NORTHERN MICRO-GRID PROJECT – A CONCEPT

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Abstract:

The electrical distribution system for the Kasabonika Lake First Nation in northern Ontario (Canada) consumed 1.2 million liters of diesel fuel in 2008, amounting to 3,434 tones of CO2 emissions. Information presented in the paper offers a conceptual path for incorporating renewable generation and storage into the Kasabonika Lake distribution system. Through R&D and demonstration, the concept objectives are to reduce the amount of diesel consumed, support the distribution system exclusively on renewable resources during light loads, engage and impart knowledge/training to better position the community for future opportunities. The paper will discuss the concept details and possible challenges.

1. Purpose of the Concept – Why & What

Uncertain diesel fuel prices and the adverse impact of green house gases on human health as well as the environment necessitate a closer scrutiny of the status quo. In addition, exorbitant fuel transportation costs due to distance and uncertain weather conditions associated with running diesel fed electrical distribution systems in remote communities underscore the need to explore innovative and holistic alternatives to the current scenario.

Hydro One is responsible for the supply of electricity to off-grid remote communities in Ontario, Canada. The electricity in these communities is produced using diesel fuel. One such community, the Kasabonika Lake First Nation (KLFN) in northern Ontario, consumed 1.2 million liters of diesel fuel in 2008, amounting to 3,434 tones of carbon emissions. There are 32 such communities in Ontario alone with an average diesel fuel consumption of about $1 M per year per community. The 32 diesel dependent communities consume over $20 M of diesel fuel annually to produce an average of 5 MW of electric power. The “Northern Micro-Grid Project – A Concept” presents developing technologies and thoughts that would address the need for clean, reliable electricity in remote off-grid communities.

The concept involves utilizing and integrating diesel, wind, and storage technologies to address the electricity need of off-grid communities like Kasabonika Lake in Northern Ontario. The integration success and lessons learned from an actual project based on the concept presented in this paper would pave the way for the implementation of such technologies in hundreds of off-grid remote communities throughout Canada and other parts of the world.

More specifically, the concept provides for a holistic low-carbon energy system that includes:

- Engagement with the community in resource and energy planning;
- Conservation and energy efficiency practices;
- An appropriately sized specially-developed wind turbine and a hydrogen/fuel cell storage system that will meet their energy needs;
- Reducing emissions/pollutants in the environment;
- Providing cost-effective power and a local solution to energy production and consumption

Through the development and installation of wind turbines, any project based on the concept presented would replace or reduce the use of diesel generators in remote communities. As wind is intermittent, a storage media for the energy is needed. Under this concept, the excess electricity produced when the wind is blowing would be converted into hydrogen using a modern electrolyser. When the wind is not blowing, hydrogen would be consumed using efficient and inexpensive alkaline fuel cells to produce electricity.


Fort Severn
Sachigo
Big Trout Lake
Bearskin Lake
Wapekeka
Kasabonika Lake
Sandy Lake
Muskrat Dam
Wawakapewin
Koocheching
North Caribou Lake
Kingfisher Lake
Deer Lake
Keewaywin
North Spirit Lake
Poplar Hill
McDowell Lake
Wunnumin
Cat Lake
Pikangikum
ONTARIO
Slate Falls
Mishkeegogamang
Lac Seul
Thunder Bay


REMOTE NORTHERN COMMUNITIES IN ONTARIO
HUDSON BAY
JAMES BAY
MANITOBA
QUEBEC
U. S. A.
LAKE SUPERIOR
FORT SEVERN
PEAWANUK
PONASK
BEARSKIN LAKE
SACHIGO LAKE
WAPEKEKA
BIG TROUT LAKE
KASABONIKA
SANDY LAKE
MUSKRAT DAM
KEEWAYWIN
WEAGAMOW
KINGFISHER
LONG DOG LAKE
DEER LAKE
WEBEQUIE
ATTAWAPISKAT
NORTH SPIRIT LAKE
WUNNUMMIN LAKE
SUMMER BEAVER
POPLAR HILL
MACDOWELL LAKE
KASHECHEWAN
NESKANTAGA (LANSDOWNE HOUSE)
FORT ALBANY
PIKANGIKUM
CAT LAKE
FORT HOPE
PICKLE LAKE
OGOKI/MARTEN FALLS
MOOSONEE
RED LAKE
NEW SLATE FALLS
MOOSE RIVER CROSSING
LAC SEUL
SIOUX LOOKOUT
ALLANWATER
ARMSTRONG
FERLAND
AUDEN
COLLINS
KENORA
DRYDEN
GULL BAY
GERALDTON
HEARST
HILLSPORT
MANITOUWADGE
OBA
NIPIGON
MARATHON
FT. FRANCES
TIMMINS
THUNDER BAY
WHITE RIVER
WAWA
SULTAN
BISCOTASING
SUDBURY
NORTH BAY
SAULT STE. MARIE
C.P.R.
C.N.R.
O.N.R.
A.C.R.
LEGEND
TOWNS ON ELECTRICAL GRID
REMOTE COMMUNITIES WITH COMMUNITY ELECTRICAL SYSTEMS (HYDRO ONE REMOTE COMMUNITIES INC.)
REMOTE COMMUNITIES WITH COMMUNITY ELECTRICAL SYSTEMS (BAND OPER.)
REMOTE COMMUNITIES WITHOUT COMMUNITY ELECTRICAL SYSTEMS
Oct '09

2. Kasabonika Lake Diesel Distribution System

Kasabonika Lake First Nation community is located 570 kilometres directly north of Thunder Bay. As of 2005, the First Nation membership was just under 1000 people, with about 850 of those members living on reserve. There were 189 single family units of which 100% had an electrical connection.

The community is supplied with electrical power by a diesel generating station (DGS) which is owned and operated by Hydro One through an Electrification Agreement between Indian and Northern Affairs Canada (INAC) and Ontario Hydro (now Hydro One). There are also three small wind turbines installed as part of an Ontario Hydro test project in 1997. Hydro One operates and maintains the DGS, wind turbines, and distribution system. The DGS consists of three diesel engines, each coupled to a 600V AC alternator, known as a genset. The gensets are nominally rated at 400kW, 600kW, and 1000kW to meet the varying demand throughout the year. The DGS rating is calculated as the remaining capacity when the largest unit is out of service; so the current rating is 1000kW. The wind turbines are 10kW each, but do not contribute to the firm generating capacity as they do not produce power continuously.

The existing community load has a diverse pattern with the highest winter peak occurring in 2008 at 879kW. The lowest load that year was 175kW. The DGS is controlled by a programmable logic controller (PLC) which determines which genset is best suited to supply the demand and thereby maximize efficiency. In 2009, the DGS generated 4,200,000 kWh of energy which required 1,200,000 L of diesel fuel to produce. The DGS site has two fuel tanks which store 95,000 L of fuel. An adjacent fuel farm owned by Kasabonika Lake FN provides 400,000 L to the DGS. The fuel to fill those tanks is supplied by transports using the winter road. The fuel required by the DGS over and above that delivered by winter road is flown in by airplane throughout the year.

Kasabonika Lake FN is currently in the process of having an upgrade designed for the DGS to increase its capacity to 2000kW. That project is funded by Indian and Northern Affairs Canada (INAC) but will be owned and operated by Hydro One Remotes once completed. The upgrade is required in order for the community to connect new buildings to the distribution system. The community has been under connection restrictions since their peak demand surpassed 85% of the station capacity in 2008. The upgrade is expected to be completed by the end of 2011.

3. Key objectives

The "Northern Micro-Grid Project – A Concept" represents a new dimension in the group of projects ("Towards Sustainable Energy Solutions for First Nations Communities") that Hydro One is participating in as part of the Province of Ontario's initiative to develop wind, hydrogen and solar technology for Ontario.

The concept seeks to develop a cost effective and reliable Micro-Grid system that would provide a renewable-based continuous energy source. Such a system could be used in remote First Nations communities of northern Ontario and commercial operations with no grid access that rely on fossil fuel such as diesel for generating electricity to meet their needs. Generating electricity from fossil (diesel) fuel power is costly and damaging to the environment and human health. This concept is expected to present significant opportunity and potential to reduce this dependency on fossil fuel and lower the carbon footprint through the use of renewable energy technologies for powering these communities. The concept is also expected to result in economic benefits for remote communities and commercial operations that are without grid access.

The concept objectives are:

- ***Reduce the reliance on fossil fuel.***
  To reduce the reliance on fossil fuel such as diesel that is now used for generating electricity to meet the needs of remote northern communities and commercial operations with no grid access. The concept is expected to present the opportunity to entirely rely on the renewable energy source during periods of light load.

- ***Enable mass deployment of renewable distribution generation (DG).***
  To ensure a reliable and sustainable long-term supply of electricity, the Ontario Government has launched several generation procurement initiatives which specifically provide for the development of renewable resources (Wind, Solar, Hydroelectric, etc.). The Government's recent Green Energy & Green Economy Act encourages the development and connection of renewable distributed generation (DG). Hydro One's goal is to enable the connection of renewable DGs and maximize their deployment in accordance with the Government initiatives. However, there are several technical challenges to the expected mass deployment of renewable DGs.

  The development of Micro-Grids as part of an overall deployment of "Smart Grid' and "Distribution Automation" especially in renewable rich areas, is seen as an option for meeting the technical challenges resulting from high penetration and mass deployment of renewable DGs. Micro Grids set up in renewable rich areas with clusters of distributed generation could be switched between "islanded" and "non-islanded" operating modes.

- ***Community engagement and knowledge transfer.***
  The involvement of the Kasabonika Lake First Nation community is considered a key element of the concept. The community's involvement through consultation and ongoing discussion among community, industry and project partners would ensure that the community and project goals are aligned. The guidance and leadership provided by the community is considered critical as it would have the following impacts:

  - The community as a whole including school children would increase their understanding of energy and renewable energy concepts. This awareness may serve to facilitate future decision making and planning efforts by the community.

  - Positive community experience in this effort may encourage other remote and First Nations communities to undertake similar projects which may result in broader community economic development benefits and commercial opportunities for project partners.

- ***Provide economic benefits.***
  As mentioned earlier, in Ontario alone there are 32 diesel dependent communities like Kasabonika Lake, with average annual fuel costs approaching $1 million per community. There are 150 such communities across Canada. Reducing diesel dependency in these communities is an urgent task especially with the expectation of rising fuel costs. Furthermore, from the commercialization and sale of the energy system and its individually viable components into the global distributed generation marketplace, this investment would generate additional economical benefits to Ontario through export revenue and job creation.

- ***Reduce Carbon Foot Print.***
  There are significant opportunities for the 150 off grid communities in Canada like Kasabonika Lake to contribute to the national goal of reducing greenhouse gas emissions by using cost-effective, reliable and environmentally sustainable energy systems to reduce their dependencies on expensive conventional fossil energy systems. In 2008, the Kasabonika Lake First Nation community in Ontario consumed 1.2 million litres of diesel fuel resulting in 3,434 tonnes of $CO2$ equivalent emissions.

- ***Integration of renewable generation with diesel system***

  The micro grid control and storage system contemplated would facilitate the integration of any renewable generation source into hybrid diesel systems of any size in both remote and road accessible areas and allow system operators to optimize operations for varying objectives.

With successful completion of a project based on this concept, the experience and lessons learned would be the first in Canada to completely displace fossil fuel use at low load periods using an intermittent energy source (wind) and stored renewable-generated energy. The knowledge gained would more broadly support the increased reliability, and therefore penetration, of intermittent renewable energy sources into both remote and grid-connected applications.

In order to achieve above stated objectives, the following technical and non-technical goals can be accomplished and demonstrated.

1. A reliable renewable energy source in the form of a robust, community sized wind turbine with remote monitoring and control suitable to remote access, and harsh climate and operating environments

2. Micro grid control system with remote monitoring and control with predictive wind modeling and optimal dispatch capabilities to seamlessly coordinate generation, storage, transmission and tie-line control

3. Integrated power management and control system to manage system stability, power quality (voltage/VAR support) and reliability

4. Hydrogen mediated energy storage system including Hydrogen production, storage and fuel cell power module with ramping, short and long term storage capabilities for back-up power, load following to reduce intermittency and black start capability

5. Community involvement in equipment siting decisions and acceptance of system components.

6. Safe and reliable integration with utility diesel plant operations and feeder/distribution system

4. Concept Key Components and Phases

The concept would result in a renewable energy-based micro grid incorporating an intermittent energy source (wind) and a large scale energy storage system (hydrogen) with sophisticated power conversion and remote micro grid controls**.** The micro grid control and storage system contemplated would facilitate the integration of a renewable generation source with a diesel fed electrical distribution system.

The concept includes research and field demonstration initiatives seeking to develop a cost effective and reliable Micro-Grid system that would provide a renewable-based continuous energy source. The success and lessons learned from this research initiative could pave the way for the implementation of such technologies in hundreds of off-grid communities and commercial operations throughout Canada and other parts of the world. The participation and commitment by all partners/contributors is contemplated to be through a Collaboration Agreement (CA).

The implementation of a project based on the concept from the point of view of its development and associated study could span a few (2 to 3) years.

Research and Development (R&D) Support (from Academia)
R&D would focus on tests of the components and sub-systems in a laboratory environment. In addition, some component and sub-system testing would be done in or at facilities provided by industry partners. Other R&D support work would include optimization of the wind turbine and analysis of system performance data from the installed systems at a convenient utility location (Utility Field Trial) and finally at Kasabonika Lake (remote location).

In parallel, community acceptance and education work would be carried out.

The R&D work would include the following:

- Test the robustness of the wing turbine design. Due to the remoteness of the eventual installation site a wind turbine that is developed is robust, able to be transported over winter roads and erected with locally available resources.
- Test various aspects of the energy storage system. This would be done on a

component and sub-system level from the point of view of optimizing performance.
  - Model and test the electrical performance of the integrated sub-systems under the control of the micro-grid controller. This would also include simulation of contingencies normally encountered in power systems.

- ***Utility Field Trial (Convenient Location on the Interconnected Grid)***

  This phase is introduced to minimize the risk associated with a new R&D project and provide a solid foundation before its final deployment in the northern community of Kasabonika Lake.

  The work at the utility field trial location would include the complete testing in real time in conjunction with (any) other “Smart Grid” related project that the utility may intend to carry out in near future.

  The field trial would allow for checking out, fine tuning, and/or confirming the predicted operation of the components as well as the entire full-scale project as part of an integrated large grid. It would be advisable to continuously monitor and analyze the power system in the vicinity of the Micro-Grid project as well as within the Micro-Grid project itself.

  While the Micro-Grid project would encounter real time steady-state and dynamic fluctuations inherent in power systems, additional system contingencies would need to be deliberately created to simulate realistic and onerous situations that the controllers and the Micro-Grid system as a whole would be called upon to address within the constraints of utility standards & operations. A full range of tests to confirm stable system operation under various contingencies would need to be carried out and results recorded. The field trial tests would provide information and data to academia and industry partners for analytical purposes and feedback for performance improvement.

- **Kasabonika Installation (Final Remote Location)**

  The full system as outlined, if implemented, would be installed and operated in the Kasabonika Lake First Nation (KLFN) community.

  In addition to running the Micro-Grid project in parallel with the diesel system, the concept is also to shut off the diesel sets during summer low demand time and to supply community load for several hours, supplying up to 250kW, solely from Fuel Cells utilizing Hydrogen accumulated using power harvested from wind turbines over a period of many weeks.

  The R&D team (academia) would have access to system if required and to data gathered.

The following Figures 1 & 2 show the “Block Diagram” and the “Single Line Diagram” respectively for the conceptual installation at Kasabonika Lake.

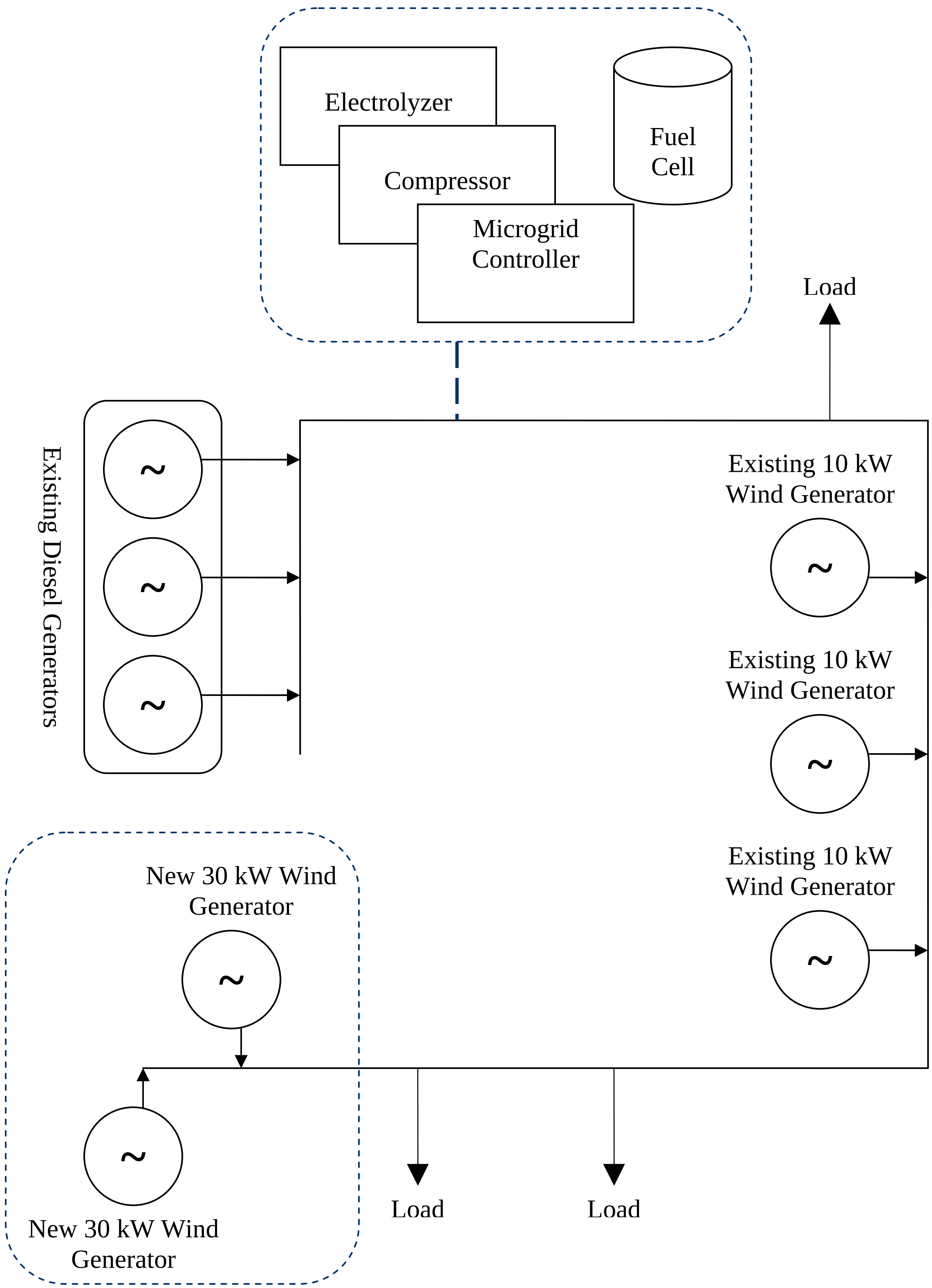
Electrolyzer
Compressor
Microgrid Controller
Fuel Cell
Load
Existing Diesel Generators
Existing 10 kW Wind Generator
Existing 10 kW Wind Generator
Existing 10 kW Wind Generator
New 30 kW Wind Generator
New 30 kW Wind Generator
Load
Load

Figure 1

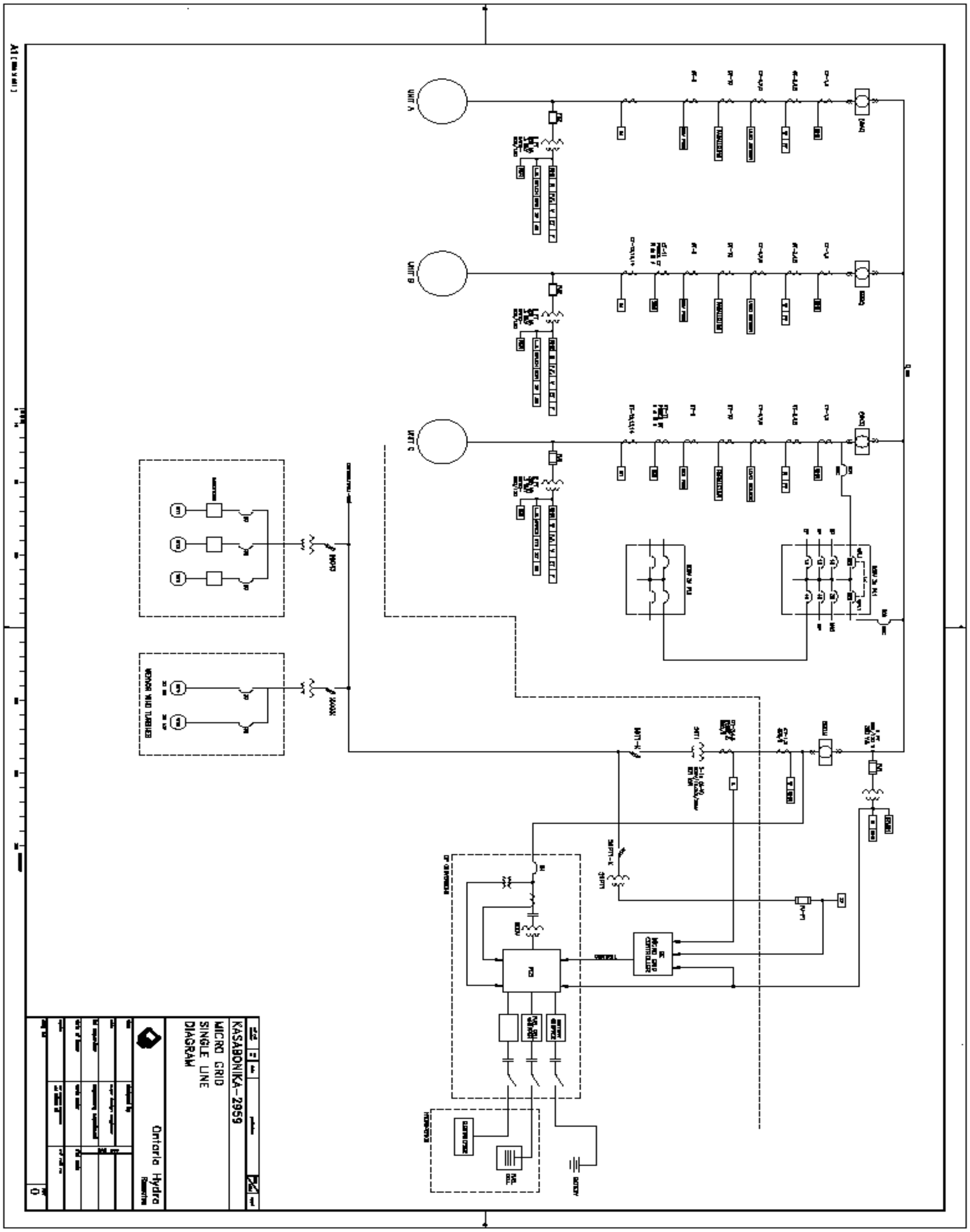
KASABONIKA-2959
MICRO GRID
SINGLE LINE
DIAGRAM
Ontario Hydro

Figure 2

The concept and resulting system would have unique features as outlined below.

- Modular hydrogen energy storage component design for scaling to load
- Plug-and-play power electronics and controls to simplify interconnections by non-expert technicians
- Containerized configuration to permit simplified delivery by ground and air and to provide protection from harsh climates and safety in challenging operating environments
- Remote monitoring and control to reduce on-site technical needs and to increase operational visibility for improved maintenance and management
- Predictive modeling to maximize use of any renewable energy resource thus minimizing fossil fuel use
- Dispatchable power (fuel cell) and system optimal dispatch capabilities to weigh resource availability, carbon intensity/price, feed-in-tariffs, time of use pricing, etc.
- First Nations partnership in project development and implementation could facilitate planning and execution of future utility serviced, independent power authority and community based renewable energy projects in First Nations communities.

5. Project Team

The project team would consist of several partners/contributors as well as one project participant, the academia component. The partners, as contemplated in the concept, would be as follows:
Hydro One
Ontario Centres of Excellence (OCE)
Industry Partner A – Wind Turbine Supplier
Industry Partner B – Integrator & Project Manager
Industry Partner C – Hydrogen & Fuel Cell Supplier
Industry Partner D – Micro-Grid Controller Supplier
Kasabonika Lake First Nation community

Hydro One Inc. (Hydro One)
Hydro One is the largest transmitter and distributor of electricity in the province of Ontario. A partner to the project through its subsidiaries Hydro One Networks Inc. and Hydro One Remote Communities Inc, Hydro One would play the lead role in the installations at the field trial location and finally in the Kasabonika Lake community.

Ontario Centres of Excellence (OCE)
The OCE would support development of expertise in Ontario and innovation to marketplace. OCE would also liaise amongst various partners on R&D issues leading to commercialization and provide funding for the research portion of the work.

Industry Partner A – Wind Turbine Supplier
Industry Partner A, manufacturer and supplier of wind turbines, would provide support for the project in the form of products and services. In particular, their contribution in terms of providing products and services to the academia for R&D purposes as well as in all other phases of the project including field trial installation and the final installation. In addition,

Project Partner A would provide all required supervision and installation coordination to assemble, install, commission and maintain the wind turbines at all three locations during the project.

Industry Partner B – Integrator & Project Manager
Industry Partner B would provide complete power system protection and control systems based on the users' choice of intelligent electronic devices (IEDs). They would also assume the role of project manager to ensure that the various equipment provided by the project's industry partners, would be deployed at the target locations in a timely and seamless manner. Support from the Industry Partner B would come in the form of financial contribution for the project and/or in-kind contribution.

Industry Partner C – Hydrogen & Fuel Cell Supplier
Industry Partner C would be responsible for providing the hydrogen and fuel cell related equipment and expertise to the project. Equipment and services provided by Industry Partner C would include the electrolyser, hydrogen storage system, fuel cell, and associated installation and commissioning services. Since the Hydrogen and fuel cell system would be new equipment to be integrated into the electrical utility system, significant involvement of Industry Partner C will be expected in all different phases of the project.

Industry Partner D – Micro-Grid Controller Supplier
Industry Partner D would supply products to enable the realization of Micro-Grid control system and to manage and optimize the generation sources and energy storage system, communications network, backup power for critical control power applications etc. Industry Partner D would work with other project consortium partners in implementing the Micro-Grid control system at the utility field trial location and then at Lake Kasabonika Micro-Grid community. Industry partner D's contribution would be primarily in the form of their products and services.

Academia (University)
Involvement of academia would be key to ensuring that different components such as electrolyser and fuel cell are optimized at the component level as well as at the sub-system level. At a high level, academia would oversee all research and have access to industry partners as required, including operational training on components and systems. Academia would provide the technical expertise for the project in the form of professors in each discipline and graduate students. Academia would also provide facilities and technical support in each technical aspect.

Kasabonika Lake First Nation (KLFN)
KLFN would support the community energy aspects of this project, which could include providing funding for the project.

6. Challenges

Any project resulting from the concept presented in the paper would be complex in nature and the team would need to be prepared for overcoming technical and non-technical challenges. A key challenge would be to justify a business case for the project where per unit costs are likely to be many-fold higher than the competing conventional and mature technologies.

Various components and subsystems in the micro grid system would present technical challenges as would the integration of all system components. The team would also be faced with significant system-related challenges such as component sizing, system control, stability and reliable operation. Other challenges that may surface include the following.

- The wind turbines themselves have to be simple and rugged and able to operate effectively over the expected range of wind conditions.
- The location is subject to a wide temperature range and icing is likely in the winter months.
- The wind turbine generators selected may have an adverse power factor impact that that would need to be addressed.
- When the diesel generators are idle, other means must be provided to act as a frequency reference and to correct the load power factor.
- The electrolyser used to make hydrogen must be able to operate over the expected range of generated turbine power available.
- The fuel cell system must be as responsive as the diesel gen set in terms of its ability to deal with the community load.
- All of the generating resources need to be managed and controlled in a seamless manner.
- The system has to be reliable, requiring only minimum maintenance.
- Site access is difficult, large equipment has to be moved in on winter roads when available.

7. Conclusion

Electricity generation using renewable sources coupled with energy storage holds a promising value in reducing the carbon footprint and our dependence on diesel fuel, especially in isolated electricity grids that are remote and in harsh climatic conditions. However, incorporation of new technologies into the electric utility industry where customer supply reliability and power quality are taken for granted requires careful planning, demonstration, and monitoring before final acceptance. We have identified a conceptual path that sheds light on the critical steps and challenges.