Office of Energy Research and Development

Natural Resources Canada

Outreach Report

Project Title:

Wind Energy R&D Park and Storage System for Innovation in Grid Integration

For

Clean Energy Fund (CEF)

By

The Wind Energy Institute of Canada

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Contents

1. Executive Summary

The Wind Energy Institute of Canada (Institute) has developed and operates a Wind Energy R&D Park and Storage System for Innovation in Grid Integration (Wind R&D Park), which consists of 10 MW of wind power and a 1 MW/2 MWh battery energy storage system (BESS). The Wind R&D Park features five DeWind D9.2 wind turbines and a battery storage system supplied by S&C Electric Company (S&C).

The intermittency of renewable energy poses significant challenges. Storage will allow higher integration of these technologies by mitigating the variations in both renewable energy production and electricity demand. The Institute along with its partners, Maritime Electric Company Limited (MECL), New Brunswick Transmission and System Operator (T&SO), Canadian Wind Energy Association (CanWEA), and the PEI Energy Corporation (PEIEC) are now able to increase knowledge in advanced wind turbine technology and the role of storage in the integration of renewable generation.

The project evolved through six tasks.

- Planning and Environmental Assessment consisted of environmental impact analyses, studies to ensure that the wind speed would allow for sufficient electricity production, and a power purchase agreement with the local utility.
- Selection and placing of a purchase order for wind turbines was completed in early 2011 once five DeWind D9.2 turbines were chosen as the best option for the site selected.
- Selection and placing of a purchase order for an electricity storage system was completed in March 2013 after a thorough investigation into the storage options available and the financial health of the bidder. The Institute examined the potential applications of the storage system and chose a system that would be able to cover a wide variety of applications.
- Design and construction of the wind park consisted of building a substation, access roads, a supervisory SCADA system, and erecting and commissioning the five turbines. After some delays the turbines were commissioned in the spring of 2013.
- Design, installation and commissioning of the electrical storage system was completed in the spring of 2014 once the battery and control system were coupled together and the connections from the storage system were completed in the substation.
- Demonstration of advanced concepts in wind turbine systems is the final task and is ongoing as the Institute gathers data from its turbines and gets comfortable with how the storage system performs. The Institute's turbines have demonstrated some of their advanced capabilities such as supporting the network voltage with their synchronous generators. Several research projects, with numerous different partners, utilizing this new infrastructure are being considered.

The objective of the project is to increase knowledge in advanced wind turbine technology as it relates to storage and grid integration. This objective will be accomplished through the five initially proposed objectives as well as additional objectives which have come forth during the development of this project. 1. Controlling turbines to reduce the power oscillations related to wind speed changes, 2. Using electricity storage to optimize the benefit of wind power to the electrical grid, 3. Demonstrating the benefits of combining utility scale wind and storage with other Supply Grid concepts such as local load control, 4. Continue to demonstrate examples of small turbines from various suppliers in order to increase the reliability and performance of small wind systems, and 5. Coordinate with researchers and providers of wind forecasting systems to improve wind forecasts. These objectives will be tested now that the Institute has the infrastructure in place and has begun their research campaign which included hiring a Scientific

Director and a Wind Integration Researcher. The Institute is open to collaborate with Industry and Academia to test concepts related to integration and wind parks.

The Institute is also forming new partnerships to investigate additional objectives as they have come forth during the development of this project. One such area of research is service life estimations and the operating efficiency of large wind turbines. This objective is to understand and predict the expected performance deterioration of wind turbines and to correctly estimate the remaining life based on current health and probabilistic projections of future loads, damage evolution, and failure models. These areas of research will be of interest to Canadian wind farm owners and operators, and will allow them to more accurately predict the expected energy production at different stages of the wind turbine's useful life. Other possible areas of research to be explored by the Institute and partners are wind turbine array losses and cliff effects on large wind turbines. This will allow for models to be modified which predict the wind speeds due to these different obstacles. In addition, the Institute is monitoring the wind and energy storage industry for future collaboration opportunities and future research directions.

This project has resulted in an operational wind park and utility scale energy storage system, which will be used to integrate wind energy in collaboration with industry and academia. The research into integration will focus on various areas such as ancillary services, peak shaving, improved reliability, and voltage control.

As with most capital projects, there are many risks involved in the building of a wind park including risks related to currency and suppliers. The lessons learned during this project are the importance of solid contracts and good relations between all suppliers. Additionally the importance of hiring employees who have experience in building wind parks ensures that inexperience does not increase the project risk. The Institute learned how relevant this project is to industry and academia and looks forward to the research opportunities that will be a result of this project.

This project will benefit utilities in Canada and throughout the world as the Wind R&D Park shows how intermittent renewable energy can be integrated into the grid through the advanced capabilities of turbines with synchronous generators and with a utility scale storage system. This will also allow policy makers to see how storage can enter the ancillary services market and be appropriately compensated for the benefits they provide to the network.

Annual reports on the progress of the project will be submitted to NRCan and will be made available with other reports from the CEF program on the NRCan website (www.nrcan.gc.ca).

Natural Resources Canada (NRCan), through the Clean Energy Fund, has invested in an excellent project that will have long lasting benefits to Canada. This project is a landmark for energy storage and shows a transition towards a Smart Grid where intermittent renewable energy can be integrated into the network through the use of storage, demand side management, and advanced communications. The Institute is open to collaboration and research to test concepts of intermittent renewable generation integration and is gaining important operational experience. The Institute is excited about the partnerships that it is currently forming and the opportunities that the infrastructure has allowed.

2. Introduction

The intermittent nature of wind, and therefore electricity generated from wind turbines, makes integrating a large percentage of wind energy on the grid challenging. This issue, of producing renewable energy while maintaining security of supply, must be addressed both by the electricity industry and by government regulators. Since electricity is consumed at the same moment it is created and the mismatch of supply and demand causes frequency variations, generation is constantly altered to ensure that it matches demand. Storage is able to alleviate part of the balancing act required in the supply and demand process increasing the amount of intermittent renewable energy the utility and system operator are able to absorb. This will allow a larger percentage of the electrical demand to be met with wind and other renewable energies.

Wind, with the exception of hydro, is the most prominent source of renewable electricity in Canada and throughout the world.[1] Wind has grown quickly over the past 15 years and now supplies 3% of Canada's electricity;[2] it is the most economically viable source of renewable energy with many estimates putting the cost on par with nuclear energy and natural gas for high wind sites.[3] Wind has been successfully integrated into the electricity network due to the flexibility of other generation sources, especially natural gas and dammed hydro. Generation which is less flexible include coal and biomass with generation coming from nuclear and run-of-the-river hydro being very difficult to alter the electricity output level. Strong interconnections to other areas allow a larger amount of wind energy to be integrated as the generation and demand can be balanced over more loads and a larger area. The large area allows the fluctuations in the wind to be mitigated and the large loads allow for a more gradual change in demand.

Prince Edward Island has a high percentage of its load being supplied by wind energy with MECL reporting 17% of its load being supplied by wind energy in the calendar year of 2013.[4] Over this same period, Summerside produced 24% of its load from its 12 MW wind farm and some of the electricity bought from NB is produced by PEI's 99 MW West Cape Wind Farm. An additional 30 MW of wind is currently being commissioned which will bring PEI's installed wind capacity to 204 MW. This concentration of wind energy, to supply a load which fluctuates between 90 and 260 MW, creates a constant mismatch of supply and demand. PEI imports its required electricity from New Brunswick up to the undersea cable limit of 200 MW, but during times of low production and high demand diesel generators are used to ensure sufficient electricity supply in PEI. During times of high production and low demand the electricity is exported to NB at a relatively low price.

Storage has a large role to play to continue to integrate renewable energy into the electricity network. Along with time-shifting wind power to a time when it is needed, storage can provide a variety of other services which will ensure the security of supply. Storage can be used to ensure voltage levels along lines, reduce distribution and transmission losses, and provide backup power at substations. This report will be of interest to various groups, potential receptors of this report include the utilities, system operators, battery companies, academia, research institutes, and wind farm developers in order to assist in quantifying the value proposition of storage.

3. Background (Program background and Consortium Participant Overview)

The following organizations participated in the development of the proposal and will continue to partner with the Institute.

3.1 The Clean Energy Fund

The Clean Energy Fund program (CEF) is part of Natural Resources Canada and was created as part of Canada's Economic Action Plan whose goal was to provide economic stimulus to the Canadian economy. The clean energy fund was dedicated to projects which ensure a healthy environment. The main areas of focus were large scale carbon capture and storage demonstrative projects, and renewable energy and clean energy systems demonstration projects, which focused on bioenergy, buildings/community energy systems, smart grid, hybrid systems/geothermal, marine/hydro, wind, and storage.

3.2 Wind Energy Institute of Canada

The Wind Energy Institute of Canada is a national not-for-profit organization with more than 30 years of experience in advancing the development of wind energy in Canada through research, testing, innovation and collaboration. Created by the transformation of the Atlantic Wind Test Site into the Institute in 2006, with an expanded mandate for research and development, an increased operating budget and new infrastructure, the Institute provides a wide range of technical and scientific research services for the wind energy industry including utilities, industry, governments, and international interests.

3.3 Maritime Electric Company Limited (MECL)

Maritime Electric Company Limited ("Maritime Electric") is a wholly-owned subsidiary of Fortis Properties Corporation (a wholly-owned subsidiary of Fortis Inc.) and operates under the provisions of the *Electric Power Act* and the *Renewable Energy Act*. Maritime Electric has delivered electricity on Prince Edward Island since 1918, owns and operates a fully integrated system providing for the generation, transmission and distribution of electricity to customers throughout the island.

3.4 Transmission and System Operator

Formally the New Brunswick System Operator (NBSO), the Transmission and System Operator (T&SO) in New Brunswick is now part of the vertically integrated New Brunswick Power Corporation. It is responsible for providing ancillary services to the Maritimes and Northern Maine. They are responsible to have sufficient electricity reserves to cover the largest generator going offline, to provide frequency control, and to maintain the voltage on lines that have a voltage above 69 kV.

3.5 Canadian Wind Energy Association

The Canadian Wind Energy Association (CanWEA) is the voice of Canada's wind industry. Established in 1984, CanWEA represents the wind energy community — organizations and individuals who are directly involved in the development and application of wind energy technology, products, and services.

3.6 PEI Energy Corporation

The PEI Energy Corporation (PEIEC) is responsible for pursuing and promoting the development of energy systems and the generation, production, transmission and distribution of energy, in all its forms, on an economic and efficient basis. The PEIEC owns and operates four wind farms in PEI with a capacity of 73.6 MW, their first wind farm went into operation in 2001 and their newest project has been recently commissioned.

4. Objectives

The objective of the Wind R&D Park will be to increase knowledge in advanced wind turbine technology as it relates to storage and grid integration. The new Wind R&D Park provides infrastructure that will enable the Institute and its partners to demonstrate, at a utility scale, advanced renewable energy and operational systems. The five objectives below as outlined in the proposal are in various stages of completion.

The first three objectives all have the goal of improving wind integration. Improving wind integration will come from a system approach where the turbines and storage work together to achieve the maximal benefits.

- Methods and concepts of controlling turbines to reduce the impact of sharp changes in wind speed. The synchronous generator wind turbine technology which has been chosen for the Wind R&D Park has the potential to create power which does not fluctuate as dramatically due to the inertia of the synchronous generator. As the Institute becomes more comfortable with the capabilities of wind turbines with synchronous generators they will look for collaborators to study the short term power fluctuations in wind farms with different types of generators. The Institute is interested in working with other partners on this research. The use of the storage system can additionally decrease the fluctuations in wind farms production.

- Using electricity storage to optimize the benefit of wind power to the electrical grid system. The storage system has many benefits to integrate wind power into the electrical grid. Currently the storage system is being used to time-shift electricity so that the Institute and Maritime Electric can become comfortable with the storage system. After three months of time-shifting electricity the other wind integration options may be examined and tested.

Demonstrating the benefits of combining utility scale wind and storage with other Smart Grid concepts such as local load control. The infrastructure is now in place for a study using a wind turbine and the storage system to provide a test-bed for examining how an isolated community could be supplied electricity through such a hybrid system. Throughout this project the Institute has been reading studies and now that we have a commissioned storage system and wind turbines we are looking to partner in studies such as the recent study by NREL.[5]

Time-shifting Electricity: Using the battery to store electricity during times of low demand and discharging this energy during peak demand.

Wind Prediction Firming: Using the battery to ensure that the electricity produced is the same as that predicted the day before. This could reduce the need for spinning reserve, decreasing the cost of ancillary services and therefore the cost of electricity.

Voltage Support: Using the battery to support the 69 kV transmission system to which the turbines are connected in order to ensure high quality electricity which increases the lifetime of electrical components.

Transmission loss reduction: Since line losses depend on the square of the current flow in the line, reducing power flow in the line during times of high production by absorbing power and returning the power during times of low wind, will not only smooth long term power fluctuations but will also reduce the losses in the transmission lines. A reduction of the estimated 4.5% transmission losses would represent a significant cost savings to the wind park and to the utility.

Reduce Output Volatility: As mentioned previously, the storage system can be used to reduce short-term and long-term production volatility.

Demand Charge Management: The substation pays a substantial demand charge for the times when there is no wind production and electricity is drawn from the network to allow the turbines to yaw and run the heaters or cooling fans. Using the storage system to supply electricity during these times would reduce the demand charge from the utility.

Ancillary Services: The storage system could be used to provide ancillary services to the network including frequency regulation, load following, spinning reserve, supplemental (secondary) reserve, and/or backup supply. As wind penetration increases the power plants that have traditionally provided these services are being taken offline which has created the demand for new systems such as storage in the ancillary services market.

- <u>Continue to demonstrate examples of small wind turbines from various suppliers in order to increase the reliability and performance of small wind systems</u>. At the core of the Institute's mandate remains a focus on small wind turbines and distributed energy resources. The Institute continues to provide testing leading to certification and R&D for innovation. Small wind continues to have performance issues and do not have a large market. The Institute has developed an abstract of a paper looking to summarize the lessons learned and are looking for partners to participate on this paper investigating the main causes of poor performance of small wind turbines to inform Canadians wanting to invest in small wind turbines. Additionally the Institute is completing wind resource assessments in remote locations, such as Canada's Arctic. Efforts in these areas will continue as long as they are a priority to the Institute and the Canadian wind industry.

- <u>Coordinate with researchers and providers of wind forecasting systems to use the Wind R&D Park to demonstrate the benefit of advanced wind forecasting systems to utilities.</u> Different forecasts are being examined to test their accuracies with large errors being noted in all the forecasts. Real-time power data along with the operational history of the turbines allows for the availability to be uncoupled from the power production to understand when forecasting errors are caused by poorly predicted wind speeds and when the forecasting error is caused by unscheduled turbine downtime. There are differences of opinions between the user groups of wind forecasting (wind farm operators, the utilities, and system operators) on who is responsible for the forecast and how it should be used. The grid requirements of wind forecasting for the system operator is not well understood by the wind farm operators. The Institute is interested in working with all of these groups to improve the forecasting at different time intervals to maximize grid security and the wind integration.

As the Institute has developed this project and has been in discussion with various user groups, other objectives have risen. It is likely that as these objectives are realized the projects will evolve and new projects will emerge. The objectives will be reprioritized as the projects evolve.

- Service Life Estimation/Operation Efficiency of Wind Energy Assets. This project, which could be academic led has the aim of being able to correctly estimate the remaining service life based on current health and probabilistic projection of future loads, damage evolution and failure models. The Institute's contribution to the project will be the loading characterization of the wind field and gathering data from the participating wind farms for analysis. Service life estimation as well as estimating the expected efficiency loss and additional investments that will be required for a wind farm is becoming an important topic as wind owners must predict the remaining life of their turbines. The Canadian Wind Energy Association has also expressed interest in this field as presented by members of CANWEA. The level of effort and scope is presently to be determined.

- Lidar Research on Wake and Cliff Effects. The Institute is looking to partner with academia to research the wake effects of our wind park and the effect of the cliff on the wind profile. The Institute provides an ideal location for such testing with multiple MW turbines in close proximity to one another and to a substantial cliff.

5. Project Evolution

The development of the Wind R&D Park was broken into 6 tasks listed below:

5.1 Planning and Environmental Assessment

In order to gain approval for the installation of large wind turbines it is necessary to go through the environmental assessment to ensure that the turbines will not have a negative environmental impact on the local area. Both the fauna and flora were studied to ensure that the turbines would not have a negative impact on either. The planning also involved studying the wind speeds to ensure that the wind regime was sufficient to be able to produce adequate electricity to make the project economically viable. The high average wind speed coupled with consistent winds throughout the year makes North Cape, PEI ideal for wind turbines. The final planning step involved deciding where the turbines and substation would be located and how they would tie into the medium voltage network which passes close to the site. The approval to connect this amount of electricity was sought from the local utility and a power purchase agreement to sell the electricity was reached. The planning stage allowed the project to proceed, developed knowledge about the area and the impact of wind turbines on the local environment. The same methodology of planning for a wind farm is continuing to be undertaken by wind developers in Canada and around the world.

5.2 Selection and placing of a purchase order for wind turbines

In 2010 many wind farms were being built and the interest from turbine manufacturers to build a five turbine wind park was relatively small. Due to the seller's market that existed in 2010, the Institute only had four bids responding to its request for proposal (RFP). These bids were evaluated in order to make a recommendation to the Technical Committee, which included representation from the local utility, the system operator, academia, and the Dutch national laboratory for sustainable energy. A technical and financial analysis led the Institute to place an order for five DeWind 9.2 wind turbines with a total nominal capacity of 10 MW in early 2011. The negotiations of the Turbine Supply Agreement and the Service and Maintenance Supply Agreement were an important and time consuming part of this task. These turbines are of advanced design such that their operation at North Cape is of interest to stakeholders both in Prince Edward Island and nationally. Interconnection studies were performed by the local utility once the turbine selection was finalized and the electrical design was performed. Having the local utility as part of the Technical Committee was helpful to solidify relations and ensure an appropriate turbine was chosen.

5.3 Selection and placing of a purchase order for an electricity storage system

Energy storage is an evolving market and each technology, company and system has its own advantages and disadvantages. The main type of energy storage systems are fluid based energy storage which includes pumped hydro and compressed air, and electrochemical batteries which include many battery types such as Ni-Cd, Lithium ion, Lead-acid, Vanadium, and $Na\text{-}NiCl_2$. An expression of interest for a storage system was released in June 2011 for the Institute to understand the options available and to gauge the level of interest. The EOI resulted in 13 responses which helped inform a request for proposals. The RFP was issued with a closing date of February 27th 2012 which resulted in six responses which was narrowed to five companies due to financial restrictions and the most suitable type of storage for this project. The same Technical Committee as for the wind turbine selection, was engaged to evaluate the five RFPs each with a different storage technology. The storage options were narrowed to a short list based on:

- The assurance of technical compatibility
- The assurance of a system that can be used as a demonstration project
- An assurance of on-going O&M cost clarity
- The potential for an expansion or addition to the battery system (with ease)
- An awareness of the financial health of the bidder.

A storage system which could provide a range of functions was desired as the application is likely to change multiple times depending on what the research partners want to discover. By June of 2012 site visits had been made to the five companies. Unfortunately due to delays in commissioning the turbines the entire selection process of the storage system was delayed. In late 2012 the S&C proposal utilizing GE's Durathon battery technology was chosen and the technical and costing details were finalized with the order being placed in March 2013.

During the selection process the Institute became aware that the storage market is still in its early stages, with many systems being untested on a commercial basis. The Institute had to invest time and effort to understand the market and the options available to have the knowledge to choose an appropriate storage technology. During this process the Institute began to understand the interest and opportunities which exist in electricity storage, especially through its involvement with the Energy Storage Association (ESA).

5.4 Design and construction of the wind park

Once the company had been chosen to supply the wind turbines the substation design was completed and work began on the substation and the access roads to the turbines. The substation was built to allow for the turbines power to be stepped-up to connect it to the transmission network. The substation was also sized to allow for the storage system to be easily implemented with the appropriate protections and sizing of the transformers.

A SCADA system was also implemented which records data in the millisecond time range to allow for troubleshooting and the data gathered can be used for a wide range of research projects. The SCADA system installed by the Institute is a very valuable piece of infrastructure and will allow for collaborating with other organizations.

DeWind provided five 2 MW D9.2 Wind Turbines which operated for a short time and issues were detected with the blades. After inspections and attempts to repair the blades it was decided by both parties that the blades should be replaced[6]. This caused a delay in the commissioning of the turbines, which were commissioned in spring of 2013, a year after the targeted commissioning date. This stressed the importance of having a strong turbine supply agreement and service and maintenance agreement to ensure that when there are technical issues that they can be resolved without undue cost to the owner.

5.5 Design, installation and commissioning of the electricity storage system

Once the storage system supplier was chosen the footprint of the substation increased to include the battery and transformation equipment. The storage system was commissioned and a plan has been developed with MECL where we will use the storage system to time-shift electricity from times of low demand to times of peak demand. This initial operation will allow MECL and the Institute to become comfortable with the storage system and will provide valuable results on the function of using the storage system to shift peak demand to off-peak hours.

GE and S&C both have new systems, coupling these systems together caused minor delays to the commissioning process. Data from the BESS was also added to the Institute's SCADA system so that the performance of the storage system could be monitored over an extended period of time so that the full costs and benefits of storage can be understood.

5.6 Demonstration of advanced concepts in wind turbine systems

The wind turbines have been able to help maintain system voltage despite the consumption of reactive power by the older wind turbines connected to the same 69 kV lines. Additionally the wind turbines have shown a high capacity factor and their improving availability increases their reliability and therefore integration potential to the network.

This project has provided the Institute with an asset which is being used in current research and will be used in future research as the Institute is able to collaborate with industry and academia. The Institute is open to various proposals for research with the Wind R&D Park.

A proposed research plan is being developed between GE, the Institute, and an academic partner; it will be a two year study with the following five steps.

- Modeling the electricity network on PEI
- Performing an environmental impact analysis
- Validating the model with measured data
- Performing a sensitivity analysis
- Issuing a final report of lessons learned

6. Description of System and its Application

The Wind Energy R&D Park and Storage System for Innovation in Grid Integration consists of two components: five DeWind D9.2, 2 MW wind turbines and an S&C 1 MW/2 MWh battery energy storage system.

6.1 Wind Turbines

The turbines chosen were 2 MW turbines with a diameter of 92 m from DeWind Co. These turbines have a synchronous generator which ensures grid stability by providing inertia to the electrical grid, responding positively to voltage dips, and providing grid support to the electrical network. The variable speed rotor is connected to the two-stage planetary gearbox through the Voith WinDrive which uses a hydraulic coupling to give the turbine a wide range of operating speeds.[7]

The supervisory control and data acquisition (SCADA) system put in place is an open protocol database server system which is used as the primary system for data exchange and storage from four major systems at the Institute's Wind R&D Park. The four systems are:

- DeWind server – provides detailed information on each of the five wind turbines
- Substation equipment – allows for detailed troubleshooting
- Utility system – shares grid and set point information crucial to wind park control
- Energy storage system – share grid, wind park and battery storage system information for energy storage and dissipation control

This management SCADA sends information and receives inputs from all of the other SCADA systems which supervise their own system. This management SCADA collects an immense amount of data and is able to coordinate the information transfer between systems.

Since all the data is stored within its database, the management SCADA can be used to trouble shoot all of the equipment being monitored in order to pinpoint any problem areas. It can also be used to generate reports using data over periods of milliseconds to years in order to make management decisions. This management SCADA system goes far beyond the industry standard of 10-min average values and allows for slight variations in production to be noticed. This data will be used to understand the deterioration of the components within the turbine.

6.2 Battery Energy Storage System

The storage system chosen is a Sodium Nickel Chloride ($Na\text{-}NiCl_2$) Battery technology which is a fail-safe battery design with a long life expectancy and allows deep discharges without adversely affecting the health of the battery. GE was subcontracted by S&C to provide the battery for this system, which is its Durathon Battery. The controls, HMI interface, and the inverters were developed by S&C. This 1 MW/2 MWh system has a wide variety of applications as will be discussed in results and future potential.

7. Results

With the commissioning of the 10 MW wind park in the Spring of 2013 and the BESS in the Spring of 2014 the Institute has begun to build a database of information which will be used to improve the integration of renewable energy.

7.1 Operational Wind Park

The Institute is collecting data and monitoring the performance of their wind turbines. The performance is continuing to be optimized as the Institute understands the capabilities of these turbines. The positive attributes of a wind turbine with a synchronous generator and voltage control will be examined as collaborations are put in place to understand these benefits. The wind park has met the generation predictions made by the Institute. As organizations become aware of the Institute's Wind R&D Park there will be more opportunities for collaboration on research into areas such as service life estimation, array losses, and cliff effects.

The capacity factor achieved by these turbines is high due to the large rotor diameter for a 2 MW generator and the excellent wind regime where they are installed. The DeWind 9.2 turbines have a number of innovative features including synchronous generators, the workhorse of electricity generation. These synchronous generators ensure sufficient inertia in the system despite moving away from traditional generation. This inertia, which is not present in typical wind turbines, is needed so that the frequency deviations caused by a mismatch between supply and demand are minimized. The synchronous generator is coupled to the variable speed rotor through the hydraulic WinDrive and planetary gearbox.

The SCADA system installed for these turbines is another innovative aspect of the project; it records at 10 Hz and retains all the data. The industry standard 1 and 10 minute compiled data is calculated for convenience. This data has sufficient quality to understand in detail the deterioration of the turbines over many years to aid in the service life estimation research.

7.2 Operational Battery Energy Storage System

The storage system chosen, Na-$NiCl_2$ technology, has shown excellent charge/discharge cycles although it has just begun its operation and any results are only preliminary. The Institute and their partners are becoming comfortable with the system and its capabilities. As the Institute and MECL gain experience with the storage system the various research goals can begin as the Institute continues to review the work of other storage owners to focus their research projects. As the project progresses the Institute will continue to develop its objectives and partner with others into the research on energy storage.

Along with the BESS a 275 kW diesel generator has been installed to ensure that the battery can be charged to provide power for the turbines in the event of the loss of power. This power ensures that the turbines are able to yaw into the wind to protect themselves during severe weather and to keep the turbines warm so that they can begin generating as soon as the electricity line is cleared for service. The BESS along with the back-up diesel generator minimizes downtime and ensures the safety of the turbines.

7.3 Wind Integration

The storage system and the advanced capabilities of these turbines allow for wind integration into the network. There are many aspects to wind integration as will be discussed in Section 9.1, which the Institute will examine. These scenarios will be examined both economically and practically by the Institute and its collaborators.

The Institute has installed a 80 m meteorological mast and has an advanced SCADA which will provide many benefits as we move forward on wind integration.

The Institute is building knowledge on the issues associated with wind integration and how a storage system along with the turbines can address these concerns. We are becoming practical collaborators who understand the system and have real data to bring to the table during collaborative research projects. Having real data allows the partnerships to build on the initial momentum rather than stalling during the initial data collection period.

7.4 Test Bed for Further Collaboration

The infrastructure will permit further research collaboration with a number of industrial and academic partners. So far partnerships have been created or are in the process of being created in the following areas:

- Research on the storage system and the impact on the grid
- Research into the effect of the turbines and the storage system on the network
- How the storage system can be used for ancillary services
- Service life estimation on large wind turbines
- Using Lidar wind speed measurement system to understand the wake effect of large turbines and the effects of the wind at the boundary layer for the transition from onshore to offshore

During the annual CanWEA conference, in October 2013, the Institute was able to meet with many members to discuss future opportunities.

7.5 Clean Energy Production

In the 2013-2014 fiscal year the wind turbines have produced over 38 GWh. This clean electricity has decreased the need of fossil fuel electricity generation both from PEI and fossil fuel generation imported from NB. Although the exact amount of displaced emissions is open to debate, using Environment Canada's 2012 report gives a CO_2 emissions reduction of 19,830 tonnes.[8]

8. Lessons Learned

8.1 Building of Project

There is risk in any major capital project; ranging from currency rate to supplier dependability. The importance of solid contracts and good relations between all suppliers will mitigate some of the risks. The exact risks in this project are company, time, site, and/or commercially sensitive but some general lessons learned will be developed.

One of the lessons learned is to not take planning lightly, to make sure to hire experienced people so that inexperience does not add to the complexity of the project. When appropriate, risk should be quantified and protection for the company should be put in place (currency hedging, insurance, etc.)

High winds caused delays in installation, planning to install during the lower wind months is suggested though sometimes unavoidable. The high winds coupled with the cold temperatures experienced at the Institute's site for half of the year was another cause of delays.

Utility scale electricity storage is still in its infancy with many new companies beginning and storage system providers declaring bankruptcy. Additionally, many storage system partnerships are in their infancy and the roles of each party have not been finalized. The Institute quickly learned that it would need to put a large amount of time and effort into understanding the market and visiting different manufacturers to understand their products. This was the main lesson learnt during the selection and building of the storage system.

Another lesson learned is that the whole system needs be integrated to work together. The turbines SCADA system along with the storage SCADA and the local utility should be integrated together to have an integrated approach to the entire system.

The local utility indicated that 1 MW should be a minimum size considered by the Institute for the project to have relevance to the utility and system operator. The Institute also desired a minimum of 1 MWh to be able to commit the unit at full capacity in order to demonstrate a significantly relevant capacity input equivalent to a generator between 100 kW and up to 1 MW, depending on the application for a significantly relevant period of time. Upon reviewing EPRI's general storage application requirements[9] the Institute noted that a 1 MW/2 MWh storage system would be able to perform most of the typical storage applications. The other considerations taken into account, such as financial health of the bidder have been discussed in Section 5.3.

8.2 Relevance of Project

The relevance of the project to the industry has become clearer over the past five years. The Institute has grown to understand where the most important area of focus is in terms of wind integration and in terms of research for large wind farms. The data collected will be used in collaborative research projects which are currently beginning.

9. Benefits/Future Potential

The level of data we are collecting has benefit to the industry, as it will allow the effects of various phenomenon including power fluctuations due to wind gusts, deterioration of components over time, and wake effects to be well understood. In order for the Institute to disseminate the results of this project and to develop a research strategy we have hired a Wind Integration Researcher and a Scientific Director (SD). The SD will coordinate our research with interested collaborators and ensure that the research is relevant to the major stakeholders (industry, utilities, universities, research organizations, government, etc.) and that it is appropriately disseminated.

This project paves the way for new wind park development by providing a model for how electricity storage can integrate renewable energy thereby allowing for an increase in the penetration of wind energy in Canada and around the world. The novel approach of the DeWind turbines which use synchronous generators and a WinDrive to permit variable speed operation allows for the inertia to remain connected to the network, despite traditional generation going offline. Over the next five years the Institute will partner with different academics and commercial partners in order to investigate potential applications for storage and how these applications can be used together to increase the potential of any one storage system. Additionally the data obtained can be used to test the models that have been created on how storage will alleviate integration concerns that utilities and system operators have in regard to intermittent renewable energy generation.

9.1 Integration of Intermittent Renewable Energy

The Wind R&D Park is working to overcome the largest hurdle that renewable energy currently faces, which is the fact that intermittent renewable energy does not match the electricity demand. Storage can be used in a number of ways to improve the integration of renewable energy, particularly by time-shifting the wind energy.

The storage system allows for wind energy integration into the electricity system. A report released by SANDIA highlights 17 benefits of electricity storage, many of which allow for more efficient integration of renewable energy.[10] The main benefits that storage provides for renewable energy integration are:

- Renewable energy time-shift
- Renewables capacity firming
- Reduce short-term output volatility
- Improve power quality
- Reduce long-term output volatility
- Transmission congestion relief/Reduce transmission lines losses
- Backup for unexpected wind generation shortfall
- Reducing minimum load violations

The benefits of each of these will be explored in the following paragraphs.

Renewable energy time-shifting is using the storage system to absorb renewable energy when it is not required/economical and using that electricity at a time when it is required. Currently the Institute is paid based on the amount of kWh it produces, so a new agreement will have to be met in order to take advantage of this proposal.

Renewables capacity firming is using the storage to create a more consistent long term output by reducing the output during times with good resource and providing power when there is a dip in the natural resource. With the appropriate storage sizing, the output of a wind turbine can achieve a capacity similar to a coal or nuclear generation facility.

Reducing short-term output volatility uses storage to combat the natural fluctuations in the wind by quickly changing the output of the storage to allow for a smooth power production. This is favourable as the demand and generation must be the same to ensure that the frequency does not vary. Without storage the traditional generators are required to alter their output more often causing wear and reducing their life-times.

Transmission congestion relief and reducing transmission line losses uses storage close to renewable energy sources to store the electricity during times of high production in order to decrease the energy flowing through the line to an acceptable level. This reduces the current in the line thereby reducing the line losses and the energy that is wasted. Since line losses depend on the square of the current, adding the electricity from the storage system when the renewable energy generation decreases will reduce line losses.

Using storage as a backup for unexpected wind generation shortfall reduces the need for conventional generation to be in spinning reserve waiting to cover the demand in the event that the wind parks under predicted their generation. Storage can be used to insure that the predicted generation will be achieved.

There are times when the renewable generation in addition to the must-run generators, such as nuclear and some small hydro, exceed the consumption needs. In these cases, if the excess generation cannot be transferred to another area, wind generation is curtailed resulting in a loss of energy produced. Since PEI has a large interconnection with NB this situation is unlikely to occur until additional wind energy is constructed, but during times of high wind PEI sells some of their wind energy to NB at a lower price than they will have to buy the electricity on the following day.

9.2 Test Bed for Future Collaborations

Below is a list of potential long term tests.

GE and S&C: Research collaboration with GE, S&C, and academics for research into the electrical infrastructure on Prince Edward Island.

Service Life Estimation: Research project to be able to estimate the current health and probabilistic projection of future loads, damage evolution, and failure modes.

Blade Condition Monitoring: Related to service life estimation is the Institute's collaboration on turbine blade condition monitoring. This partnership began due to the Institute's need to replace their own turbine's blades.

Time-shifting: Currently the Institute is testing the storage system with a time-shifting program where the storage system is charged during times of low demand and discharged during the supper-time electricity peak.

System Operators: The Institute is looking forward to working with electricity system operators to show how their storage system can be used as a model to test the impact of storage for the system operator.

Further collaboration is also done through workshops, site visits, and conferences: The Institute hosted a site visit for the Wind Integration Workshop which was held in September of 2013 and was jointly funded by NRCan, ACOA, and CanWEA. This workshop was one of the many site visits by professionals interested in the integration potential of storage system for intermittent renewable energy. Additionally the Institute has presented at many conferences including the renewable energy storage summit on the many benefits of storage.

10. Conclusions

NRCan through the Clean Energy Fund has invested in an excellent project which will have long lasting benefits in Canada and around the world. The operational experience of a utility scale storage system will allow utilities and system operators to understand the benefit of storage in order to integrate the increasing penetration of intermittent renewable energy. Since utilities and system operators have a limited mandate and budget to investigate storage and wind integration this project will allow the potential benefits to be examined in a real world application. This application can then be used to develop aggressive but realistic policies to encourage storage and therefore renewable energy.

This project has relevance for wind farms as the lessons learned can be shared and other wind farms will be able to benefit from the Institute's experience. There are many lessons to be learnt on storage and on large scale wind turbines. The Institute now has the infrastructure in place and has begun testing the storage system to confirm the theoretical benefits of electricity storage. This infrastructure will be used by the local utility, the system operator, the Institute as an independent power producer, the storage industry to test scenarios and products, as well as academia to test models of how storage will affect the future of the grid and how it will fit into the smart grid concept. The Institute has positioned itself as a leader in Canada both as a test site for small and large wind leading to certification and as a leader in research with partnerships including with GE and S&C to research the applications of their storage system. Having MECL, the provincial utility, as a partner will bring relevance of this project to utilities around Canada and the world.

The Institute is open to collaboration and research to test concepts of intermittent renewable generation integration. The Institute is excited about the partnerships that it is currently forming and the opportunities that have risen from the installed infrastructure.

11. References

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