Among a variety of topics, the TEAM group selected Energy Storage for the Pickering Wind Turbine as their topic this year. Within the first month the students had already done an impressive amount of work and had the various technologies evaluated. They did a lot of the legwork for us and were very receptive to customer needs and feedback.

We both learned the legal, environmental and financial constraints on energy production from this increasingly popular renewable energy resource. Thanks to Queens TEAM-OPG, we have quantified what it will take to make this source of energy production more stable and reliable. Not only have our practical siting details been addressed but we now have a strategy we can follow when the economic environment is right.

In summary this has been a very efficient and informative project. It was a pleasure to work with such a motivated and bright group of students. Thank you TEAM!

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Energy Storage Options for The Pickering Wind Turbine

Executive Summary

A study was performed to determine the potential for energy storage for OPG's 1.8 MW Pickering Wind Turbine (PWT) for the purpose of shifting wind generation output from low-demand times to high-demand times. A full analysis was performed on the most appropriate storage technology for the PWT including an environmental, hazard, risk and financial and sensitivity evaluation.

Among numerous solutions possible the following 4 were selected for detailed evaluation:

- pumped water storage (tanks),
- hydrogen generation,
- flywheels, and
- 'flow' batteries.

Detailed data on each including operating experience world wide was gathered.

An analytical model was developed based on very detailed data from the existing wind turbine. Its capacity averages 0.2 to 0.4 MW for summer and winter respectively. The model was used to determine the optimum size of facility and to test various time-of-day and costing scenarios. Wind predictions a day in advance were found to be quite good and could be used to plan energy storage and dispatch.

One of the 'flow battery' energy storage technologies was found to be the most appropriate system to store energy for the PWT in terms of meeting design requirements and lower costs. This technology involves transporting electrolyte across cell membranes where a reversible 'redox' reaction causes a current to flow through an external circuit. The equipment needs to be housed in a temperature controlled environment.

For the specific system selected a detailed site evaluation was then performed along with a thorough environmental assessment. Potential hazards and mitigating recommendations were provided and an overall risk management strategy was proposed. The environmental and hazard assessment found that there were no insurmountable problems with installing a flow battery facility adjacent to the PWT.

The financial analysis found that, under either current market electricity prices or current Ontario Power Authority 'Standard Offer' prices, the preferred flow battery system is not an economically viable option for the PWT. It was found that an increase in the market price differential (from overnight to peak) would have to double even with incentives. On the current spot market the situation is even less attractive. A differential approximately 19- 28 cents/kWh is required to make the flow battery viable or a capital cost reduction in the technology of 90%.

Therefore, it is recommended that OPG continue to monitor both the power market conditions and price of storage options. Should changes of the magnitude identified in this report materialize; an energy storage option can be pursued. No credit was taken for

greenhouse gas reductions or carbon taxation which may become economic factors in the near future.

A related finding resulting from this work is that the recommended technology should be considered for installation for a remote community power supply. A flow battery-wind turbine-diesel generation hybrid was found to be a more cost-effective and environmentally friendly alternative than all-diesel generation. Also, a flow battery storage installation in a remote community can serve as a pilot energy storage system. Should this pilot installation prove successful, it can be expanded to other remote communities which would reduce costs and greatly reduce CO_2 emissions.

Finally, a pilot installation can provide insight into the future of energy storage in Ontario. As wind energy generation continues to grow, methods will need to be established that can mitigate the problems associated with the variability of wind. The knowledge and experience gained from a pilot installation can help OPG, the IESO, and the OPA better understand the role energy storage can play in improving the viability of wind energy generation in Ontario.