa.pdf

Smart Grid I The Regulatory Perspective: Mark Garner, Ontario Energy Board: http://www.ieso.ca/imoweb/pubs/smart_grid/OEB-SmartGrid-The_Regulatory_Perspective.pdf

4.0 DISTRIBUTION

Smart Grid to Provide Capacity Relief to Distribution Utilities: Jim Blackman and M.L. Chan, Quanta Technology, LLC: http://www.ieso.ca/imoweb/pubs/smart_grid/Quanta_Technology.pdf

CURRENT Smart Grid Overview: Daniel Ripchensky, Current Group, LLC: http://www.ieso.ca/imoweb/pubs/smart_grid/CURRENT_Group_Presentation.pdf

EDA's Vision: Local Distribution Utilities' Future Role in Building the Sustainable Communities of Tomorrow: Bryan Boyce, Electricity Distributors Association; David Collie, Burlington Hydro; Michael Angemeer, Veridian Corporation; Bill Hawkins, Electricity Distributors Association: http://www.ieso.ca/imoweb/pubs/smart_grid/EDA.pdf

5.0 DISTRIBUTED ENERGY RESOURCES

Distributed Energy: Paul Shervill and Kevin Devitt, Ontario Power Authority: http://www.ieso.ca/imoweb/pubs/smart_grid/OPA-Distributed_Generation.pdf

Presentation to Smart Grid Forum: Colin Clark, Brookfield Power Corporation: http://www.ieso.ca/imoweb/pubs/smart_grid/Brookfield-Smartgrid.pdf

DG Integration Key to Smart Grid: Ravi Seethapathy, Hydro One Networks: http://www.ieso.ca/imoweb/pubs/smart_grid/HydroOne-DG.pdf

Demand Response: Dan MacDougall, Rodan Energy and Metering Solutions, Inc.: http://www.ieso.ca/imoweb/pubs/smart_grid/MacDougall-Rodan.pdf

Farm Biogas – Cogeneration in Ontario: Aidan Foss, ANF Energy Solutions Inc.: http://www.ieso.ca/imoweb/pubs/smart_grid/Aidan_Foss-Farm_Biogas_Cogeneration_in_Ontario.pdf

6.0 MICRO-GRIDS

The Smart MicroGrid Revolution: Kurt Yeager, Electric Power Research Institute (EPRI) and Galvin Electricity Initiative: http://www.ieso.ca/imoweb/pubs/smart_grid/KurtYeager-EPRI.pdf

Energy Hub Management System: David Curtis, Hydro One; Dr. Ian Rowlands, University of Waterloo: http://www.ieso.ca/imoweb/pubs/smart_grid/UW-H1_Rowlands-Curtis.pdf

7.0 ELECTRIC VEHICLES

Electric Vehicles and the Grid: Arindam Maitra, Electric Power Research Institute (EPRI): http://www.ieso.ca/imoweb/pubs/smart_grid/ArindamMaitre-EPRI.pdf

Plug-in Electric Vehicles – Standards: Tom Odell, General Motors of Canada: http://www.ieso.ca/imoweb/pubs/smart_grid/GM-TomOdell.pdf

Better Place – Introduction: Sean Harrington, Better Place: CONFIDENTIAL PRESENTATION

8.0 STORAGE, STANDARDS AND SECURITY

An Overview of Smart Grid Standards: Grant Gilchrist, EnerNex Corporation: http://www.ieso.ca/imoweb/pubs/smart_grid/Gilchrist-EnerNex.pdf

Cyber Security and the Smart Grid: Doug Westlund and Peter Vickery, N-Dimension Solutions Inc.: http://www.ieso.ca/imoweb/pubs/smart_grid/N-Dimension.pdf

Electricity Storage: A Multi-valued Technology Opportunity: Rob Brandon, Natural Resources Canada: http://www.ieso.ca/imoweb/pubs/smart_grid/NRCAN-Brandon.pdf

9.0 TRANSMISSION

Context and Candidate Outcomes to Shape North American Electric System Transformation: Carl Imhoff, Pacific Northwest National Laboratory: http://www.ieso.ca/imoweb/pubs/smart_grid/PNWL-Carl_Imhoff.pdf

10.0 THE CASE FOR ONTARIO

Value Proposition and Drivers for Change – The Case for Ontario: Helen Lainis, IESO: http://www.ieso.ca/imoweb/pubs/smart_grid/IESO-The_Case_for_Ontario-Transmission.pdf

11.0 TECHNOLOGY COMPENDIUM

Smart Grid – Technology Status and Prospects: Lisa Dignard-Bailey, Natural Resources Canada: http://www.ieso.ca/imoweb/pubs/smart_grid/NRCan_Technology_Status_and_Prospects.pdf

ADDITIONAL SOURCES OF SMART GRID INFORMATION

GRID 2030 – A National Vision for Electricity's Second 100 Years: United States Department of Energy: http://www.ieso.ca/imoweb/pubs/smart_grid/DOE_Grid_2030.pdf

U.S. Department of Energy Office of Electricity Delivery and Energy Reliability: http://www.oe.energy.gov/smartgrid.htm

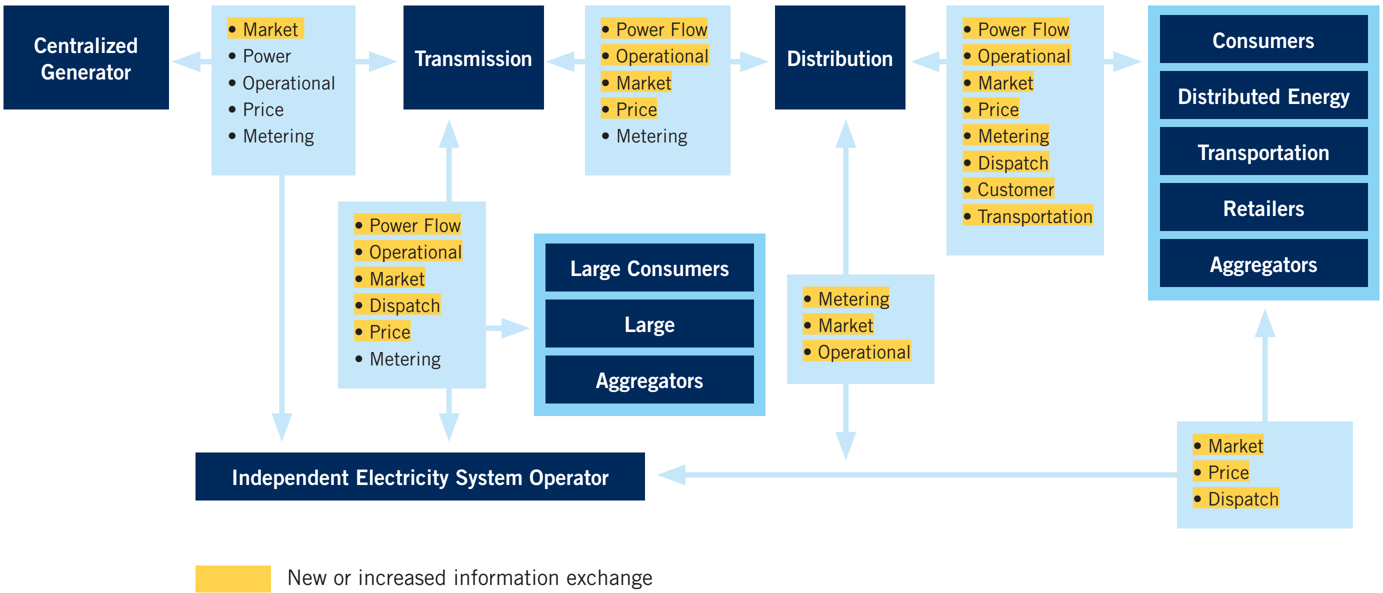
Congressional Research Service, Smart Grid Provisions in H.R. 6, 110th Congress: http://www.fas.org/sgp/crs/misc/RL34288.pdf

European SmartGrids Technology Platform – Vision and Strategy for Europe's Electricity Networks of the Future: European Commission, European Union: http://www.ieso.ca/imoweb/pubs/smart_grid/EU_Smartgrids_Visison_and_Strategy.pdf

Smart Grid Newsletter: http://www.smartgridnews.com/

U.S. DOE Smart Grid Primer: http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages.pdf

Appendix B – Information Exchange for Coordinating Smart Grid Operation



- The above diagram illustrates the need for increased coordination amongst the divisions of the electricity system to enable effective smart grid operation, enabled through new or increased information exchange.
- This coordination is characterised by the bi-directional flow of information, shared functional objectives, enabling of cross-boundary benefits, and mutual cooperation and support.
- The information exchanged may include:
  - Power Flow – voltage, frequency, phase, load flow, losses, outages status, power quality
  - Operational Information – protection, control, system state, supply and demand, weather, spare capacity, short circuit levels, planned outages, islanding control, time-to-restoration
  - Dispatch – control signals for dispatching generation and load
  - Market Information – generation mix, reserve capacity
  - Price – price of electricity, rates, connection costs, tariffs
  - Metering – interval metering, meter data management
  - Customer – billing, home device control, carbon footprint, choices/overrides, consumption history, call centre, utility programs/offers, demand response, behind-the-meter generation control
  - Transportation – plug-in hybrid vehicle (PHEV) control, vehicle-to-grid (V2G) control, managing intermittent demand

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