EB-2013-0321

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Issue 5.1 (a) ***Could the storage of energy improve the efficiency of hydroelectric generating stations?***

First, I apologize for not commenting on this issue at the Technical Conference held on the morning of April 22, 2014. I did not receive the agenda until two days later so I was not prepared. However, some of the same considerations were relevant to the Technical Conference held on the following day re. Refurbishment of the Darlington Facility. RT

Most of the OPG hydroelectric generators (Exhibit A1, Tab 4, Schedule 2) are run-of-the river generators. A few are identified as peaking generators, implying that they are primarily in operation at times when there is a need for extra power, but most run continuously, with some being identified as "intermediate", suggesting that they serve both peaking and baseload requirements.

Run-of-the-river generators commonly have low capacity factors, a consequence of:
(a) a low demand for power at the time the hydro power was available
(b) a low rate of water flow in the river, or
(c) other factors, such as maintenance, repairs, river regulations, etc.

Given a means of storing any surplus power then under consequence (a) the capacity factor for the generator could be increased. It would be useful if OPG would undertake to provide a table of capacity factors for their hydroelectric facilities that identifies the contributions of (a), (b) and (c). From such a table the extra energy supply capacity of the stations could be determined.

There are two other methods for using storage to make such generators more efficient. One is to employ demand shifting - moving a power load from a period of high power demand to a time when there is surplus power available - and the other is rapid stored energy discharge (for example a car battery can be charged at a low rate but can then deliver its charge at a very high rate, as when starting a car).

All three of these methods can be used together to achieve very large increases in the supply capability of hydroelectric generators. Appendix A contains the slides for a presentation made at NRCan in Feb (2014), showing how the run-of-the-river generators in eastern Ontario could meet a large part of the region's energy needs, including both electricity and thermal needs. Appendix B contains a peer-reviewed paper that describes the principles.

The type of energy store described in Appendix A does not require any modifications or connection to the generators themselves other than a signal from the generator that indicates when surplus power is available and when the grid demand is high so the storage input should be turned OFF. The stores themselves are located near the buildings they serve and there could be many such stores serving each community. In that type of storage facility the energy is stored in the ground in the form of heat, using a small number of boreholes per store (typically 17) that can be drilled at a very modest cost. Appendix C outlines some of the ways in which such storage facilities can be optimized for use in the various regions of Ontario.

The cost per peak MW of storage can be much less that the cost of the same amount of power from generation facilities, whether they be hydro, nuclear or gas-fired generators. The potential for employing storage is very large - in the tens of thousands of MW - being determined by the ratio of the peak demand to the annual average demand. That brings us directly to the purpose of the EB-2013-0321 review. The price of power could potentially be progressively reduced if OPG employed storage instead of relying on generation to meet the peak loads. OPG has stated that they do not plan to use storage, ergo the price of electricity will continue to skyrocket as predicted in the Energy Ministry's LTEP (KT 2.2) until some agency (like the OEB) steps in and directs them to consider the storage alternative. There is already a directive to that end from the Ministry of Energy (Appendix D) so one response might be that the OEB could require that OPG follow that directive and come back to the Board with a report on the potential for using storage instead of relying completely on generation. The Ministry directive calls for an initial storage of 50 MW but in an application like run-of-the-river hydro energy storage the power output of the store could be 20 times greater than the input power because of the cumulative effects of the three factors described above. In that case the reduction in the peak generation capacity would be 1000 MW, which is a significant difference in the OPG plan outlined for the immediate future, and it offers a method for reversing the long term trend to higher electricity prices. Storage can be applied to all of OPG's generation facilities, not just the hydro facilities. The Energy Ministry directive is addressed to the IESO and the OPA but it would be OPG that would actually be generating the power. There are many experts in Ontario on the subject of energy storage who could present and defend evidence (we would be happy to provide a list of names).

Appendix A

Slides appended as the file "kegs.pdf"

Appendix B

Paper appended as the file "WSF3 Exergy Storage.pdf"

Appendix C

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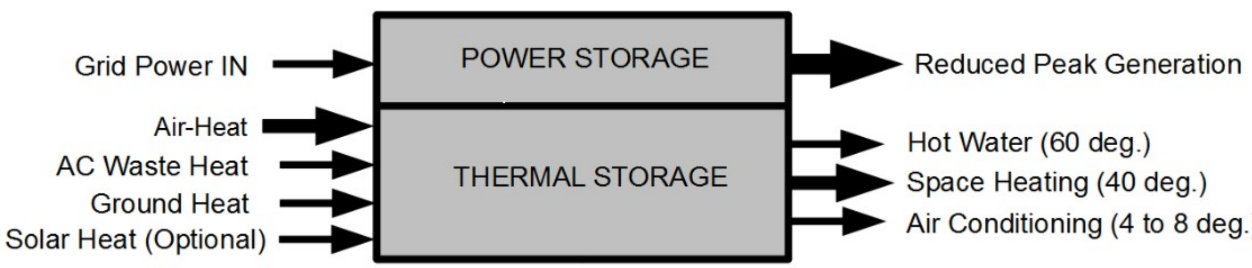
Re: Directive from the Minister to develop a diversified portfolio of storage technologies

The following outlines a storage technology that should be included in your responses to the Minister's letter. It stores electricity in the form of exergy.
(1) Explanation   Exergy storage provides an inexpensive means of storing grid power on both a small scale (tens of kW) and on a large scale (thousands of MW). Such storage systems would be installed at the consumer end of the distribution network. They take up very little space, are silent, safe, nearly invisible, and they could quickly solve problems like the current dramatic swings in electricity prices even if only a few stores are installed. However, the overarching considerations are their huge capital cost advantage over supply-side storage (batteries, pumped storage, etc.), their potential to reverse the trend toward higher electricity costs and their potential to eliminate the very high levels of GHG being produced by the use of natural gas in Ontario.



As with other grid power storage methods, the input power is converted into a storable form (thermal in this case) and this stored energy is used to reduce the need to generate power during peak demand periods. With most storage methods the output is less than the input but in this case the output is 2 to 4 times greater than the input because the associated thermal sources contribute exergy to the output. In effect a substantial amount of the thermal energy is converted into electricity.

The primary source of energy for the exergy store is heat that is extracted from the summer air. The electric input drives a heat pump that moves the heat (while contributing some additional heat) from the periphery of the store to the two internal storage rings that are maintained at the temperatures that are needed for domestic hot water and space heating, with the outer ring being used for air conditioning. The process raises the temperature, thus boosting the exergy of the stored heat, and the design ensures that almost no heat and little exergy is lost over the annual cycle. The concentric-ring store can concurrently supply all three temperatures that are needed by the buildings. No power is consumed when the heat is withdrawn from the store. The process eliminates the big summer demand peak that is caused by the AC loads, the corresponding winter demand peak, and the year round power demand for hot water, shifting the entire electrical load for thermal applications to off-peak periods (i.e., during the night and the low demand seasons). The timing of the power consumption can be directly controlled by the grid operator while the timing of the thermal outputs are determined by the building owners.

There are four variants of the design that are suitable for four different regions of Ontario:
GTA area   This area primarily uses nuclear power, which needs to match a fixed generating station output to a highly variable load. This exergy store variant would normally not include a solar input. It is designed for maximum load levelling but it adds less electricity to the output than the other variants.

Eastern Ontario   This region generates about 2000 MW of power from run-of-the-river hydro stations. The capacity factor of such stations can be boosted if storage is added. In addition to providing storage the exergy systems would substantially increase the power output of the existing generators.

South Western Ontario The wind turbines in this area require storage because of their intermittency. Their energy output peaks strongly in the winter so the exergy stores would supply the energy when it is most needed. They can function without the solar input.

Northern Ontario and remote communities At sites that are deficient in electricity the exergy stores can incorporate extra solar thermal collectors that are five times more efficient in producing electricity (in the form of demand reduction) than solar PV panels, and the load levelling can be optimized to minimize the cost of transmission via long power lines.

(2) Performance When the grid operator wants to store energy he sends a signal to any required combination of exergy storage sites to automatically start up their heat pumps. The power demand increases immediately, and the grid operator directly controls both the storage locations and the amount of power (by selecting the appropriate number of sites). The command could be system wide, but is more likely to be directed to the locales where the storage will be most useful. No changes are required in the transmission grid.

(3) Resilience Exergy stores would make the Ontario energy system much more resilient. In the event of a power failure the stores would continue to deliver heat, hot water, air conditioning and a basic amount of electricity for as much as a month or more because large amounts of heat are stored and the storage zones are already at the three required output temperatures.

(4) Limits The storage boreholes are permanently sealed and are buried underground. They have an anticipated lifetime of about 100 years and can be located under buildings, streets, parks, parking lots, etc. so they take up almost no useful space. Some variants will have solar thermal collectors that will be slightly larger in total area than those conventionally used for DHW but are otherwise the same. Most will use air-heat collectors that are similar in size to the air-heat exchangers that are commonly used in most buildings.

Scope for installations Since the electrical storage capacity and the potential thermal storage capacity are linked, the former is limited by the latter. That sets the potential electrical storage capacity at over 10,000 MW.

Lives are at stake There have been many fatalities that have resulted from carbon monoxide poisoning, fires and explosions caused by natural gas and other fossil fuels. Governments tend to adopt the opinion that such fatalities are inevitable but here is a case where that is not true. Such deaths can, and should be a thing of the past.

Smart storage Weather forecasts can be used to modulate the medium term storage for both heating and cooling.

Insurance In the event of an exceptionally cold winter (as this past winter, for example) the natural ground heat around the store provides a large amount of insurance that there will be extra heat available.

(5) Capital costs The cost per MW(avg.) of storage for exergy storage (currently about $500/kW) is about 1000 times less than that of Li-ion battery storage for the same storage capacity. Both are capable of rapid energy delivery for short times and they have have comparable potentials for economies of scale.

(6) Current applications in Ontario   The Volker Thomsen house in Kingston provides a working example of a small system and the Enwave installation in Toronto is a working example of a large exergy system, although neither incorporates some of the most recent design features. A high priority should be given to building demonstration examples of the four specialized designs that are suitable for the four regions in Ontario described above.

(7) Natural gas-fired generation   Even a modest deployment of exergy stores would be sufficient to eliminate the need for gas-fired peaking stations altogether. The power demand peaks are created by the power demands for air conditioning and heating so by eliminating those demands the need for peaking stations is also eliminated. Note, however, that the consumption of electricity is not necessarily changed - the storage systems are primarily moving the demand from peak demand periods to periods of surplus supply. This storage is augmented by the conversion of heat to exergy.

(8) First Nations   The exergy storage systems would be very suitable for use in First Nations communities, and would reduce their dependence on diesel-fired generators at a highly competitive price. Note, however, that there will still be a need for some baseload electricity generation.

(9) Ontario power prices   In Ontario the price of power is primarily dependent on the capital cost of the systems that are needed to provide enough MW of peak power, and that objective can be met either by increasing the generation (and the grid transmission) capacity or by using storage. Since the cost per MW of storage via exergy storage is more than an order of magnitude cheaper than the available generation alternatives the way is open to reversing the trend to higher power costs.

(10) GHG emissions   Ontario presently consumes about 1 Tcf/y of natural gas for energy applications. That amount of natural gas produces 105 million tonnes of CO_2 (equivalent) that could be progressively eliminated if Ontario used exergy storage systems.

(11) Proposed action   We have identified some potential users of exergy stores and their corresponding LDC's. There are four different variants of the design that are suitable for four different regions of Ontario so it would be desirable to start with installations that represent all four variants/regions. The individual stores are not expensive so investing in multiple sites does not present an economic barrier. Although the exergy storage concept is innovative it is based on the use of conventional components and they are all used within their normal operating ranges. We have had four years' experience in operating the prototype system in Kingston so the pressing need is to build demonstration systems, not initiate R&D projects.

An exergy source is a dual function system that concurrently serves two very different purposes - storing electricity for the grid and storing heat for buildings. The two functions can be managed almost independently providing the LDC agrees to follow a weekly schedule for loading the energy. The timing is left to the LDC operator, providing he sticks reasonably closely to the weekly quota.

(12) Incentives   At the present time 100% of the capital cost of building an exergy store falls to the building owners but nearly all of the benefits are realized by the other players. The power generating companies reap the capital cost benefit (potentially billions of dollars) from using storage in place of generation. The LDC's reap the benefit of the lower operating cost because they would be buying power at night. The public as a whole (and the provincial government) gains because of the GHG reductions, but that is not reflected in any economic reward to the builders. Even the federal government gains because Canada would be using domestically-produced energy instead of imported

shale gas.

The buildings that use exergy storage would be employing local, natural sources of energy but even that potential economic advantage will be reduced and possibly eliminated by the increasing price gap between the costs of electricity vs. natural gas that is proposed in the LTEP.

What is needed is a practice under which the investments are made by the players that reap the benefits. For example, if any combination of government-generators-distributors were to undertake to build and maintain the exergy stores then the building owners would have a strong incentive to use this technology. They would enjoy clean, less expensive power and reduced capital costs. The gains of the other three parties would be in direct proportion to the number of users so they should have a strong interest in maximizing that number.

The generators/LDC's are not likely to move until there are enough systems already in use in the various Ontario districts to provide the planning numbers they need. That suggests the the Ontario government should seize the initiative to build a group of demonstration exergy stores, bearing in mind that they could build 1000 such stores for the same price as one battery-based store of the same total capacity.

To a sustainable future!

Ron Tolmie

Link to a description of the principles of exergy storage.

Appendix D

Appended as "appendix-d.pdf"

Signed: Ron Tolmie, Sustainability-Journal.ca