Annual Planning Outlook

Operability Module

March 2026

Connecting Today.
Powering Tomorrow.

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1. Introduction

A reliable system is one that is both adequate and operable, with an operable system having the attributes of flexibility, durability and diversity. To assess these attributes as the electricity system transitions, a number of detailed assessments have been conducted to ensure that future resource mixes possess sufficient additional services that are essential to ensuring the reliable operation of the system (i.e., essential reliability services). Today, Ontario's power system consists of resources that provide energy and capacity, as well as the essential reliability services needed to support reliable grid operations and respond to the inherent variability and uncertainty of electricity supply and demand.

Figure 1 | Components of Operability

What are **Essential Reliability Services** (ERSs)?

The North American Electric Reliability Corporation (NERC) Essential Reliability Services Task Force defines ERSs as operational attributes that are necessary to reliably operate the power system. Examples are reactive power to maintain system voltages and physical inertia to maintain system frequency.

ERSs have traditionally been provided by conventional resources such as large nuclear, hydroelectric and fossil-fueled generators. With an evolving resource mix that includes retirements of conventional resources coupled with increasing amounts of variable generation and battery storage, ensuring a sufficient amount of ERSs is critical to maintaining an adequate level of reliability through the energy transition.

The NERC Essential Reliability Services Task Force indicated that the key attributes of a reliable grid can be categorized into **frequency support** and **voltage support**.

This module provides an overview of the essential reliability services that ensure reliable system operations. It also describes the methodologies used in assessing the following essential reliability services included in the 2026 Annual Planning Outlook (APO).

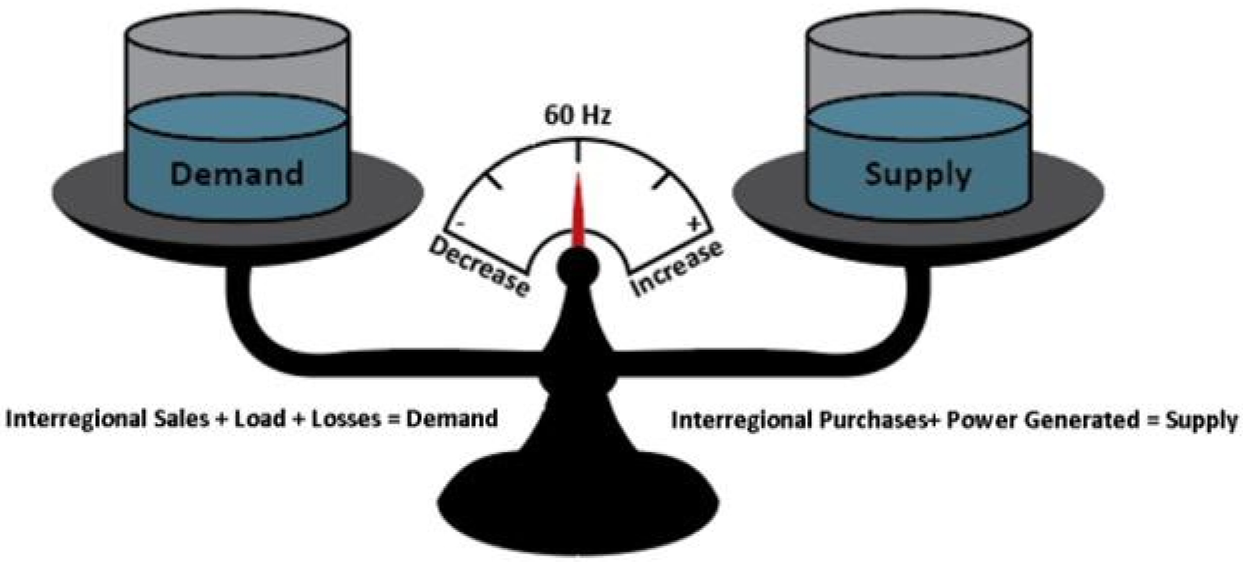
- Primary Frequency Response (“Frequency Response”)
- Regulation
- Operating Reserve (OR)
- Load Following

2. Frequency Support and Balancing

2.1 What is it?

Rotating electrical equipment on the power system operates at a continuously varying rate (i.e., frequency) of 60 cycles per second, or 60 Hertz (Hz). Frequency will be constant on the system when there is a balance between supply and demand. When supply exceeds demand, frequency increases beyond the scheduled value of 60 Hz until energy balance is achieved. Conversely, when there is a temporary supply deficiency, frequency declines until the balance between supply and demand is restored.

Figure 2 | Frequency Balancing



2.2 Why is it important?

The Independent Electricity System Operator (IESO) is required by NERC Reliability Standards to continuously match supply and demand so as to maintain the system in a state of readiness for disturbances that inevitably occur. During normal operations, it is typical for small mismatches between total demand and total supply to occur. Typically, the system is designed to automatically respond to these small mismatches by making continuous adjustments that maintain this delicate balance. However, significant mismatches between supply and demand for a prolonged period put the power system at risk of losing generation and/or load, and potentially causing local or widespread blackouts.

2.3 How are frequency support and balancing achieved today?

In real-time operations demand and supply are constantly changing, with resources providing a range of balancing mechanisms to respond to changes as they occur, effectively maintaining system frequency under all conditions. As shown in Table 1, balancing occurs over a continuum of time on the power system and is achieved with a variety of mechanisms (with some overlap in timeframes of occurrence).

Table 1 | Mechanisms of Achieving Balance

	Inertial Response	**Primary Frequency Response**	**Regulation**	**Operating Reserve**	**Load Following Capability**
What is the response time?	Immediately following a system event	Within the first few seconds following a system event	Within minutes of a mismatch between supply and demand	Within 10 minutes or 30 minutes of a system event	Five minutes to hours
How is balancing currently achieved?	Drawn from the stored kinetic energy of rotating equipment	Automatic adjustment of energy output by generators	Signal from IESO tools to a resource to adjust energy output	Activated by the IESO	Scheduled by the IESO's dispatch scheduling engine

It is important to note that the ability of any resource to provide multiple balancing mechanisms at a given time may be limited by physical or operational characteristics such as a resource's total megawatt (MW) capacity or its ability to vary its output (i.e., ramp rate). Market design features also determine what balancing mechanisms resources can provide at any given time. In the IESO market, resources that provide regulation service cannot concurrently provide operating reserve. Figure 3 illustrates how balancing services may be allocated for different resources.

Figure 3 | Resource Provision of Multiple Balancing Mechanisms

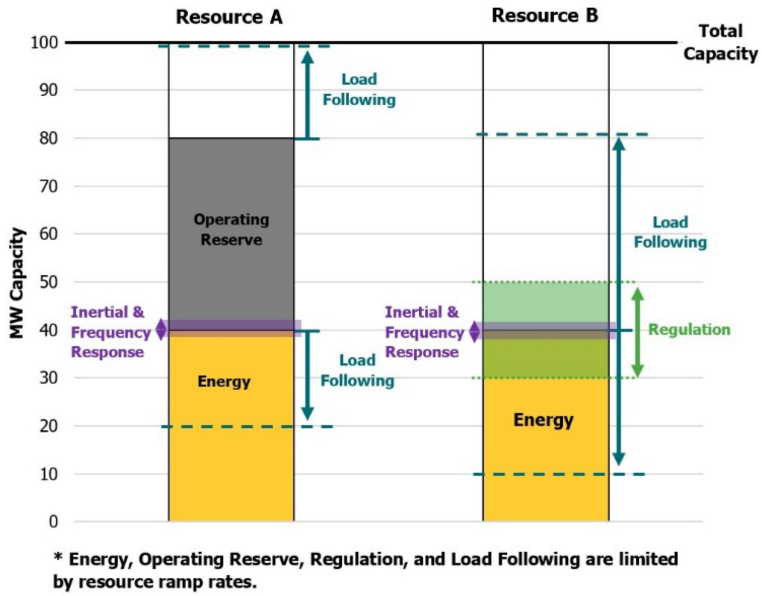


Figure 3 illustrates two dispatchable generation resources, each with 100 megawtts (MW) of capacity available to serve the needs of Ontario's grid. Resource A is providing 40 MW of energy and 40 MW of operating reserve. Resource B is providing 40 MW of energy and ±10 MW of regulation service with bounds indicated in the figure using dotted green lines. Both resources provide inertial response, are frequency responsive, and have the flexibility required to provide load following by increasing or decreasing their energy output, subject to the resource's ramp rate limitations as represented by the dashed teal lines. This figure provides an example of how physical or operational limitations may affect the provision of multiple ERSs from the same resource. An adequate and operable grid must be equipped with an appropriate resource mix capable of meeting energy and capacity requirements while simultaneously providing sufficient ERSs.

3. Inertial and Primary Frequency Response

3.1 What is it?

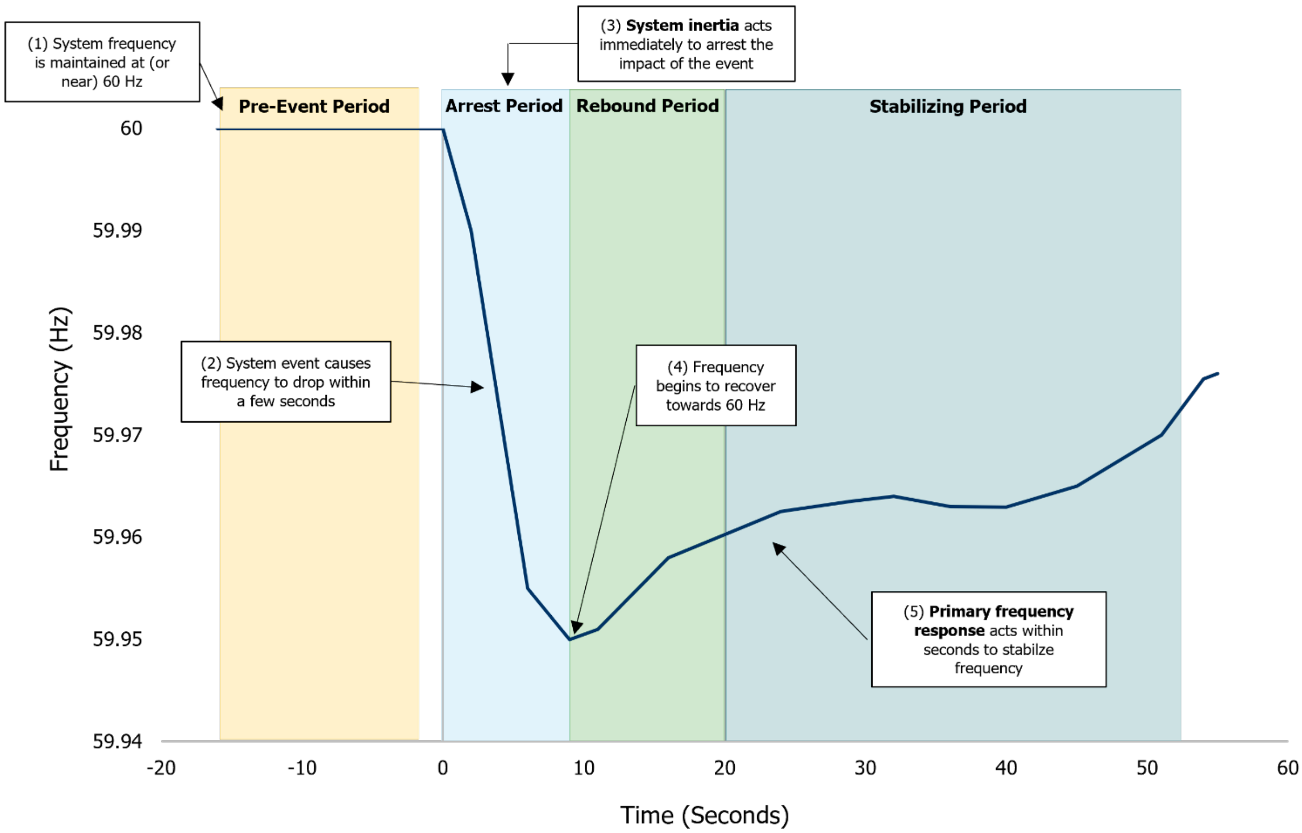
Inertial and primary frequency response are essential reliability services that make up the primary components of frequency support. These services are traditionally provided by resources that are electrically synchronized to the grid – known as synchronous resources – that rotate at the same speed as other resources and quickly respond to conditions that arise on the system. Synchronous resources have large rotating masses that provide inertia to immediately arrest the impact of system events, and governors that sense changes in local system frequency to automatically adjust the energy output of the resource to recover and stabilize system frequency.

3.2 Why is it important?

Frequency support is required to restore system frequency to the scheduled value of 60 Hz after an event such as the sudden loss of a large generator that results in an imbalance between load and generation. Such an event initially causes frequency to drop, as stored kinetic/rotational energy is released in an attempt to arrest the electrical imbalance (inertial response), as shown in Figure 4. Arresting further decline in system frequency requires an immediate response from resources connected to the grid. That response slows the rate at which frequency declines by increasing the power output of generators within seconds to stop the fall and stabilize frequency (primary frequency response).

Together, inertial response and primary frequency response act to maintain the stability and reliability of Ontario's power system and the broader Eastern Interconnection, of which Ontario is a part. These reliability services are essential to preventing power system equipment damage, automatic load shedding and ultimately a widespread blackout.

Figure 4 | Frequency Response



3.3 How are these services provided?

Ontario's large hydroelectric and natural gas fired generators provide both inertial and primary frequency response to maintain balance during system events. Baseload nuclear resources also provide inertia but are unable to provide primary frequency response, as they typically operate at full output power and do not adjust energy output to counteract changes in frequency.

Ontario is also strongly connected with the broader Eastern interconnection[1] through interties with New York and Michigan, which can provide supplementary frequency support to Ontario if needed.

Energy sources such as wind and solar, and storage units such as batteries and flywheels, are known as **inverter-based resources (IBRs).** These resources are connected to the grid through electronic inverters, and either have no rotating masses, or the effects of their rotating masses are isolated from the grid by their inverters. As a result, the IBRs do not naturally contribute to the inertial response of the system; however, the control systems of IBRs are increasingly being outfitted with the capability to simulate this type of response.

[1] The power system of North America is divided into four main frequency-independent islands - the Eastern Interconnection, Western Interconnection, Texas and Quebec.

3.4 What are potential challenges and considerations for the future?

Ontario's future resource mix is anticipated to have an increasing amount of inverter-based resources, a large proportion of nuclear generation, a relatively static hydroelectric fleet, and a reduced reliance on gas-fired generation. This evolving mix is anticipated to have an abundance of system inertia once new and refurbished nuclear resources come online in the mid-2030s and beyond. Ontario's existing hydroelectric fleet will continue to provide both inertia and a significant portion of the system's primary frequency response. Additional frequency response requirements that are currently met by gas-fired generation are expected to shift to new technology types with frequency responsive capabilities that differ from conventional generation.

Fast frequency response is an emerging product that can be provided by multiple generator types and demand response and may replace a portion of traditional frequency support. Inverter-based resources (e.g., battery storage) have demonstrated the ability to provide fast frequency response in other jurisdictions and may be increasingly relied upon to do so in Ontario as conventional generation retires. As technological capability advances, there is potential for frequency support to also be provided by resources such as small modular reactors and natural gas resources retrofitted to use hydrogen as a fuel.

Further technical study will be required to determine the ability of future resource mixes to provide sufficient frequency response during system events, and the minimum amount of synchronous generation capacity that is required on the system to ensure that there is sufficient frequency response as the resource mix is decarbonized.

4. Regulation Service, Operating Reserve and Load Following

Table 2 describes three additional essential reliability services that are required to ensure that balance on the power system is maintained. These are regulation service, operating reserve and load following.

As the resource mix evolves and system needs change as a result of the broader energy transition, ensuring a sufficient amount of regulation service, operating reserve and load following may be challenged. Further considerations that will be required are discussed in this section.

Other resources may be able to satisfy the system's balancing requirements provided they have the demonstrated capability to respond to system needs as described in Table 2. These resources may include storage resources, flexible demand products, and combustion turbines that have been retrofitted to utilize cleaner sources of fuel such as hydrogen. Future operability assessments will consider the contribution of these resources to meeting future needs as technological capability advances and operational experience is gained.

Table 2 | Reliability Services

Requirement	Regulation Service	Operating Reserve	Load Following
What is it?	Balances normal fluctuations in supply and demand, and helps restore frequency after a system event, and following the primary frequency response	Stand-by power or demand reduction that can be called upon in short notice	The ability to follow changes in Ontario demand and variable generation (wind and solar)
When is it needed?	On a minute-to-minute basis	Following a system event (e.g., loss of a large generator)	Many times a day: on a five-minute basis in real-time and to meet demand forecast for future hours
Why is it important?	Regulation compensates for the normal variations between what is forecast (for demand and variable generation output) and what actually materializes, and is necessary to help maintain system frequency at the scheduled value	Operating reserve helps to restore system frequency to the scheduled value, and maintain reliability following an unexpected event that creates a mismatch between supply and demand	Load following is essential to ensuring that online resources are able to respond to increases or decreases in demand within an hour and in future hours (e.g., during evening pick-up or large variable generation ramps)

Requirement	Regulation Service	Operating Reserve	Load Following
How are needs met today?	Mainly by hydroelectric resources that also provide energy to the system	Mainly by hydroelectric and natural gas-fired resources that are scheduled in the IESO's operating reserve markets	Some hydroelectric resources; natural gas-fired resources; and the scheduling of interchange with other jurisdictions

4.1 What are potential challenges and considerations for the future?

4.1.1. Regulation Service

Several demand and supply-side factors have the potential to impact regulation service needs in the coming decade. Overall demand growth will contribute to increased magnitude of forecast errors that will require additional regulation service to compensate. In addition, the expected electrification of industrial load processes, mass transit and the potential growth in large data center loads will result in larger minute-to-minute fluctuations in demand.

On the supply side, the potential addition of variable generation (wind and solar) on the system will result in more and/or higher magnitude variations between the forecast and actual output of these resources in the future. All of these factors are expected put upward pressure on regulation requirements.

4.1.2 Operating Reserve (OR)

Meeting operating reserve requirements today is already a challenge during certain periods of the year, such as the spring or fall seasons when demand is typically lower and very few natural gas-fired resources are online to provide energy and OR. This is further exacerbated when these periods coincide with periods of freshet and the hydroelectric resources are utilized to maximize energy production and are not available to provide OR to help respond to system events.

With the Pickering nuclear generating station shutdown in late 2026 and nuclear refurbishment program expected to continue over the next decade, the IESO expects an increased reliance on gas-fired and hydroelectric generation to meet energy needs. This will result in less available capacity from these resources to meet OR requirements.

With natural gas resources providing a significant amount of Ontario's operating reserve requirements today, the changing resource mix will need resources that can help meet provincial operating reserve requirements at all times of the year and under various system conditions. For example, battery storage resources are anticipated to play a role in providing operating reserve in the future. However, their limited energy capability will mean that once activated to produce energy, they will be available for a finite amount of time after which they will need to be recharged. Replenishing battery charge will impose additional load on the system, which may not be feasible during periods of high demand (such as on peak summer or winter days) or days when output from variable generation resources is low.

4.1.3 Load Following

Load following, also known as ramping, refers to the ability of Ontario's dispatchable resources to follow real-time changes in Ontario demand and variable generation output, collectively referred to as net load[2]. In real-time operations, the IESO utilizes both five-minute and hourly forecasts for Ontario demand and variable generation to generate dispatch instructions and hourly forecast schedules for energy and OR. Ontario's dispatchable resources use these dispatches and forecast schedules to follow changes in net load throughout the day.

Ontario's demand profile is typically characterized by a morning load pick-up, evening load pick-up, and overnight load drop-off. This demand profile varies seasonally with end-user consumption patterns and changes in distribution-connected generation output. As sectors of the economy continue to electrify, a change in today's demand profiles is anticipated. Changes in demand profile are impactful on load following requirements as periods of load pick-up and drop-off change in frequency and/or magnitude. Load following requirements will continue to be assessed based on changing factors such as demand forecast updates or forecasted increases in variable generation installations which result in steeper changes in load pick-up and drop-off.

The variability of wind and solar generation contributes to increased load following requirements. Solar resources generate during day and decrease output at sunset. When this decrease coincides with the evening load pick-up, it increases the net load ramp that must be met by dispatchable generation. Similarly, variable wind output can contribute to additional load following requirements by increasing net load ramps.

Figure 5 illustrates the impact that variable generation output has on net load ramps, which results in higher load following requirements.

With natural gas resources meeting a significant amount of system ramping needs today, a transitioning resource mix may be increasingly challenged to meet daily ramps in demand as they occur in real-time or are anticipated to occur in future hours. This can also be further exacerbated during periods of freshet when hydroelectric resources are unavailable to provide load following capability. Similar to OR, battery storage resources have the potential to contribute to meeting load following needs in a peak-shaving role but will be limited by their storage capacity and the system's ability to recharge them during periods of high demand. The IESO will assess the performance of batteries to meeting load following and operating reserve needs as additional operational experience is gained in the coming years.

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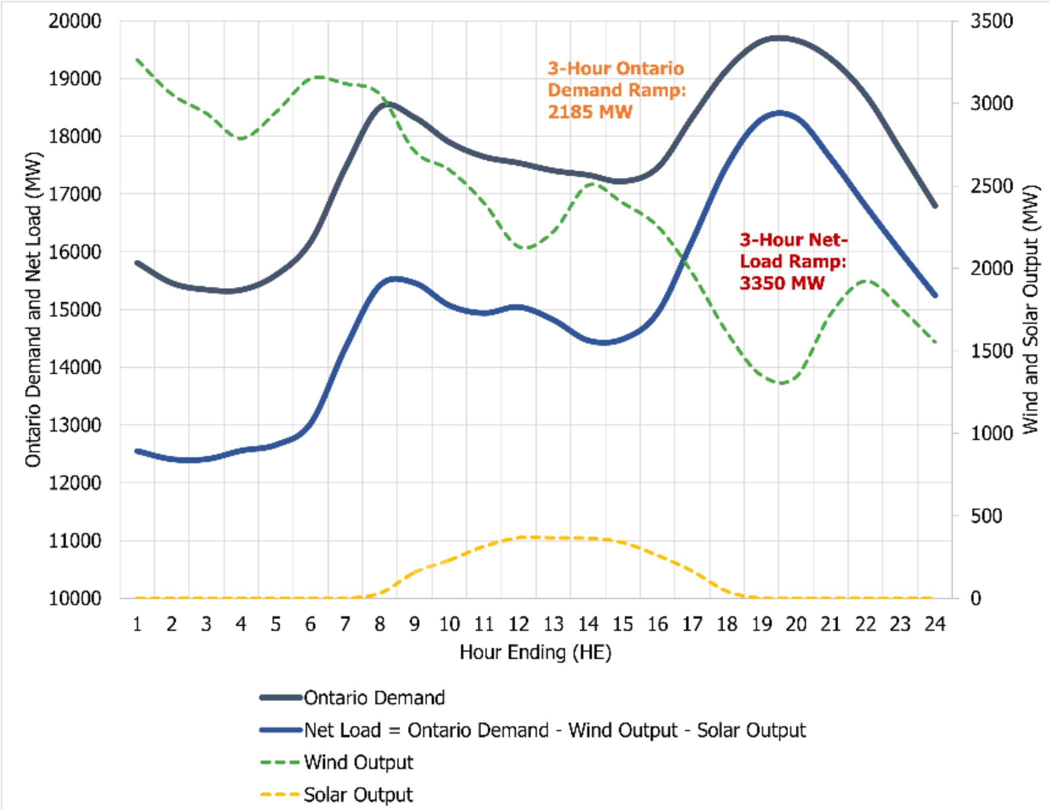
[2] Ontario Net Load = Ontario Demand - Wind Output (grid-connected) - Solar Output (grid-connected)

Figure 5 | Impact of Wind and Solar output on Net Load Ramps



5. Operability Assessment Methodology

This section describes the methodologies used in the operability assessments included in the APO:

- Primary Frequency Response ("Frequency Response")
- Regulation Service
- Operating Reserve (OR)
- Load Following

5.1 Frequency Response Assessment Methodology

The frequency response assessment quantifies the expected frequency response capability installed on the Ontario grid and compares it to the expected minimum frequency response requirement over the forecast period.

5.1.1 Frequency Response Requirement

Frequency response is governed by NERC reliability standard BAL-003 and is measured as the inverse change in power output (MW) relative to the observed change in system frequency (Hz). NERC annually allocates a minimum amount of frequency response that Ontario must provide to the Eastern Interconnection, called the Frequency Response Obligation (FRO).

IESO's FRO has remained relatively static year-over-year and generally falls within -40 MW/0.1Hz and -45 MW/0.1 Hz. This historic FRO range is used to establish the minimum required frequency response over the forecast horizon in this assessment. The IESO will continue to monitor annual NERC FRO allocations and adjust the frequency response requirement accordingly.

5.1.2 Frequency Response Capability

The frequency response capability of Ontario's existing and committed resources is assessed for four categories of resources:

- Baseload Resources – Existing resources expected to provide frequency response capability at all times: consisting of baseload hydroelectric resources and a small number of gas-fired resources. Ontario's existing nuclear resources do not provide frequency response.
- Non-Baseload Resources – Existing resources expected to provide frequency response only when required online to provide energy and operating reserve: consisting of peaking hydroelectric, majority of gas-fired resources, and other thermal resources (e.g., biofuel, oil). Ontario's existing wind and solar resources do not provide frequency response.
- Committed gas-fired resources under Same Technology Upgrades (STU), E-LT1 and LT1 procurements.
- Battery storage resources committed under E-LT1 and LT1 procurement contracts.

Frequency response capability is determined by compiling the historical frequency response performance of existing resources into a historical data set[3], using a set of frequency events identified through the NERC BAL-003 Reliability Standard[4] compliance process. From this set of historical results, a median response value is selected for each existing resource and applied to the Baseload and Non-Baseload Resource categories described above.

For gas-fired resources committed under Same Technology Upgrades (STU), E-LT1, and LT1 procurement cycles, frequency response capability is estimated using results from the historical analysis described above, from other units of the same technology type and scaled to the installed capacity of the committed resources.

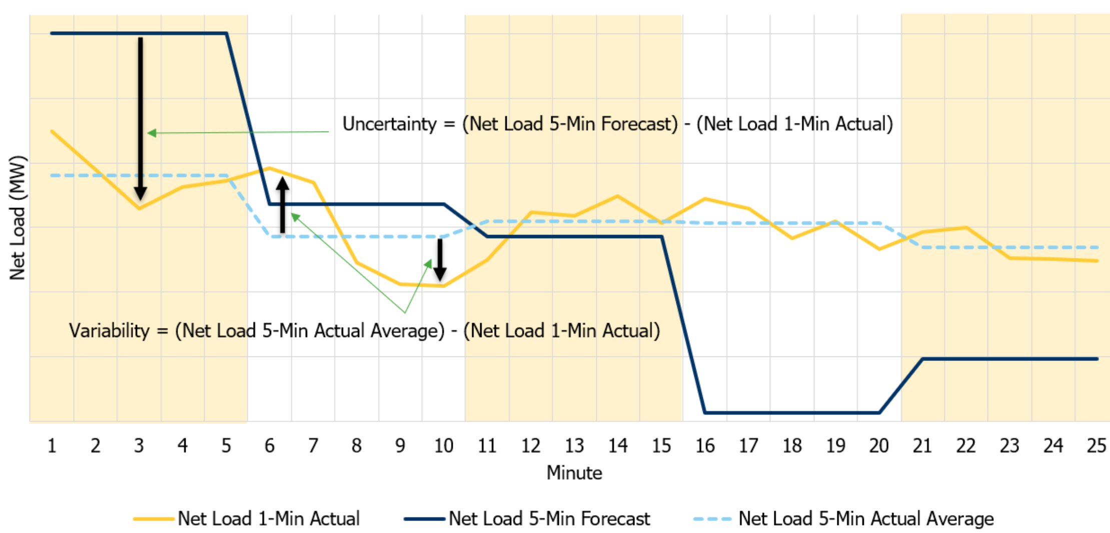
For battery storage resources, a potential frequency response capability is estimated for each committed resource based on grid connection requirements specified in the IESO's Market Rules[5].

5.2 Regulation Needs Assessment Methodology

The regulation needs assessment determines the expected amount of regulation capacity required over the forecast period.[6]

Regulation service is required to mitigate imbalances caused by forecast *uncertainty* and *variability* within IESO's five-minute energy dispatches. Forecast uncertainty is the product of real-time net load deviating from five-minute forecasts of demand and variable generation that are used to determine dispatch instructions. Variability is the product of fluctuations in real-time net load across each five-minute dispatch interval. Figure 6 illustrates the concepts of uncertainty and variability.

Figure 6 | Net Load Uncertainty and Variability



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[3] Data set consists of the most recent five years of historical frequency response performance.
[4] NERC Reliability Standard BAL-003-2
[5] IESO Market Rules Chapter 4: Grid Connection Requirements – Appendix 4.2
[6] System regulation capability is not assessed as regulation service is a contracted ancillary service that is typically procured from existing or future resources.

To determine future regulation service needs, the assessment uses historical forecast and actual data to quantify the magnitude of net load uncertainty and variability. The following values are calculated for every five-minute interval of a historical base year:

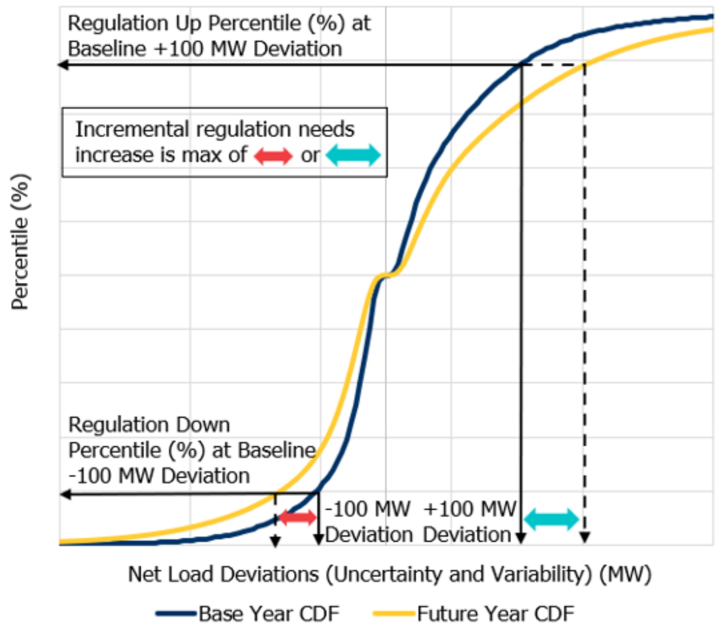
1. Uncertainty: the largest positive and negative deviation of one-minute actual net load relative to its five-minute forecast, and
2. Variability: the largest positive and negative deviation of one-minute actual net load relative to the five-minute average net load.

The resulting data set represents the maximum amount of regulation to maintain system balance for every dispatch interval of the historical base year. The data set is plotted on a cumulative distribution and percentiles corresponding to ±100 MW of regulation[7] are determined (see "Base Year CDF" in Figure 7). This represents the quantity of uncertainty and variability mitigated by ±100 MW of regulation in the base year and establishes a baseline level of regulation required to mitigate uncertainty and variability that maintains compliance with NERC Reliability Standard BAL-001[8].

To determine future year regulation needs, data from the historical base year is adjusted by adding forecast and load profiles for expected fluctuating loads in the future year. An equivalent data set of uncertainty and variability is determined for the future year and plotted on a cumulative distribution (see "Future Year CDF" in Figure 7). The incremental need is determined by finding the points on the Future Year CDF that correspond to the Base Year CDF percentiles associated with ±100 MW of regulation. The greater of the two values is selected as the incremental regulation need.

[7] Chapter 0.5, Section 4.4 of the Market Rules currently specifies a minimum regulation requirement of ±100 MW to meet applicable reliability standards.
[8] NERC BAL-001-2: Real Power Balancing Control Performance

Figure 7 | Cumulative Distribution Functions (CDF): Base Year vs. Future Year Adjusted for Fluctuating Loads



Future regulation needs may change based on updates to the demand forecast, changes to the in-service dates or composition of future industrial loads, transit electrification and expansion, or increased penetration of variable generation resources. Actual operating experience from in-service industrial loads will be incorporated in future regulation assessments. The IESO will continue to assess needs that incorporate these dynamic factors and will adjust future regulation needs accordingly.

5.3 Operating Reserve (OR) Assessment Methodology

The OR assessment quantifies the expected OR capability of Ontario resources over the forecast period.

To determine system OR capability, the assessment considers flexible resources that have historically provided OR, and assesses their 10-minute ramping capability by taking the minimum of the installed capacity, the ramp rate multiplied by 10-minutes, or the difference between the installed capacity and the minimum loading point:

$$OR\ Capability = \min(Installed\ Capacity, Ramp\ Rate\ x\ 10min, (Installed\ Capacity - Minimum\ Loading\ Point))$$

This reflects the flexible resources' capability to provide 10-minute OR[9]. For battery storage resources, OR capability was assumed to be equal to the resources' capacity estimation aligned with the APO's resource adequacy outlook methodology. This is the resource's installed capacity times an assumed round-trip efficiency. The capabilities of resources that exclusively provide 30-minute OR[10] are assessed based on 30-minute ramping capability.

To determine future OR capability, the OR capabilities determined above are applied to the existing and committed resources over the forecast period. Consistent with load following capabilities, annual summer capabilities are reported.

Demand-side resources and economic imports are not included in this OR capability assessment. Future assessments will consider quantifying their OR capability.

Future OR Requirement Considerations

NERC and Northeast Power Coordinating Council (NPCC) reliability standards[11] require the IESO to carry a minimum amount of OR at all times equal to:

- The IESO's largest single contingency for 10-minute OR.
- Half of the IESO's second largest single contingency for 30-minute OR.

The IESO's largest and second largest nominal single contingencies are currently represented by the largest nuclear units in Ontario. This is not expected to change over the 2027 to 2036 assessment period. During temporary outage or grid configuration conditions, the loss of a single element may result in a loss of generation greater than the province's largest nuclear unit. With the significant addition of generation in the coming decade, these temporary conditions are expected to increase in frequency, resulting in temporary increase in OR requirements.

In the long-term, as large-scale nuclear developments reach commercial operation, it is expected that the size of the nuclear units could increase the largest contingencies, which could increase the OR requirements.

5.4 Load Following Assessment Methodology

Load following is required to respond to both increases (ramp-up) and decreases (ramp-down) in net load. This assessment focuses on ramp-up load following needs[12] and quantifies the ramp-up requirement of Ontario net load and the ramp-up capability of Ontario resources over the forecast period.

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[9] 10-minute OR is reserve capacity required to be available within 10 minutes of request.
[10] 30-minute OR is reserve capacity required to be available within 30 minutes of request.
[11] NERC BAL-002-3: Disturbance Control Standard – Contingency Reserve for Recovery from a Balancing Contingency Event; NPCC Directory 5: Reserve
[12] Ontario's ramp-down capability is not expected to be of significant concern over the 10-year outlook period. Future assessments may consider ramp-down load-following as needs emerge.

5.4.1 Ramp-Up Load Following Requirements

The IESO assesses ramp-up requirements as the 99.8th percentile of three-hour net load ramp-up deviations determined over a specified period. These three-hour ramp-up values are calculated from a net load profile on a rolling five-minute basis by taking the difference in net load between one five-minute interval to another five-minute interval three hours later. Ramp-up requirements are assessed on a seasonal basis, however this assessment focusses on the summer period where requirements are the highest.

Net load profiles for future years are derived from a combination of annual production profiles for transmission-connected variable generation and Ontario demand from the most recent operational year, and the APO Long-Term Demand Forecast.

A static allocation is added to the ramp-up requirement to represent capacity that is required to be held back to meet real-time OR requirements. This recognizes the real-time trade off made by flexible and dispatchable resources which contribute to load following capability and are often also eligible to provide OR. The installed resource mix must maintain sufficient load following capability to meet load following requirements while also satisfying OR needs.

5.4.2 Ramp-Up Load Following Capability

The ramp-up load following capability is assessed for the summer season, focusing on dispatchable thermal (e.g., natural gas) resources which provide a large portion of Ontario's current load following capability, as well as existing and committed battery storage resources.

Ramp-up load following capability is defined as the maximum amount of energy a resource can provide over a three-hour period to help meet ramp-up requirements. The IESO assesses this by taking the minimum of the resource's ramp rate multiplied by 180 minutes, the resource's 90th percentile maximum energy offer, or the difference between the 90th percentile maximum energy offer and the minimum loading point of the resource where applicable. The 90th percentile maximum energy offer is used to represent the resources' maximum capability and account for some planned and forced outages. Data for ramp-up load following capability is based on the last five-years of operational data.

$$Ramp\ Up\ Capability = min(\text{90th Percentile Max. Offer}, Ramp\ Rate\ x\ 180min, (90th\ Percentile\ Max. Offer - Minimum\ Loading\ Point))$$

For gas-fired resources committed under Same Technology Upgrades (STU), E-LT1, and LT1 procurement cycles, ramp-up capability was calculated based on the capability of other units at the same facility scaled to the installed capacity of the committed resource.

For battery storage resources, ramp-up capability was assumed to be equal to the resources' capacity estimation aligned with the APO's resource adequacy outlook methodology. This is the resources installed generation capacity times an assumed round-trip efficiency. The contribution of battery storage will be refined as more operational experience is gained.

Flexible hydroelectric resources, known as peaking hydro, also contribute to meeting Ontario's load following requirements. Peaking hydro resources have fast ramp rates but their energy availability is variable due to the seasonal and annual fluctuations in water availability. For this reason, a conservative estimation of hydroelectric load following capability is required. This load following assessment did not include contributions from peaking hydroelectric resources, but future assessments will work to appropriately quantify their load following capabilities.

Demand-side resources and economic imports are not included in this load following assessment. Future assessments will consider quantifying their load following capability.

Load Following Capability Assessment Limitations

The load following capability assessment quantifies the overall installed capability of the Ontario generation fleet to meet expected changes in net load. However, load following adequacy in real-time operations is contingent on this load following capability remaining accessible when net load ramps occur. This assessment methodology does not reflect real-time availability of load following resources. For example, if a load following resource is utilized to supply baseload energy requirements, this would detract from the load following capability that is available when net load begins to rise. Further assessment is required to quantify the impact of flexible resources being utilized to serve baseload energy needs or other factors which impact the availability of load following capability in real-time.

6. Reactive Support and Voltage Control

6.1 What is it?

Reactive support and voltage control service is required to maintain acceptable reactive power and voltage levels on the power system.

6.2 Why is it important?

Acceptable voltage levels are required to move power through the transmission and distribution system from generators to end consumers. Maintaining adequate voltage profiles across the power system is critical to reliably operating the system, both during normal operations and following a system event. Power sags (dips) and prolonged low-voltage events can affect large areas and create more widespread events, while high-voltage events can result in equipment damage and potentially the loss of life.

6.3 How are reactive support and voltage control needs met today?

All generating resources injecting energy into the system are required to provide a certain level of reactive support and voltage control service in accordance with the Market Rules. The IESO also contracts some resources to provide additional amounts of this service in order to meet system needs.

6.4 What are potential challenges and considerations for the future?

Synchronous resources provide the system with a significant amount of reactive power and voltage control today, which may be challenged in the future by a resource mix with a decreased proportion of synchronous resources. Considerations to ensure a system with a sufficient amount of reactive support and voltage control may include:

- Enhancing the capability of conventional power electronic inverter-based resources to exhibit similar characteristics as synchronous resources, and
- Integrating technologies such as synchronous compensators (rotating machines that contribute to reactive power and voltage control but do not produce power) on the power system.

7. Additional Considerations

In addition to the essential reliability services discussed above, other areas of study will be required as the resource mix evolves to ensure reliable operation of the power system.

7.1 Black Start Capability

Black start capability is critical to restoring the power system in a timely manner following a power system blackout. This service is provided through certified black start resources that have the ability to start without drawing power from the grid or other sources of generation. Once started, these resources can in turn support the energization of transmission elements, other generation units and load in a defined area of Ontario.

Today, hydroelectric and natural gas resources provide black start capability in Ontario. In-depth analysis will be required as the resource mix evolves to ensure that the system has sufficient black start capability; this will include a transmission analysis that incorporates the location of black start resources. As technologies advance, other types of resources may also be able to provide this service in the future.

7.2 Ability to Manage Resources

Significant effort will be required to maintain reliability of the power system during the energy transition. Another system attribute and key focus area for the IESO is manageability, which is a critical aspect of reliable operations. Manageability is the attribute that enables the IESO to have visibility of, monitor and direct the operation of the majority of resources across the system.

The 2023 Electric Reliability Organization Reliability Risk Priorities Report indicated that the power system is becoming more complex as a result of the energy transition, with the need to model, analyze and operate the system at higher fidelity. This can increase the risk to reliability posed by human error as training, staffing and workforce issues increase to support grid transformation and decarbonization. To manage this risk, updates will be required to the IESO’s internal models, tools and processes to effectively integrate and operate new resource types and technologies. Changes may also be required to current planning, operating and market approaches to optimize existing resources and enable new resources to support the transition.

7.3 Seasonal and Extreme Event Analysis

Seasonal weather changes and extreme events such as a heat wave or cold snap can impact power system equipment and the performance of resources. For example, extreme heat conditions typically result in higher forced outages on the system, as well as low water conditions that can reduce hydroelectric output and impact the ability of these resources to provide energy and operating reserve. In-depth analysis will be required to ensure that the electricity system is resilient through a variety of conditions, and that the resource mix possesses the characteristics necessary to withstand these conditions. In addition, a changing climate that results in more periods of drought may not only limit the ability of hydroelectric resources to provide operating reserve, but also energy.

7.4 Future Essential Reliability Services Needs

The IESO is taking a proactive approach in assessing the essential reliability services needed to maintain operability. As the future grid evolves, the inherent variability and uncertainty of electricity supply and demand will increase. The IESO will continuously update the assessments with most up to date information and provide appropriate signals to serve the near to long-term essential reliability services needs of Ontario.

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