Completion Report

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1. Introduction

Basically, this feasibility study shows how London Hydro, a wholly-owned subsidiary of the City of London, assessed the technical and economic feasibility of creating a DC grid for electric vehicle charging and other DC loads by constructing a 2.5 – 3 MW photovoltaic solar farm, through four phases of analysis and design as shown below. This summary report outlines the key activities, challenges, findings, outcomes, and lessons learned.

This project has been championed by Gary Stevens, Chief Scientist, s2e Technologies developments Inc., 10 Front St, St Jacobs, Ontario. The Implementation Team at s2e:

- Elham Akhavan Rezai, Member of the Technical Staff
- Ady Vyas, Vice President of Mobility and Energy Solutions

Phase I: Develop Evaluation Framework

Identify Potential Brownfield Sites for Assessment
Detail Possible Routes for MVDC Link from Candidate Sites
Identify Vendors of DC Converters/Switchgear and EV/LED Gear
Create Scope of Work for Local University Micro-Grid Team
Identify Battery Storage and Management System Vendors
Identify Best-in-Class PV Module, Racking and Electronic Hardware
Information Meetings with Community and Municipality to Discuss Project Implications

Phase II: Conduct Study

Assess Suitability of Brownfields based on soil analysis, topology and location
Assess MVDC Route Options w/Regard to accessible infrastructure, EV stations and line losses
Contact DC Equipment Vendors to assess gear regarding suitability, cost and features
Design DC micro-grid w/EV stations integrated with AC grid, as Smart Hybrid Grid
Design and Model PV Array for performance and cost
Select Battery Storage System(s) based on performance and cost

Consulting Meetings w/ Community and Municipality regarding number/locations EV chargers
Specification and Design of DC gear that may not be readily available
Specification and Design of PV mounting system that minimizes soil disruption

Phase III: Evaluate and Make Recommendations

Completion of Hybrid Micro-grid Design with PV array, EV Chargers and Battery Storage
Modelling of Micro-grid Performance with regards to efficiency and stability
Mapping of Micro-grid, MVDC Link and EV station locations
Design of Buildings' DC Circuits for LED lighting/Electronics and Outdoor LED Lighting Circuits
Market Evaluation to Determine Level of Acceptance Regarding Output of Study
Market Study of Software Options and Cost Recovery Models for EV Charger Customers
Study Power Bill Reconciliation via Virtual Net Metering
Final Consultation and Presentation of Study Output to Community and Municipality
Specification and Design of Smart Hybrid Micro-grid Software and controls
Project Management

Phase IV: Reporting

Preliminary Report on Study Objectives and Scope-of-Work
Interim Report on Study Outputs and Issues
Third Party Engineering Firm Documentation of Hybrid DC/AC Micro-grid Design
Report w/ Recommendations for the Generation, Distribution and Micro-grid EV Chargers
Report with Analysis of Probable Impact for Vehicle Emission Reductions and Fuel Savings

2. Feasibility Study: Findings and Recommendations

Brownfield Sites: As the West 5 community was designed to be Net Zero in energy usage, there was some concern that it may be necessary to generate some of the energy for the site with a supplemental PV array, perhaps outside of the community, in order to cover energy usage by EV's. One of the key elements of this feasibility study was to identify possible brownfields, predominately located to the east of downtown London, as candidate brightfield sites to bring additional renewable generation capacity into the West 5 Net-Zero community to supplement electric vehicle (EV) charger loads.

Based on available converters, switchgear and protective hardware, an MVDC link was modeled at available voltages of 5kV and 10kV. The model indicated that the idea of filling a brownfield with a PV array and constructing a medium voltage direct current (MVDC) feeder to West 5 encountered two significant obstacles; potential brownfield candidates in London being predominately on the East side of the city results in distances of ~12 - 15 km for a potential MVDC feeder. Analyses of the voltage and energy losses for the two feasible voltages for this feeder, 5kV and 10kV, produced unacceptable results for distances exceeding 3km and 5km, respectively. Increasing the size of conductors to compensate for this issue was also found to not be economically feasible. This aspect of the original proposal was found to be infeasible for the City of London because the nearest brownfield to West 5 exceeds 12km in distance.

And considering that the issue of mixed voltages was already presenting problems for London Hydro in the downtown district, a possible alternative which would support public EV charging station in the city was proposed. This path proposed the use of a brownfield near the airport as an EV charging station, supported by PV energy generation and battery storage in a net metered configuration. This study indicates a minimum of 50 charge sessions per day would lead to a potentially viable business proposal. London Hydro has held numerous meetings with stakeholders on charger infrastructure within the London proper, which has led to several conclusions: 1) There is currently an abundance of free chargers available in London, compared to the number of EVs on the road. 2) The need for charge stations that are fee-based is a few years into the future, likely around the time 500-1000 PEV's are in use in the area. 3) This would be the threshold for a proposed brightfield charger station, that provides a minimum of 50 charge sessions daily, to be viable. Based on 2017 data, about 0.7- 0.8% of new vehicle sales in Ontario were EVs, representing about 2000 vehicles in a province with more than eight million registered passenger vehicles. These numbers indicate that around 50 EVs were added to the roads of London that year, meaning total EVs in London had not yet exceeded 100. Although this could eventually be a viable operation, the lack of EVs on the roads today as well as the location of the brownfield made the viability of the concept questionable at best. However, the outcome of this analysis is bookmarked for future use, as the EV count comes closer to the necessary threshold.

A possible alternative transportation electrification solution has been proposed for this brownfield site as it is located reasonably between the downtown London core and the municipal airport, it has the potential for electrification of a municipal transport bus fleet. It has recently become apparent in the energy industry that the first phase of the transportation electrification revolution involves public transport rather than private vehicles. This phenomenon is evident in the leading country for transport electrification, China, which already has almost half a million electric buses on the roads. Municipal transport fleets are already shown to benefit from electrification, when lifetime maintenance costs are considered, and do not rely on provincial and federal incentives for early adoption in Canada. This site would be able to support a fleet of about a dozen city commuter buses with PV electricity generation.

Further analyses show that only 1 – 1.5 MW of PV is enough to support ~ 500 EVs, allowing for generation to be deployed over the storm-water trench along the west border of the West 5 development, obviating the perceived need for incorporating additional PV generation offsite. This improvement in the baseline assumption is due to several factors in both the generation side (I.e., single axis tracking PV array, string level DC optimizers, and avoiding unnecessary AC/DC conversion losses) and the consumption-side (i.e., EV efficiency that is more than 6 km/kwh, daily commuting distance adjustments, and advances in EV energy management systems (EVEMS) that open some capacity to support more EV charging without increasing the service panel capacity).

Hardware Availability: Along with the microgrid designs, a scoping study of available hardware for the microgrid was also necessary. During the more than one year that it took to fully launch this study, many of the inherent DC hardware solutions that are needed, have begun to become commercially available. As an example, during the first 12 months of the study, there was a lack of buck/boost converters to shift voltages between MVDC and LVDC. Since that time, and true to expectations, this type of product is now available and at reasonable power levels. There is still a lack of hardware for voltage levels above 5kV, particularly breakers and switches. This is not an issue for the West 5 hybrid microgrid design, as voltages in the DC bus are not proposed to exceed 2.5 kV. Most other hardware needs, including battery storage, specialty PV racking, and PV string-level DC optimizers, are readily available today. Also, in the case of EV chargers, several options for pure DC-powered chargers have recently become available, satisfying the need for EV chargers tied directly to the DC bus as a native DC load. There are also a few vehicle-to-grid charger options available, but only the 2019 Nissan Leaf is currently configured for V2G, and solely in the Japanese market.

Microgrid Design: During the first half of the study a preliminary DC/AC hybrid microgrid design was developed and accordingly static and dynamic models were created using MATLAB and PSCAD software to evaluate the system performance under normal and contingency operational conditions. A +/-1250 kV MVDC link to +/-380V load services in West 5 would work well, according to the models.

Although microgrid grounding strategies and cybersecurity were not readily anticipated and envisaged to be required in this study, these elements have been absorbed into the project scope without significant impact to timelines or the budgetary bottom line. Different grounding strategies for primary and secondary sides of the hybrid microgrid were extensively analyzed and their impact on the microgrid protection scheme were compared. Cybersecurity measures and their associated costs to the utilities are included in the study. It was found that addressing Cybersecurity concerns dictates a de-centralized microgrid control hierarchy, rather than centralized or distributed control scheme.

Another interesting lesson learned was the use of HOMER software to develop the financial models for the microgrid, coupled with PVSYST inputs for PV production, which brought to light the need for advanced synthetic load profiles for buildings that have yet to be designed. The existence of detailed energy models for mixed-use buildings in West 5 that have been designed, has allowed for extrapolation to similar buildings in the ten-year build-out plan. The DC side load profile of the microgrid (i.e., EV load profile and LED lighting) was relatively simpler to model. The HOMER model is the best available tool for cost analysis, but it does have limitations, particularly regarding energy storage, as it can only model one battery technology at a time.

The bulk of effort in the final stage of the study covers many hours evaluating multiple iterations of the original microgrid design, some interfaced to the utility feeder and some interfaced to the building mains, as well as fine-tuning parameters such as voltage levels, conductor and energy storage sizing, loss calculations, power sharing, load shedding considerations, and protection schemes through various fault case studies. Ultimately, the leading candidate configurations were interfaced to the building mains, with the interconnection between buildings being DC in one case and AC in the other case. From a stability and protection analysis standpoint, shown by PSCAD models, the DC interconnected configuration was shown to be most acceptable. A review and cost analysis of these configurations by an independent third party, Quanta Technologies, Inc., indicates that the DC interconnected configuration would have higher communication and controls costs but that overall costs for either configuration would be similar. This evaluation is specifically for the case of West 5, other configurations could make the most sense for other locations, each situation likely has a unique microgrid solution.

The DC-interconnected configuration has other advantages over the AC-connected configuration. For the former configuration, the Ontario regulatory authorities would likely see fewer issues, as the possibility of moving energy between buildings (behind the utility meters) could be prevented by avoiding the use of bi-directional inverters. The DC-interconnected configuration would still allow the selective movement of energy from the DC-tied PV arrays to buildings that need to be topped-up for net metering and net-zero purposes. This advantage of the DC/AC hybrid microgrid has always been apparent and was considered essential if Virtual Net

Metering (VNM) were no longer an option, which is now clearly the case after numerous meetings with the OEB and Ministry of Energy on this topic. This is now the only approach that avoids the barriers to community solar that are in place regarding IESO regulations. With the current design, it will be possible to set up community solar configurations in developments that do not exceed three kilometers in scale. This type of asset sharing has become a key factor in large scale adoption of residential solar in many states in the US, with Minnesota a leading example.

Environmental and Market Analysis of EVs: The report also contains an evaluation of the environmental impact (GHG reduction) of EV adoption in West 5. Another section evaluates possible business cases and investment returns for installation of public chargers in West 5, with the likelihood that even a few level III chargers could be part of the business proposal. Market research by s2e indicates minimal barriers to EV adoption in Canada and the London area, making West 5 an ideal candidate site for promoting EV usage.

3. Lead Applicant's Next Steps

With the completion and submission of the GMF study, London Hydro will begin undergoing the process of construction for the West 5 hybrid microgrid highlighted in this report.

4. Lessons Learned

The lack of a readily available brownfield to support DC loads in West 5 changed a bit of the scope of the study, but most of the inherent environmental benefits of the embedded DC microgrid within West 5 will still be captured in this hybrid microgrid design. It is still clear from the models and indicators that an embedded DC microgrid with generation, loads and storage has efficiency advantages over an AC alternative. Anticipated barriers regarding DC hardware have been minimal, due to the recent emergence of DC-based grid solutions. The use of DC appliances in a residential setting would also be interesting, as that market develops.

This project may have been better suited for municipalities with a larger number of brownfields, although it does appear to be suitable for many municipalities in Canada.

5. Project Management

This project has been championed by Gary Stevens, Chief Scientist, s2e Technologies developments Inc., 10 Front St, St Jacobs, Ontario. He has led the University teams and other research partners such as Natural Resources Canada's (NRCan's) CanmetENERGY laboratory and documented the progress to date. London Hydro has put together a team to address microgrid issues as well as completed studies on the applicability and timing of instituting EV charger infrastructure within the London area.

Any community considering a similar project would be well advised to consult the materials provided from this feasibility study as well as consult with the proponent of this study. The most important aspect of any microgrid design is to fully develop and understand the load profile of the service area at the outset, otherwise the design will end up going through multiple iterations at considerable cost of time and resources.

6. Acknowledgement

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