2016 IESO Operability Assessment - Summary

Review of the Operability of the IESO-Controlled Grid to 2020

June 2016

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Introduction

This report summarizes the results of an operability assessment, which considered the changes expected on the system in the next few years and identified operating challenges. The changes expected on the power system that were considered in this assessment include:

- Continued integration of variable generation (VG)
- Increased combined cycle natural gas generation capacity
- Refurbishments of nuclear generators
- Transmission enhancements
- Changes to load behaviour

This assessment identified operating challenges due to a number of factors including the operating characteristics of Ontario supply resources. More specifically:

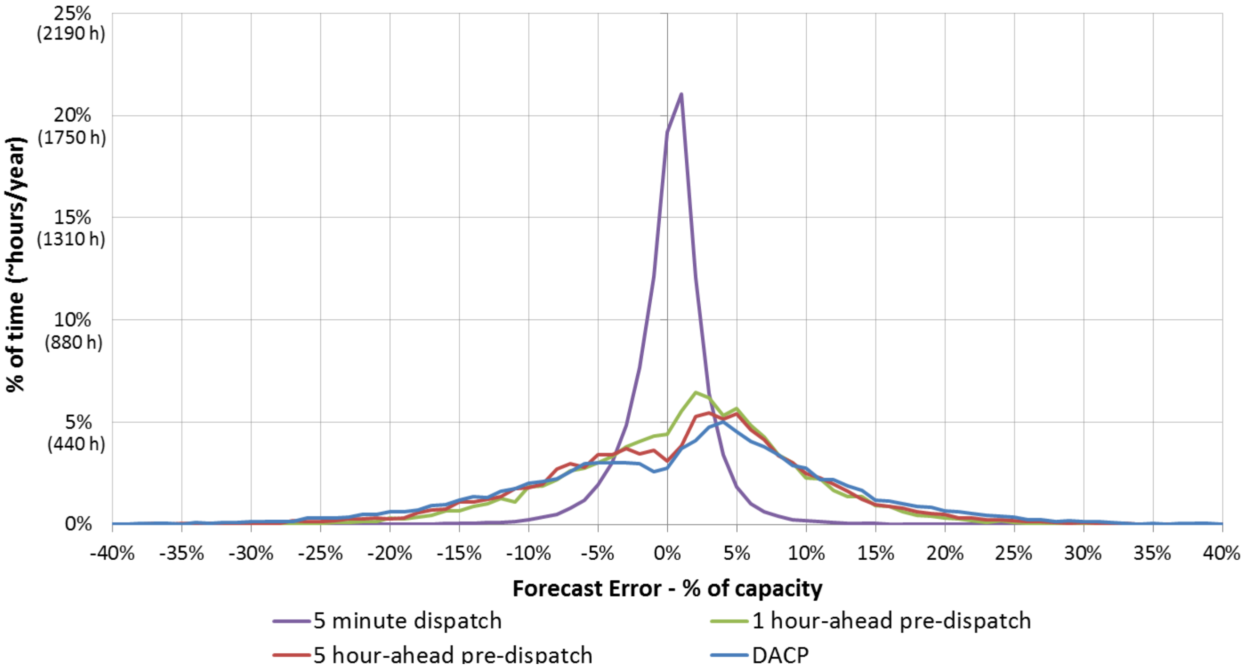
- The quantity and timing of variable generation output is less predictable than that of conventional generation, which makes it difficult to efficiently commit non-quick start resources or schedule transactions on the interties. Over-forecasting the output of the variable generation fleet ahead of real time may create a reliability issue, as insufficient resources may be available in real-time to satisfy Ontario demand.
- Most supply resources in Ontario are not very responsive (e.g. slow to come online or subject to environmental restrictions), which makes it challenging in the hour ahead of real-time to manage a situation where the output of the variable generation fleet was over-forecasted.
- The uncertainty in the output of the variable generation also increases the need for more regulation services; that is, resources capable of balancing the power system on a second-by-second basis.
- Challenges to manage voltage on the transmission system are increasing due to reduced power transfers resulting from increased quantities of supply resources connecting to the distribution system and increased energy conservation.

In addition to identifying these operating challenges, the operability assessment also determined that Ontario will have sufficient load following capability in the next few years, that the supply variability introduced by connecting additional wind and solar generation will not increase the operating reserve requirements in Ontario, and that the frequency and magnitude of surplus baseload generation (SBG) in Ontario over the next few years can be managed by existing IESO mitigation approaches.

This report will describe these findings in more detail.

Generation Commitment and Intertie Scheduling

Chart 1: Variable Generation Uncertainty



What is it? Chart 1 presents a historical distribution of the difference between actual variable generator output and the variable generation forecast used in the 5 minute-dispatch, hour-ahead pre-dispatch, 5 hour-ahead pre-dispatch and day-ahead (DACP) scheduling sequences; expressed as a percentage of the variable generation fleet capacity[1].

Why do we need to know? Variable generation forecasts are inputs into IESO market scheduling tools. Forecast inaccuracies impact IESO's ability to effectively commit gas generation in the day-ahead (DACP) and day-at-hand (5 hour-ahead pre-dispatch) timeframes, and to schedule imports and exports in the hour-ahead pre-dispatch timeframe.

What is it telling us? The variable generation forecast accuracy is roughly the same from day-ahead through to hour-ahead timeframes. The forecast prepared for and used by the IESO's 5-minute dispatch scheduling algorithm is substantially more accurate.

[1] The accuracy of the VG forecast we receive from our forecast vendor is consistent with industry norms.

Operability considerations? Forecasting future system conditions is becoming increasingly challenging, with increasing uncertainty introduced the VG forecast, the evolution of demand side resources and increased conservation participation.

When the VG fleet produces more energy than expected (i.e. VG output is under-forecast), IESO operators can dispatch down transmission-connected variable generation resources (if necessary) to balance supply and demand. On the other hand, when the VG fleet produces less energy than expected (i.e. VG output is over-forecast), the IESO might have under-commit gas generation facilities and/or over-scheduled exports, which is a reliability concern.

Today's supply mix has limited flexibility to effectively compensate within the hour when we the output of the variable generation fleet has been over-forecasted. Hydroelectric generation is being operated in an increasingly steady manner due to restrictions imposed by facility owners, and nuclear generation facilities are generally operated at their full capability. The York Energy Centre (YEC; ~2x200MW simple cycle gas generators) is currently the only gas generating station in Ontario capable of starting[2] in a short period of time. The remaining gas generating stations typically need several hours to start due to their combined-cycle processes.

Knowing that the VG forecast is frequently going to be materially incorrect, but not knowing when or by how much, IESO operators are taking actions to compensate. Ahead of the dispatch hour, they might manually reduce the VG forecast or increase the Ontario demand forecast to overcommit gas generation – and dispatch down VG if, as a result of these actions, we have scheduled too much energy in real-time (increases greenhouse gas emissions, and is costly and inefficient). In the dispatch hour, our operators might curtail exports mid-hour if we have under-committed generation (not a good utility practise). This situation is made worse when YEC is unavailable or its capacity is insufficient to compensate for the variable generation forecast error.

As the quantity of transmission-connected wind and solar generation in Ontario increases towards ~10,000 MW by the end of 2020, we will increasingly witness instances when the magnitude of the VG forecast inaccuracies will be larger than the capacity of YEC generators to efficiently manage the change.

Recommendations? We recommend enhancing the flexibility[3] of Ontario supply resources to ensure that there are increased quantities of resources able to address the hour-ahead VG forecast inaccuracy, 95% of the time[4]. This translates to needing ~1,000 MW of additional

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[2] 'Starting' means receiving a dispatch signal from the IESO, synchronizing the generation unit and increasing output to its minimum loading point.

[3] 'Flexibility' in this context means the ability to start within ~30 minutes.

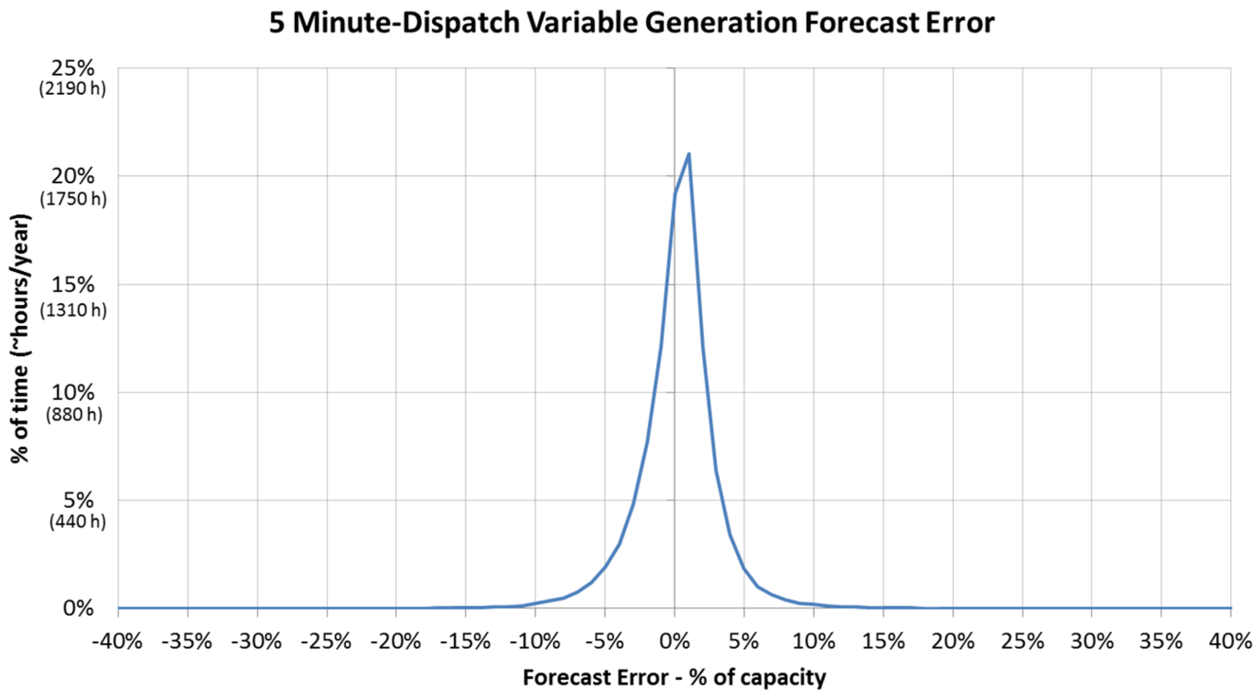
[4] The remaining 5% of the time, the IESO would rely on the limited incremental flexibility provided by the hydroelectric fleet and utilize short term flexibility on Ontario's interties where available.

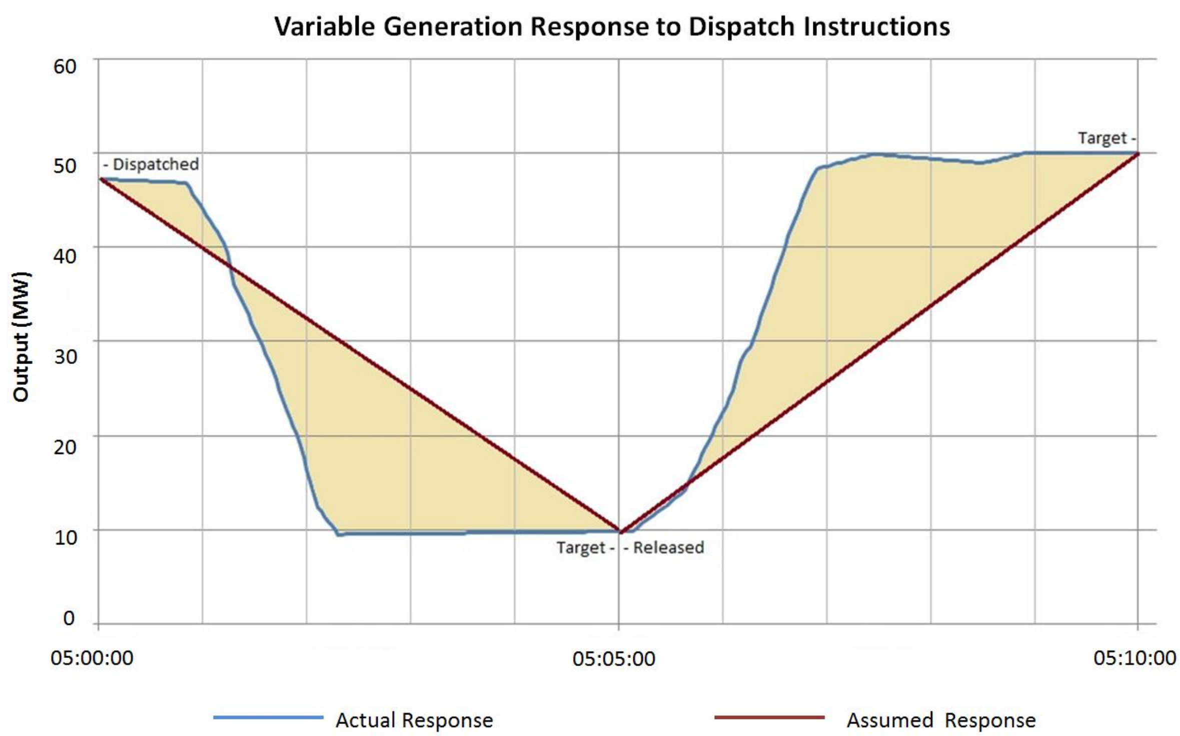
flexibility. The additional flexibility needs to be located in unconstrained parts of the system to ensure they can operate without restriction.

Methods to enhance the flexibility of Ontario resources could include: increased utilization of existing resources, enabling simple cycle operation at combined cycle plants, or adding new peaking generation, grid energy storage or demand response resources. Methods chosen, which are expected to happen through open competitive processes, must ensure that they are cost effective and can meet expected operational duty requirements – given that these resources are required in the near-term to address reliability needs.

Regulation

Chart 2: Regulation Issues





What is it? The first figure is a historical distribution of the difference between actual variable generation output and the forecast used by the IESO's 5 minute-dispatch algorithm, expressed as a percentage of the variable generation fleet capacity.

The second figure shows an example of fast response from a variable generator in response to dispatch instructions[5]. The shaded area represents where regulation resources[6] contracted by the IESO were dispatched to compensate for the fast response of the variable generation resources.

Why do we need to know? The 5-minute variable generation forecast inaccuracies directly affect real-time dispatch decisions. If variable generation output is over-forecast or under-forecast in real-time, there can be a supply-demand imbalance because the IESO's scheduling algorithms would not dispatch the right amount of supply from other resources.

These dispatch inaccuracies are compensated for by resources that the IESO contracts to provide regulation service. If Ontario is under-generated in real-time, a signal will be sent to generators that are providing regulation service to increase their output. Regulation resources are also used to address demand non-linearity between dispatches, compensate for demand forecast errors and for generation/load resources that are not following their dispatch instructions. If the magnitude of the dispatch inaccuracies exceed the amount of regulation resources scheduled, then some of the balance will be made up automatically with energy flowing into, or out of Ontario on the interties, introducing potentially significant deviations from scheduled quantities.

Regulation service is also used to compensate for responses to dispatch signals by the variable generation fleet that are different than our expectations – the IESO's automated dispatch algorithm assumes a linear progression between dispatches.

What is it telling us? The difference between the actual VG output and the variable generation forecast used in the 5-minute dispatch is significant.

The IESO typically schedules +/-100 MW of regulation service each hour[7]. This quantity of regulation service compensated for the variable generation forecast inaccuracies only 53% of the time in 2015; this amount is expected to decrease to 40% of the time by 2020. This shortfall does not account for other operability issues that regulation service also aims to correct.

[5] Variable generators normally generate without restriction and are usually only dispatched for local constraints or SBG. When the condition causing the variable generators to limit their output concludes, they are then released to generate without restriction.
[6] Regulation is also known as Automatic Generation Control (AGC).
[7] The IESO has a market rule requirement to schedule at least +/- 100MW of regulation service each hour.

In addition, the use of regulation service increases when the variable generation fleet responds to dispatch instructions faster than expected. This also reduces the amount available to compensate for other second-by-second supply-demand imbalances.

Operability considerations? Maintaining the current quantity of regulation service scheduled each hour will result in increased reliance on the interties to compensate for real-time supply-demand imbalances.

Recommendations? We recommend improving regulation service, including:

- Increase the amount of regulation scheduled from +/-100MW to +/-150-200 MW in some hours to compensate for VG forecast errors and other dispatch inaccuracies.
- Update the IESO's current methodology for determining the required amount of regulation service scheduled each hour. Ontario's needs for regulation vary during the day – for example, the need for regulation service are typically less during those times of the day when Ontario demand is flat and unchanging.
- Examine the feasibility of accommodating different regulation service characteristics, including those regulation service providers that can:
    - provide only a single direction of regulation, and
    - provide the service with different response times (e.g. "fast" hydroelectric response vs. "very fast" flywheel response).

We also recommend examining the implementation of a ramp rate requirement for variable generators and other fast acting resources, since their very fast response results in increased usage of regulation service.

Grid Voltage Control

Chart 3: Over-Voltages during Low Demand

What is it? Chart 3 highlights areas where over-voltages were observed in IESO simulations of light load conditions in the year 2020.

Why do we need to know? The market rules and reliability standards require that the IESO must maintain voltages within specified levels defined by the transmission asset owner.

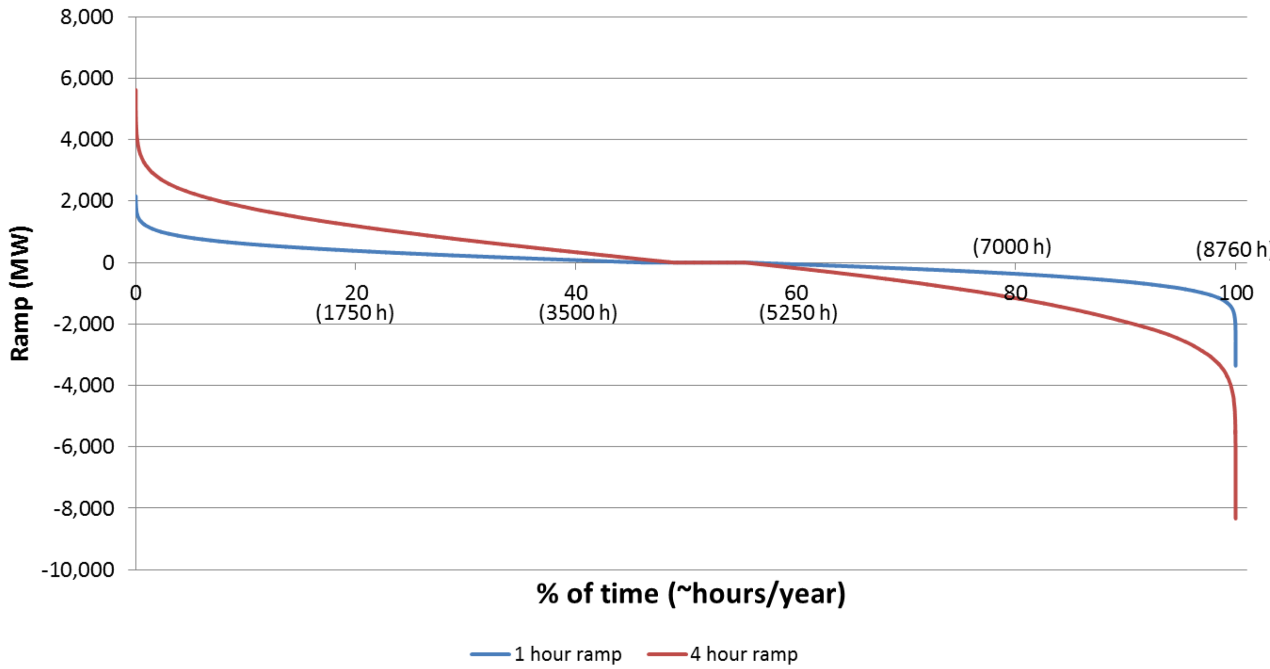
What is it telling us? During low demand scenarios, existing voltage control devices are unable to maintain transmission system voltages within allowable limits in some parts of the system.

Operability considerations? Reductions of demand due to conservation programs and distribution-connected generation has reduced the reliance on centralized generation facilities and the transmission system, at times leaving transmission circuits lightly loaded. This can make it difficult to maintain voltage within acceptable levels (a lightly loaded transmission system leads to high voltages). This is particularly true in areas with existing high voltage control challenges (e.g. downtown Toronto and Eastern Ontario) where exceptional control actions have included removal of lightly loaded transmission circuits from service – sometimes for weeks at a time. There is risk when switching out lightly loaded equipment, as there is no guarantee that the transmission circuits can be brought back online quickly if needed following a power system event, especially if the lines are out-of-service for an extended period of time.

Recommendations? We recommend the installation of additional reactive control devices in downtown Toronto, northwest GTA and Eastern Ontario to manage high voltage situations during low demand periods. Hydro One's evolving (increased) restrictions to manage high voltages will trigger the need for an appropriate mix of static (shunt reactors) and dynamic (static VAR compensators) reactive control devices.

Ramping

Chart 4: 1- and 4-Hour Ramp Duration Curves



What is it? These duration curves show the expected changes over a one-hour and four-hour period ("ramp") in the portion of demand not supplied by baseload generation in 2020.

Why do we need to know? To ensure that the current generation fleet is able to follow changes in Ontario demand during times of large demand increases.

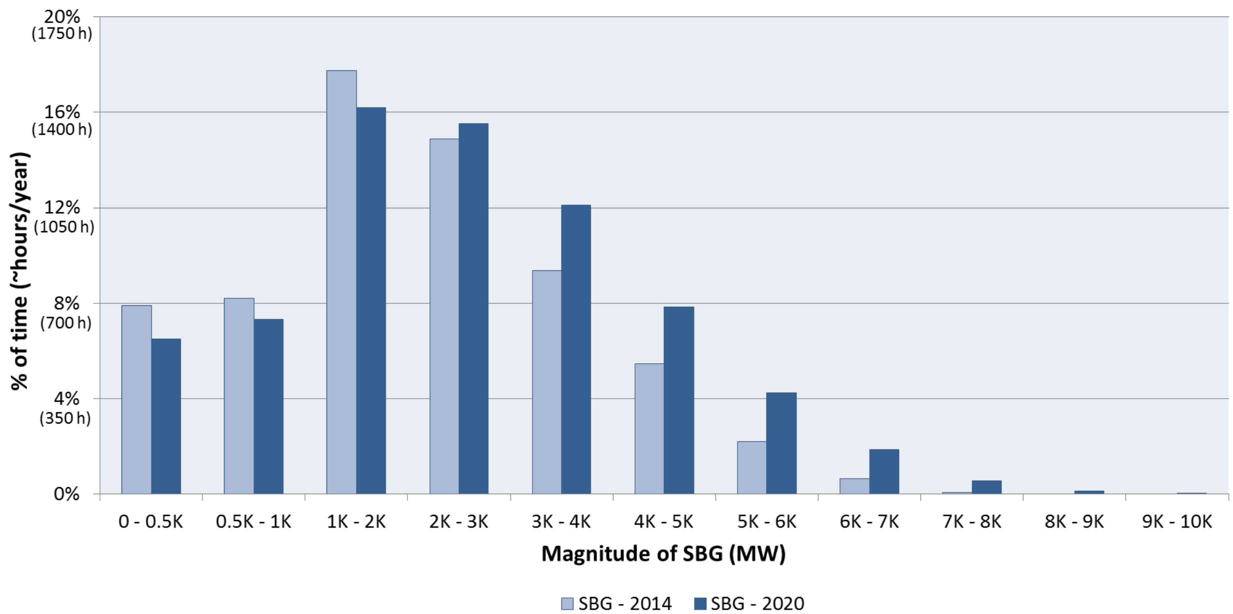
What is it telling us? One-hour ramps in 2020 are expected to be within +/- 1000 MW, 95% of the time. The maximum one-hour ramp-up is expected to be 2,200 MW. Four-hour ramps in 2020 are expected to be within +/- 3000 MW, 95% of the time. The maximum four-hour ramp-up is expected to be 5,600 MW.

Operability considerations? The ramping capability of the gas fleet alone is expected to be sufficient for both timeframes.

Recommendations? None. The ramping capability of the existing generation fleet is expected to be sufficient to meet Ontario needs for ramp during those times of the day when Ontario demand is increasing - provided that the market effectively commits gas generators when needed. Therefore, no ramping enhancements are required.

Surplus Baseload Generation (SBG)

Chart 5: 2014 SBG vs 2020 SBG



What is it? Chart 5 shows the magnitude of surplus baseload generation in the year 2014 in comparison to the results of a simulation for the year 2020.

Why do we need to know? To ensure that our current SBG mitigating measures are sufficient in 2020.

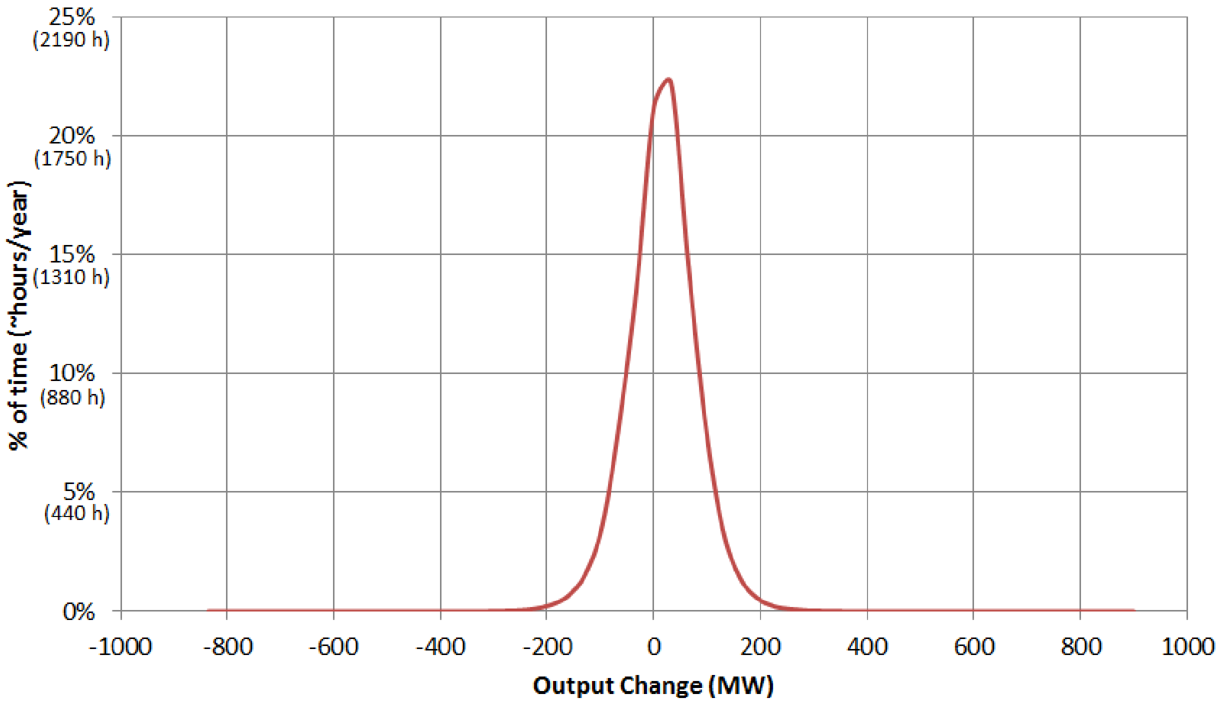
What is it telling us? SBG conditions in 2020 are expected to be comparable in magnitude and frequency to those experienced in 2014. Ontario experienced SBG conditions ~66% of the time in 2014. This is expected to increase to ~72% of the time by 2020.

Operability considerations? The IESO's current SBG mitigating measures are expected to be sufficient to manage SBG in 2020. These mitigating measures include: hydroelectric spill, economic exports, variable generation dispatch and nuclear manoeuvers/shutdowns.

Recommendations? None. We do not anticipate requiring significant changes to our processes to mitigate SBG, as the current measures are expected to be sufficient.

Operating Reserve Requirements

Chart 6: Variable Generation Changes over 10 Minutes



What is it? Chart 6 presents the simulated distribution of the change in output of transmission and distribution-connected variable generation over a 10-minute period for the year 2020.

Why do we need to know? To ensure that the natural changes in variable generation output do not introduce additional operating reserve requirements.

What is it telling us? The curve show that 99% of the time, the output changes will be within +/-160 MW, with the maximum natural drop in generation being approximately 850 MW.

Operability considerations? Even the outlier, a 1 in 10 year event, is not expected to exceed Ontario's first or second contingency losses, which are both at least equal to a Darlington unit.

Recommendations? None. The single largest generation loss in Ontario is not expected to increase due to natural drops in variable generation production over 10 minutes. Therefore, we do not anticipate increasing the amount of 10-minute or 30-minute operating reserve scheduled to manage drops in VG output over those time periods.