More wind means more risk to the Ontario electricity grid

By: Donald Jones, P.Eng. - 2011 January 2

In order to accommodate more wind onto its electricity grid without decreasing its reliability Ontario will have to export all the wind electricity it generates, at very much below its generation cost, and depend on more accurate wind forecasting. Consumers will also have to pay wind operators for the large amount of generation that is available but cannot be accommodated on the grid. Let's take a look at the Ontario grid envisaged under the recently issued government Long-Term Energy Plan (LTEP) and see how this could happen.

The LTEP calls for 12,000 MW of nuclear capacity to provide just 50 percent of total generation, since anything more than 50 percent causes concerns about nuclear turndown in low demand periods. By 2018 there will be 10,700 MW of installed wind, solar and bioenergy - let us assume 8,500 MW of installed wind - and 9,000 MW of hydro, including run-of-the-river and storage. The gas-fired generation will be maintained at its current level of over 9,500 MW - say 10,000 MW - and there will be 1,000 MW of Combined Heat and Power added to the baseload supply. Wind is intermittent and hydro generation depends on lake levels and precipitation and can vary significantly through the year and in the future may be affected by climate change. Water spillage, if necessary to reduce hydro-electric generation, is restricted by water management regulations, environmental concerns and by public safety around spillways at the dams. Gas generation would consist mostly of combined cycle gas turbine units and a small amount of less efficient simple cycle units that can be called in to help with peaking and operating reserve. With nuclear units undergoing refurbishment over the next twelve years or so there will be more gas-fired generation on line. See APPENDIX for a description of how the Ontario grid works.

When the wind picks up and starts feeding power into the grid gas-fired units will be the first to be dispatched down for economic and supposedly environmental reasons. The grid operator, the Independent Electricity System Operator (IESO), says that the combined cycle gas turbine generation is dispatchable down to a power level of 70 percent of full power. This means when in this power range the units will respond to the dispatches sent out every five minutes by the IESO. They can be taken down below this level but will then be slower to respond to dispatches. However hydro can be used in the short term until the gas turbine units power up. The combined cycle units should be able to go down to 40 to 50 percent of full power, the limit set by meeting nitrogen oxides and carbon monoxide emission limits, combustion stability etc. Anything lower than this means shutting down part of the combined cycle generating plant (i.e. one or more gas turbine-generator units of a multi-gas turbine plant) which would mean losing that generation when the wind drops unless they can work simple cycle after isolation of the heat recovery steam generators associated with the shutdown turbines. Operating combined cycle units at part load and stopping and starting turbines leads to increased emissions and greenhouse gases per megawatt-hour generated as well as wear and tear on the units.

If we assume the maximum available 10,000 MW of dispatchable gas generation is on line and that it is all combined cycle and that it can get down to, say, 50 percent, then it can integrate 5,000 MW of wind. The 50 percent is an average figure since some plants may be kept at the bottom of their dispatchable range while others may be down at say 20 percent with some turbines in a multi-gas turbine plant shutdown. The other 3,500 MW of wind would have to be integrated by reducing hydro generation by 3,500 MW. If hydro can be dispatched down to the must-run hydro minimum of around say 2,000 MW it means that there must be at least 5,500 MW of hydro on line to accommodate the remaining 3,500 MW of wind. Water spillage, if necessary to achieve the hydro must-run minimum load condition during periods of Surplus Baseload Generation (SBG), may take some time to set up.

The above shows that there could be potential concerns during a day when gas and hydro are operating at less than their maximum capacity and wind kicks in. For example take a day in the future in which there are no exports and the Ontario demand during early afternoon is say 19,000 MW and that demand is being met by 11,000 MW of nuclear, 3,600 MW of gas and 4,400 MW of hydro with no wind. Assume the 3,600 MW of gas is being provided by 4,800 MW of generation working at 75 percent capacity, to allow for possible later demand increases. Now the wind picks up to provide 5,000 MW. Gas may be dispatched back to 50 percent, 2,400 MW, to integrate 1,200 MW of wind. However even if hydro can be dispatched down to the must-run output of around say 2,000 MW it means that it can only accommodate 2,400 MW of the remaining 3,800 MW of wind. If this wind were under the old wind contracts and not the newer feed-in-tariff (FIT) program, and if gas were not taken down below the 50 percent level, a SBG condition would exist and 1,400 MW of nuclear might have had to come off line and, if shutdown were necessary, be unavailable for up to three days due to nuclear operating reasons. For the wind under the FIT program the IESO can request the wind operators to shutdown wind units and if (if - because they are not obliged to obey the request) they comply they still get paid for the forecast lost generation.

Thus on this particular day just 3,600 MW of wind (and even this is more than twice the amount of normal operating reserve) of the 5,000 MW available could be integrated into the grid no matter how much potential gas generation was available but under the FIT program the wind operators would still get paid for the balance of the 5,000 MW, that is, the 1,400 MW that could not be accommodated on the grid. This shows that increasing the amount of gas capacity above the 10,000 MW in the LTEP does not allow more wind to be integrated if the demand on the grid does not need it although it could in the future if Ontario's demand increases and gas is used instead of nuclear.

The situation described on this day puts the grid in a precarious position if the 3,600 MW of wind now on the grid is "suddenly" lost because of the wind fading or increasing to unsafe levels (Aside: by mid-2012 the IESO will implement central wind forecasting) since a large part of the gas fired generation is well below its dispatchable range. The hydro units (and, if necessary, any peaking simple cycle gas turbine generators that are on hot or cold standby) must move up from 2,000 to 5,600 MW to accommodate the lost 3,600 MW of wind until the combined cycle gas generation can pick up the load. This assumes that 5,600 MW of hydro is available in the first place which may not be true in drought conditions. Imports could help but these may be constrained since neighbouring utilities may be suffering the same wind loss. Plan B would be to drop some of the load! And this is for just 3,600 MW of "lost" wind - potentially there could be lots more. A prudent grid operator would reduce risk to the grid by keeping the combined cycle gas turbine generators at a higher output, since the wind operators, under FIT rules, get paid the same anyway.

The grid operator may have a more stress free life when there are significant exports out of the grid. For example if there were at least 5,000 MW of hourly contracted exports on the particular day in the future in question the gas and hydro generators would not have had to be dispatched down. Presently the IESO exports much more power than that generated by wind. More gas would have to be used if the wind dropped, in order to meet the contract amount of hourly export. Of course if wind picked up during the contract period gas and hydro would have to be dispatched down but the gas units would be operating in the upper end of their dispatchable range and could accommodate more wind and may still be responsive to dispatches if the wind is "suddenly" lost. Wind exports or not, the gas-fired and hydro units are dispatched by the IESO at five minute intervals to move power up or down as necessary. When exports have not been high enough nuclear units at Bruce B have had their power reduced, using steam bypass, because of SBG. Bruce Power has said that SBG is its "number one operational concern" and that "manoeuvring nuclear units represents a significant reliability risk to the province".

Wind needs dispatchable generation for it to be accommodated on the grid so in Ontario this will mean hydro (when available) and gas which are dispatched at five minute intervals. It makes no technical, environmental or economic sense to manoeuvre new multi-billion dollar nuclear plants every five minutes to accommodate the intermittency of wind. Actually coal generation, which is to be phased out by 2014, is much more flexible than gas since it can be dispatched down to 20 percent of full power compared to around 70 percent for gas. With nuclear limited to meeting 50 percent of demand and hydro, depending on water supply conditions, optimistically meeting 25 percent, dispatchable gas generation and wind/solar must pick up the rest. Long and short term dispatchable support of wind will normally be by gas although any available hydro could be used if required in the short term if some gas generation is temporarily out of its dispatchable range. The real concern with a wind and gas combination on the grid is recovery after a "sudden loss of wind event" (Aside: Let's call it a SLOWE) when combined cycle units are operating well below their dispatchable power range, and it is not the requirement for them to cater to the variable nature of wind which is part of the usual ups and downs on the grid and is looked after by normal five minute dispatching. It would make little environmental or economic sense to have enough simple cycle gas turbine generator capacity available to cater for a SLOWE if that is more than the amount required to meet normal peaking and operating reserve requirements.

Thus it looks as if the reliability of the grid could depend on a continuing export market and on the accuracy of the wind forecast. Without significant exports to increase the amount of gas-fired generation it will not be possible for the grid to accommodate all the potential wind generation that will have to be paid for nevertheless. On shore wind generation that is costing the Ontario consumer 13.5 cents per kilowatt hour is being exported at less than a third of this price. The grid is a complex beast and this an over simplification and may even be making wrong assumptions but it makes one wonder if all the risk to try and incorporate wind, that isn't needed anyway, is worth it, especially if it needs to be exported in order to minimize risk to the grid.

Appendix

How the Ontario power grid works

Ontario's grid consists of many and varied generating stations located throughout the province feeding consumers through a network of high voltage transmission lines, transformers, switchgear, and low voltage distribution lines to major consumers including local utilities. Electricity cannot be stored in large amounts so generation and demand has to be kept in balance at all times. If demand exceeds supply all the generators on the grid slow down and the normal grid frequency of 60 Hertz (reversals per second of alternating current) will drop. All electric motors working off the grid would similarly slow down. If supply exceeds demand the frequency will increase. It is the job of the Independent Electricity System Operator (IESO) to ensure that these frequency swings keep within very tight tolerances on a seconds to minutes time scale. It does this by dispatching generators (hydro, coal, gas) on the grid at five minute intervals, not necessarily the same generator, to move power up or down. In the morning the power moves would generally be in an upward direction and in the evening in a downward direction but there can also be small reversals in the general trend. This is called load-following (load-cycling refers to shutting down or powering down units overnight when demand is low). This brings the grid into a rough balance. In order to bring the frequency into its narrow operating range of around 60 Hertz the IESO automatically controls the output of a very small number of selected generators that have the capability to continuously and rapidly vary their output. These are some hydro units at Niagara Falls and, in the past, some coal-fired units. This is called Automatic Generation Control (AGC). The second to minutes supply/demand variations on the grid, including the erratic fluctuations of wind, are smoothed out by the rotational kinetic energy of the grid generators, by the hydro and fossil turbine-generators on the grid changing their output by normal speed governor action over a limited range, and by AGC. The current AGC regulation service requirement from the IESO is for at least plus or minus 100 megawatts at a ramp rate of 50 megawatts per minute but this may be changed to allow other generators to supply this service. The designated unit that is on AGC service is kept in its desired operating range by dispatching hydro, coal and gas generation at five minute intervals. This dispatching allows for the normal daily demand changes (load-following), including the intermittency of wind. Since valuable hydro is fully committed, gas or coal generation is used to cater for wind intermittency. As well as frequency voltage levels at points on the grid also have to be maintained but that's another story.