New York ISO
Independent System Operator

Grid Services from Renewable Generators

A Report by the
New York Independent System Operator

August 2021

Table of Contents

Introduction

A key component of the New York Independent System Operator's (NYISO) mission is reliable operation of the New York electric system.[1] To help fulfill this obligation, the NYISO procures several grid services, often referred to as "ancillary services," which are critical for providing reliable and secure electricity to New Yorkers. The ancillary services that the NYISO procures include Voltage Support Service, Black Start Capability, Operating Reserves and Regulation Service.[2] It is essential to procure these grid services to safeguard against disruptions that threaten reliable operations and could lead to equipment damage or blackouts. Each of the grid services procured from generators in the New York Control Area (NYCA) must satisfy requirements developed by reliability authorities[3] and plays a unique role in sustaining grid reliability.

As the New York generating fleet continues to evolve in response to New York State clean energy goals, it is important to examine the capabilities of renewable resources to provide increasing support to grid reliability. In a future with a much larger renewable share of the generation mix, renewable resources may need to provide grid services that are currently provided by fossil-fueled generators. Developments in modern renewable technologies enable these resources to provide certain grid services.[4,5] Revising market rules to permit renewable technologies to provide more grid services could provide additional market revenues to renewable resources, decrease the cost of renewable integration, and lead to reduced emissions while maintaining reliability.

This report addresses a defined set of renewable technology types and a specific set of grid services. The renewable technologies considered in this study include land-based wind, offshore wind, utility-scale solar photovoltaic (PV), Behind-the-Meter (BTM) solar PV, and Limited Control Run-of-River hydro (LCRoR hydro). This group of technologies is consistent with the current and incoming renewable resource types in the NYCA. Land-based wind, utility-scale solar PV, and LCRoR hydro facilities are currently in-service in the NYCA. The NYISO does not have any offshore wind resources in service at this time. However, the New York Energy Research and Development Authority (NYSERDA) has provisionally

[1] FERC. New York Independent System Operator. 2010. https://www.ferc.gov/sites/default/files/2020-05/nyiso-rto-metrics.pdf. Page 198.

[2] Capitalized terms that are not defined in this report have the meaning assigned to them in the NYISO's Market Administration and Control Area Services Tariff or in the NYISO's Open Access Transmission Tariff.

[3] The authority to administer reliability standards for New York lies with several organizations, including the North American Electric Reliability Corporation (NERC), the Northeast Power Coordinating Council (NPCC), and the New York State Reliability Council (NYSRC).

[4] California ISO, Avangrid Renewables, GE, NREL. Avangrid Renewables Tule Wind Farm: Demonstration of Capability to Provide Essential Grid Services. https://www.caiso.com/Documents/WindPowerPlantTestResults.pdf 11 March 2020.

[5] NREL. *Demonstration of Essential Reliability Services by a 300 MW Solar Photovoltaic Power Plant*. https://www.nrel.gov/docs/fy17osti/67799.pdf. March 2017.

procured 2,490 MW of offshore wind to date and has plans to procure more.[6] The NYISO also does not have any BTM solar aggregations participating in its markets at this time, but there are over 3,000 MW of BTM solar in New York[7], and such facilities will be able to participate in NYISO markets using the DER participation model in the future. The NYISO has roughly 32 MW of utility-scale solar PV. Lastly, this report focuses on LCRoR hydro technology because the capability of larger, more controllable hydro facilities is well known[8] and comparable to that of conventional generator types.

The grid services evaluated in the study include Voltage Support Service, Black Start Capability, Operating Reserves, Regulation Service, Fast Frequency Response, Primary Frequency Response, Inertial Response, and Flexible Ramping. The first four services in this list comprise the ancillary services that the NYISO currently procures. The last four are services that have been discussed and/or procured in other regions. It may become prudent for the NYISO to procure some of these grid services in the future.[9] Descriptions for each of these services are discussed in the body of this report.

Many renewable generators have the controls and equipment necessary to respond to NYISO dispatch signals and provide certain grid services without need for substantial upgrades. This includes advanced Power Plant Control (PPC) systems that enable fast and accurate output response rates, provided the plant has input energy available for conversion to electrical energy. While the equipment and control systems found in renewable generating facilities make the provision of certain wholesale grid services feasible, the ability of specific technology types to provide these services is contingent upon applicable reliability rules. Procurement of services that support grid reliability in New York is subject to standards imposed by the North American Electric Reliability Corporation (NERC), the Northeast Power Coordinating Council (NPCC), as well as the New York State Reliability Council (NYSRC).[10] These standards are rooted in the reliability need for various grid services and the ability of resources to provide a particular service for a duration of time when called upon. The following sections discuss the interplay between the technological

[6] NYSERDA Offshore Wind Solicitations: https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/Focus-Areas/Offshore-Wind-Solicitations.

[7] NYISO Gold Book. "Table I-9a: Solar PV Nameplate Capacity, Behind-the-Meter." https://www.nyiso.com/documents/20142/2226333/2021-Gold-Book-Final-Public.pdf/b08606d7-db88-c04b-b260-ab35c300ed64.

[8] The NYISO regularly relies on large hydroelectric generating facilities to provide grid services that include Regulation Service and Operating Reserves.

[9] NERC report examining potential future grid service needs: https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/ERSTF%20Framework%20Report%20-%20Final.pdf.

[10] NERC standards apply to the entire North American bulk power system. NPCC requirements apply to a region that includes New York and New England. The NYSRC rules only apply to New York. The Relationship between NERC and Regional Reliability Standards, Regional Reliability Criteria, and NYSRC Reliability Rules is explained at: https://www.nysrc.org/pdf/MeetingMaterial/RRSMeetingMaterial/RRSAgenda111/Relationship%20Between%20NERC%20%20NPCC%20and%20NYSRC%20Criteria.pdf.

capabilities of renewable generators and the reliability rules that apply in New York. These two elements play a key role in establishing the grid services renewable generators can provide.

The NYISO's research for this study included discussions with various subject matter experts, including market design and operations staff at other ISO/RTOs, industry groups such as the Electric Power Research Institute (EPRI) and the National Renewable Energy Laboratory (NREL), as well as renewable developers and renewable generator operators in New York. Significant portions of the information in this report are sourced from those conversations. From this research, the NYISO learned that offshore wind resources should be expected to have similar grid service capabilities to land-based wind facilities. Thus, discussion in subsequent sections pertaining to wind facilities applies to both land-based and offshore wind. Similarly, the NYISO learned that adequate control technologies exist to enable both utility-scale solar PV and BTM solar aggregations to respond to NYISO dispatch instructions for grid services. However, the necessary control equipment is not necessarily installed in these facilities and may not be installed in new resources due to economic factors discussed later in this report. Discussion of "solar" capabilities in this report pertains to both utility-scale solar PV and BTM solar aggregations and assumes the advanced controls necessary to provide grid services are in place.

This report is organized by grid service and whether the NYISO procures that service. Each section begins with a description of the selected grid service, as well as relevant reliability rules that impact the eligibility of renewable generators to provide the service. The report then outlines the technological capabilities of the selected renewable resource types to provide each grid service. The study findings demonstrate that the evaluated technologies have similar capabilities to provide each of the grid services discussed, with two exceptions that are explained in the footnotes to Figure 5 in the Summary section of this report. The report concludes with discussion of possible market rule changes that could improve market efficiency, enhance system flexibility, support reliable grid operations, and possibly enable greater participation by renewable generators in New York.

Key Terms

Discussions relating to renewable resources often use certain key terminology interchangeably, which is not always accurate. Three resource categories referred to in this study that have important and distinct meanings are inverter-based, intermittent, and renewable. While each of these terms has a unique meaning, some resource types belong to multiple categories.

Figure 1: Key Term Definitions

Key Term	Definition
Inverter-Based	Inverter-based technologies can include variable-speed wind, solar PV, and battery energy storage, as these resource types frequently utilize an inverter to convert power that the facilities produce into AC power that can be injected into the grid.[11]
Intermittent	An Intermittent Power Resource (IPR), as defined in the NYISO Market Services Tariff, is an energy source that "(1) is renewable; (2) cannot be stored by the producing device; and (3) has variability that is beyond the control of the facility owner or operator. In New York, resources that depend upon wind, solar energy or landfill gas for their fuel have been classified as Intermittent Power Resources."[12] Resources outside of the IPR definition, such as LCRoR hydro, can also have intermittent characteristics. The term "variable" is also commonly used to describe intermittent technologies.
Renewable	A renewable energy resource relies on fuel that is naturally replenished and not finite as compared with fossil fuels. However, the quantity of energy generated from renewable resources is often restricted by inherent limitations in the amount of fuel that can be available per unit of time.[13]

The focus of this study will be on the third resource category: renewable technologies. All the included technologies (land-based wind, offshore wind, utility-scale solar PV, and BTM solar PV, and LCRoR hydro) are renewable and can also be classified (to a greater or lesser degree) as intermittent. Additionally, all studied resource types are inverter-based with the exception of LCRoR hydro, which is a synchronous generator.

Reliability Rules and Grid Services

Grid services safeguard the reliability of the electric system. Disturbances such as unplanned generator outages and transmission line failures can impact key contributors to grid stability such as frequency, voltage, and available operating reserves. Since these elements are critical to maintaining reliable delivery of power to customers, reliability authorities have established rules to which the NYISO and other ISO/RTOs must adhere. These standards include requirements pertaining to the quantity and

[11] Type 1 wind generators are direct-connected induction machines, but they are no longer used in grid scale projects.

[12] NYISO Market Services Tariff. Section 2: Definitions. https://www.nyiso.com/regulatory-viewer.

[13] U.S. Energy Information Administration. "Renewable Energy Explained." Updated May 18, 2021. https://www.eia.gov/energyexplained/renewable-sources/.

nature of services that grid operators must procure. The goals of most reliability standards are to prevent system events from having catastrophic impacts and to permit quick recovery and return to normal operation when an event occurs.

The NYISO complies with a multitude of reliability rules that govern grid service procurement. The regional nature of reliability rules is particularly relevant with regard to this study, as the reliability standards applicable in New York are stricter than those in most other regions of the country and world.[14] Variations in reliability rules influence the types of grid services that certain resource types can be eligible to provide in different areas. Reliability rules may evolve as the generating fleet transitions towards cleaner fuel sources, but the NYISO is not aware of any proposed or pending revisions to reliability rules that would permit renewable resources to provide a broader range of grid services in New York. Discussion of how reliability rules impact the provision of specific grid services is addressed in subsequent sections of this report.

Grid Service Descriptions and Renewable Generator Capabilities

Each of the following sections includes a grid service definition, relevant reliability rules, the mechanism by which the NYISO procures the service where applicable, and the capability of renewable generators to provide the service. The ancillary services that the NYISO procures include Voltage Support Service, Black Start Capability, Operating Reserves, and Regulation Service. Grid services the NYISO does not currently procure include Fast Frequency Response, Primary Frequency Response, Inertial Response and Flexible Ramping. Sections of the report discussing grid services that the NYISO does not procure identify any other regions of the U.S. that procure them, as well as explain why the NYISO does not procure each service today. Potential future changes to NYISO ancillary service procurement are discussed in the "Possible Market Revisions and Items for Future Consideration" section.

[14] The Energy Policy Act of 2005 adopted a new Section 215 of the Federal Power Act authorizing FERC to enforce mandatory reliability standards. Section 215 also contains a special New York savings clause that allows the State of New York to adopt reliability rules that are more specific or more stringent than the standards adopted by NERC and by the NPCC, so long as the rules do not degrade reliability outside of New York. The New York State Reliability Council adopts and enforces rules that are specific to New York State and certain local reliability rules specific to New York City and Long Island.

Typical Renewable Resource Configurations

Below are simplified diagrams illustrating the typical NYCA configurations for each of the resource types considered in this study. Equipment configurations inform how different resource types operate and the ability of different technologies to provide grid services.

Figure 2: Typical NYCA Wind Facility Configuration[15]

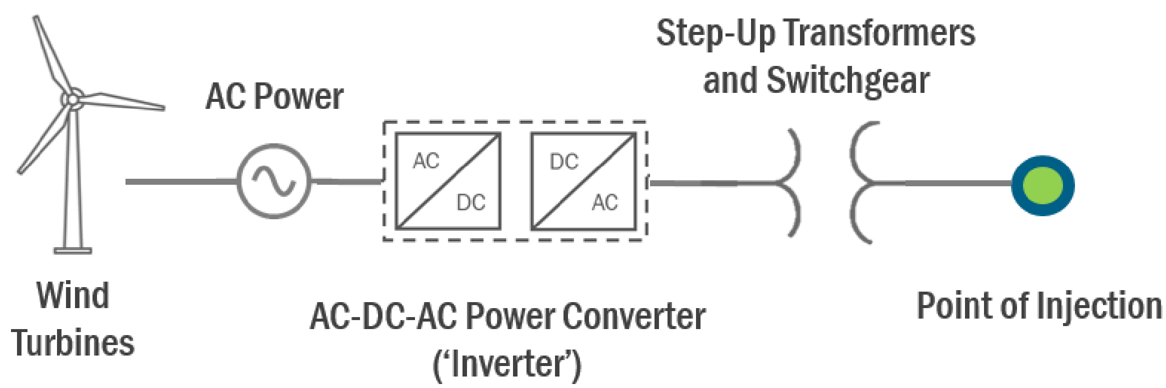
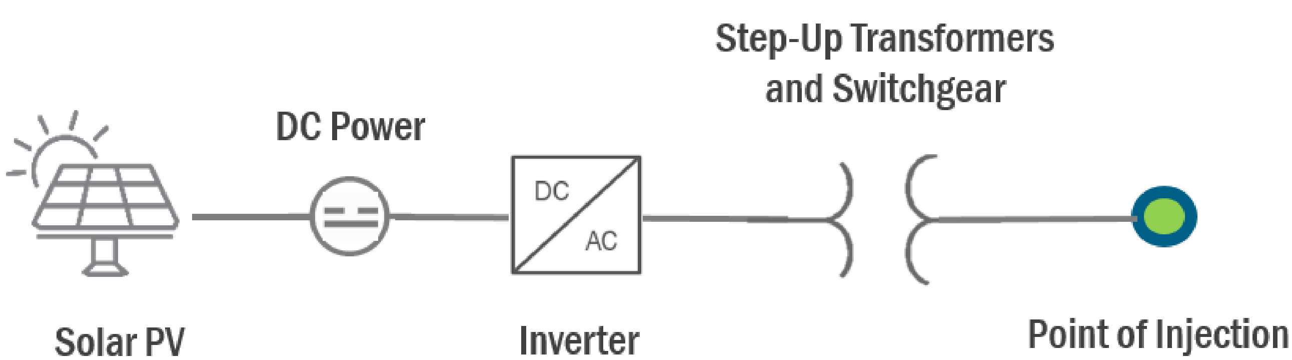
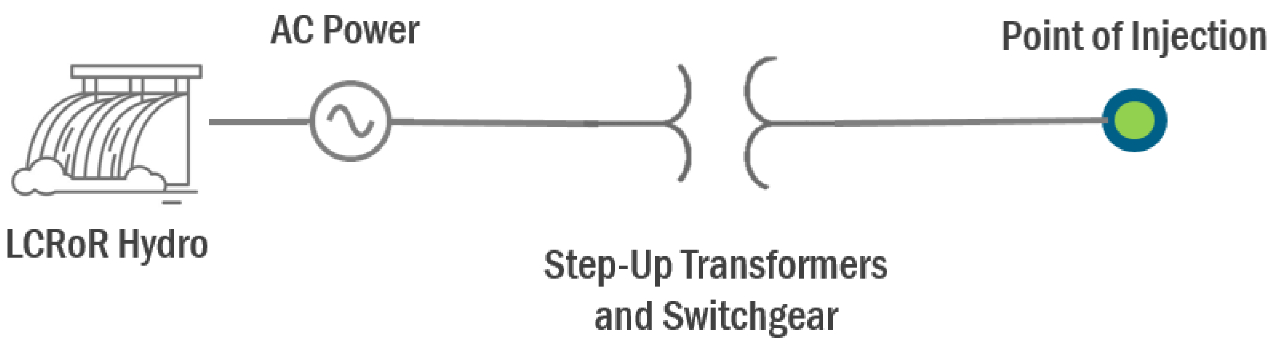


Figure 3: Typical NYCA Solar PV Facility Configuration



[15] Most NYCA wind facilities are Type 3, which have an AC connection directly to the grid and the inverter is connected on the rotor side of the wind turbine.

Figure 4: Typical NYCA Limited Control Run-of-River Facility Configuration



Grid Services that the NYISO Procures

Voltage Support Service

Description

Voltage Support Service (VSS) is the service whereby resources absorb or produce reactive power in response to the needs of the transmission system. Qualifying resources must demonstrate the ability to automatically respond to voltage control signals, including both Lagging and Leading Reactive Power capability. Additional detail regarding the structure and qualifications for the Voltage Support product can be found in the NYISO Ancillary Services Manual.[16]

Relevant Reliability Rule

Procurement of Voltage Support Service is required by NERC standard VAR-001-5, which states that the NYISO must "ensure that voltage levels, reactive flows, and reactive resources are monitored, controlled, and maintained within limits in real-time to protect equipment and the reliable operation of the Interconnection."[17]

NYISO Method of Compensation

The NYISO procures VSS through a "cost of service" framework, which compensates qualifying resources on a monthly basis, based on the capability demonstrated in annual tests.[18]

---

[16] NYISO. Manual 2: Ancillary Services Manual. Section 3: Voltage Support Service (page 5). https://www.nyiso.com/documents/20142/2923301/ancserv.pdf/df83ac75-c616-8c89-c664-99dfea06fe2f.

[17] NERC Reliability Standards: https://www.nerc.com/pa/Stand/Reliability%20Standards/VAR-001-4.1.pdf.

[18] NYISO Market Services Tariff Section 15.2. "Payments for Supplying Voltage Support Service": https://nyisoviewer.etariff.biz/viewerdoclibrary/mastertariffs/9TariffSections/177.htm.

Renewable Generator Capability to Provide Voltage Support Service

Renewable generators are eligible to supply VSS, and several NYCA renewable generators currently participate. Roughly 700 MW (75%) of NYCA LCRoR hydro facilities provide VSS, as do roughly 900 MW (46%) of NYCA wind facilities. Respectively, these resources supply approximately 3% and 2% of the total VSS procured in the NYCA. While the NYISO does not have a large population of solar resources today, the technology exists to enable the provision of VSS by solar facilities.

Black Start Capability

Description

Black Start Capability requires that, following a blackout, providers of this service must be able to self-start, energize the transmission system, and maintain steady operation until other resources can be brought online. These tasks must be accomplished without reliance on the electrical system for startup power. The NYISO selects generating units located in strategic areas for NYS Power System restoration to provide Black Start Capability. Additional detail regarding the Black Start product can be found in the NYISO Ancillary Services Manual.[19]

Relevant Reliability Rule

Procurement of Black Start Capability is required by the NERC mandate *EOP- 005-3*, which states that the NYISO must "ensure plans, facilities, and personnel are prepared to enable system restoration from Black Start Resources to ensure reliability is maintained during restoration and priority is placed on restoring the Interconnection."[20]

NYISO Method of Compensation

Black Start Capability is procured through a "cost of service" mechanism, which compensates providers based on annual tests and the costs associated with preparation for and provision of the service.[21]

Renewable Generator Capability to Provide Black Start Capability

One of the key abilities necessary for providing Black Start Capability is that a facility must be able to self-start, which none of the evaluated renewable technologies can achieve. All evaluated resource types rely on power from the grid in order to begin injecting current to the grid. LCRoR hydro facilities are restricted in their ability to provide Black Start Capability due to limitations in pondage (water kept in

---

[19] NYISO. Manual 2: Ancillary Services Manual. Section 7: Black Start Capability Service (page 94). https://www.nyiso.com/documents/20142/2923301/ancserv.pdf/df83ac75-c616-8c89-c664-99dfea06fe2f.

[20] NERC Reliability Standards: https://www.nerc.com/pa/Stand/Reliability%20Standards/EOP-005-3.pdf.

[21] NYISO Market Services Tariff Section 15.5. "Payments and Charges for Black Start and System Restoration Services": https://nyisoviewer.etariff.biz/ViewerDocLibrary/MasterTariffs/9TariffSections/MST%2015.5%20FID1315%20w1182%20corrected_23982.pdf.

reserve), which inhibits provision of consistent output during system restoration. Additionally, the governors at LCRoR plants are not normally designed to operate in standalone mode to support loads. There is ongoing research and testing regarding the Black Start capabilities of LCRoR hydro facilities, but provision of this service is not currently viable.[22]

A second requirement to provide Black Start Capability is the ability to operate in "grid-forming" mode. Grid-forming mode requires inverters to actively control their output power frequency in order to initiate grid restoration following a blackout. Grid-forming controls are under development for intermittent resources but are not currently commercially available. Most inverters used in solar PV and wind facilities operate in grid-*following* control mode. Grid-following mode entails control systems monitoring terminal voltage and aligning inverter switching to ensure output current remains in synch with the grid. A pre-existing, energized grid is required for resources that operate in grid-following mode since they align their voltage and frequency to match the system with which they are synchronizing. Voltage and frequency control is a critical component of Black Start Capability. Most intermittent resource types have rapid active power frequency control and voltage regulation capability but are only able to synchronize with an energized grid. Furthermore, any resource that is a Black Start provider needs to operate in a manner that allows the protection systems of the facilities with which they connect during restoration to function properly. The resource types evaluated in the study typically cannot provide the currents needed under a fault condition in order for protection systems to operate correctly and protect the transmission system.

An additional criterion precluding intermittent renewable resource types (wind and solar) from providing Black Start Capability is the inability to provide consistent reliable energy and energize the grid following a blackout. Even if a wind or solar facility were to install the capability to start without the use of grid power, the variable nature of their fuel would not allow these resources to be fully relied upon for system restoration. Output intermittency can lead to challenges in achieving stable operation during restoration. This creates difficulty in utilizing intermittent generation during real-time restoration to maintain load/generation balance. Wind and solar resources are subject to the natural intermittency of their fuel, while LCRoR hydro resources experience seasonable variations in fuel, both of which pose a threat to output consistency.

[22] NREL Black Start Report: https://www.nrel.gov/docs/fy20osti/75327.pdf.

While renewable generator technologies have some capabilities that are important for providing Black Start Capability Service, various technological challenges indicate that further developments are needed in order for the renewable resource types included in this study to be able to provide the service.

Operating Reserves

Description

Operating Reserves provides backup generation and/or demand response in the event that the NYISO experiences a real-time power system contingency requiring emergency corrective action. There are three types of Operating Reserve products: 10-minute Spinning Reserve, 10-minute Non-Synchronized Reserve, and 30-minute Reserve. The NYISO procures 10-minute Spinning Reserves, 10-minute total reserves (which may be met by suppliers that are eligible to provide either Spinning Reserve or 10-Minute Non-Synchronized Reserve) and 30-minute Reserves (which may be met by suppliers that are eligible to provide any Operating Reserve product). Resources must demonstrate sufficient ramp rate capability in response to NYISO signals to qualify for a given level of Operating Reserves (e.g., either 10 or 30 minutes). Additional detail regarding the structure and qualifications for the Operating Reserve products can be found in the NYISO Ancillary Services Manual.[23]

Relevant Reliability Rule

NYISO procurement of Operating Reserves is governed by several reliability rules,[24] including NPCC requirement R6 that "a Balancing Authority's synchronized reserve, 10-minute reserve, and 30-minute reserve, if activated, shall be sustainable for at least one hour from the time of activation."[25] Additionally, in accordance with NYSRC Reliability Rule Manual Section E-1, the statewide Operating Reserves requirement must equal one and one half times the single largest contingency, which is currently 1,310 MW. The NYISO currently procures total Operating Reserves in a quantity equal to twice the single largest contingency in order to further support reliability, which amounts to a total of 2,620 MW. This Operating Reserve requirement must be scheduled in every dispatch interval. The NYISO also has requirements that a minimum amount of reserves must be procured in downstate areas that are more transmission-constrained in order to support transmission security requirements.

In addition to the above reliability criteria, NYSRC rules further dictate that the NYISO must procure "sufficient 10-minute operating reserve to replace the operating capacity loss caused by the most severe

---

23 NYISO. Manual 2: Ancillary Services Manual. Section 6: Operating Reserve Service (page 41). https://www.nyiso.com/documents/20142/2923301/ancserv.pdf/df83ac75-c616-8c89-c664-99dfea06fe2f.

24 NERC BAL-002 is an important reliability rule governing Operating Reserves: https://www.nerc.com/files/BAL-002-0.pdf.

25 NPCC. *Regional Reliability Reference Directory #5.* R6. Page 7. https://www.npcc.org/content/docs/public/program-areas/standards-and-criteria/regional-criteria/directories/directory-5-reserve-20200426.pdf.

contingency observed under Normal Transfer Criteria" and be able to restore 10-minute reserves within 30 minutes following a contingency.[26] The NYISO satisfies these reliability rules through procurement of its Operating Reserves products.

NYISO Method of Compensation

Operating Reserves are procured via a market-based structure. NYISO co-optimizes its procurement of energy, Regulation Service and Operating Reserves in day-ahead and real-time markets. Operating Reserve providers are compensated when scheduled by the optimization software, with clearing prices resulting from the marginal cost of providing the reserve. This can be based on unit offers, opportunity costs with procuring energy or Regulation Service, or a demand curve when NYISO is unable to procure sufficient Operating Reserves to meet requirements.

Renewable Generator Capability to Provide Operating Reserves

The uncertainty inherent in the ability of the evaluated renewable generator types to increase or sustain output largely conflicts with the NPCC requirement that reserve providers must be able to maintain output for one hour if activated. This limitation is particularly relevant to resources that rely upon wind and solar as their fuel source. These resource types are not eligible to provide Operating Reserves to the NYCA. LCRoR hydro resources are capable of qualifying to provide Operating Reserves, as this technology can divert water from its turbines, leaving headroom to increase output if necessary. LCRoR hydro is also more controllable than wind and solar resources, as LCRoR hydro generally observes daily or seasonal variability, rather than minute-to-minute variability. Additionally, water as fuel is more predictable than other intermittent fuel types, such as wind and solar.

Regulation Service

Description

Regulation Service is necessary for the continuous balancing of supply (generation and NYCA interchange) with load. This service assists in maintaining the scheduled Interconnection frequency at 60 Hz and helps minimize the Area Control Error (ACE) in accordance with reliability standards. Regulation "Capacity" reflects the amount of capability that a resource is scheduled to be available to provide for Regulation Service, whereas Regulation "Movement" is defined in the NYISO Market Services Tariff as "The absolute value of the change in Energy or Demand Reduction over a six second interval, measured in MW, that a Regulation Service provider is instructed to deliver for the purpose of providing Regulation Service."

---

[26] NYSRC Reliability Rule Manual. Section E-1. Requirement R2. https://www.nysrc.org/pdf/Reliability%20Rules%20Manuals/RRC%20Manual%20V43%20Final%5B4070%5D.pdf.

The NYISO procures only Regulation Capacity in the Day-Ahead Market. It procures both Regulation Capacity and Regulation Movement in the Real-Time Market. The amount of Regulation Capacity that the NYISO is required to procure is established annually, and the quantities vary by month and hour.[27] Regulation Movement signals are issued to resources on a 6-second basis through the Automatic Generation Control (AGC) system. Regulation Service provider performance is assessed using a 30-second or less response time criteria measuring from the time that the NYISO issues a dispatch signal through AGC. Much of the performance lag is driven by the necessary data processing time.[28] Further detail regarding the structure and qualifications for the NYISO's Regulation Service product can be found in the NYISO Ancillary Services Manual.[29]

Relevant Reliability Rule

The NYISO procures Regulation Service in accordance with NERC standard BAL-001-2, which requires that each ISO/RTO must "control Interconnection frequency within defined limits" such that "the Control Performance Standard 1 (CPS1), is greater than or equal to 100% for the applicable Interconnection in which it operates for each preceding 12 consecutive calendar month period." Additionally, "Each Balancing Authority shall operate such that its clock-minute average of Reporting ACE does not exceed its clock-minute Balancing Authority ACE Limit (BAAL) for more than 30 consecutive clock-minutes."[30] These performance-based rules function to ensure that system frequency stays within acceptable limits to safeguard generating equipment, which guides the needed requirements for Regulation Service to support grid reliability.

NYISO Method of Compensation

The NYISO procures Regulation Service through a market-based structure, with prices for both Regulation Capacity and Regulation Movement. NYISO co-optimizes its procurement of energy, Regulation Service and Operating Reserves. Qualifying resources are compensated when scheduled by the NYISO's optimization software, with prices resulting from the marginal cost of providing Regulation Service. This can be based on unit offers, tradeoffs with procuring energy or Operating Reserves, or a demand curve when NYISO is unable to procure sufficient Regulation Service to meet requirements.

---

[27] NYISO Regulation Requirements: https://www.nyiso.com/documents/20142/3694424/nyiso_regulation_req.pdf/6efc0df8-edc2-41bc-9e39-5fed576ba7bc.

[28] NYISO Accounting and Billing Manual. Section G.7. "Positive Control Error for Suppliers that are Providing Regulation Service." https://www.nyiso.com/documents/20142/2923231/acctbillmnl.pdf/.

[29] NYISO. Manual 2: Ancillary Services Manual. Section 4: Regulation and Frequency Response Service (page 20). https://www.nyiso.com/documents/20142/2923301/ancserv.pdf/df83ac75-c616-8c89-c664-99dfea06fe2f.

[30] NERC reliability standards: https://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-001-2.pdf.

Renewable Generator Capability to Provide Regulation Service

All renewable generator types included in this study have the ability to respond to 6-second AGC signals from the NYISO to increase or decrease output, provided fuel is available. This capability to respond to AGC is required of Regulation Service providers. Provision of this service may require reconfiguration of resource SCADA systems in order to be able to process data effectively, but this is within the capability of the studied renewable technologies without equipment upgrades.

However, NYISO market rules do not currently contemplate regulation market participation by wind and solar resources. Furthermore, the evaluated renewable technologies may experience challenges in satisfying the NYISO performance tests to qualify to provide Regulation Service, since this test requires responding to signals to increase and decrease output across several specific hours, including the morning ramp and evening load decline. The Regulation Service qualification test specifies that a unit must:

> "bid Regulation Service such that it gets scheduled within a calendar week, for 24-hours, including at least two 4-hour periods, one that spans the morning pick up from hour beginning 5:00 through hour beginning 8:00 and the other that spans the evening load drop-off from hour beginning 19:00 through hour beginning 22:00. The participant must bid into the Day-Ahead or Real-Time Market the maximum Regulation Service capability that wish to qualify. This value must be the lesser of the Regulation Capacity response rate * 5-minutes or the Operating Capacity of the unit… A time weighted Performance Index greater than or equal to .85 must be demonstrated over the calendar week period in order to pass the prequalification test."[31]

This performance requirement may be difficult for resources that rely on intermittent fuel to satisfy, since the ability to increase output is not guaranteed. In addition, providing Regulation Service would likely require wind or solar resources to elect not to produce energy that they are capable of producing. Some LCRoR hydro resources have qualified to provide Regulation Service by withholding a certain amount of output in order to satisfy the required performance tests.[32]

[31] NYISO. Manual 2: Ancillary Services Manual. Section 4.11: Regulation Service Qualification and Performance Criteria (page 37). https://www.nyiso.com/documents/20142/2923301/ancserv.pdf/df83ac75-c616-8c89-c664-99dfea06fe2f.

[32] Unlike wind or solar generators, LCRoR hydro generators can "pond" and later produce MWh that are temporarily withheld to provide Regulation Service, so the cost impacts to the two types of resources are different.

Grid Services that the NYISO Does Not Procure

Fast Frequency Response and Primary Frequency Response

Description

Fast Frequency Response (FFR) and Primary Frequency Response (PFR) are rapid-response services that stabilize system frequency. PFR is traditionally provided by generator turbine governors, which automatically respond to deviations in local frequency without need for direction from the system operator. Fast frequency Response has many similarities to PFR, with the main difference being that with FFR, delays and full response time are not limited by thermal or hydraulic processes but rather achieved through digital controls. FFR and PFR are distinct from Regulation Service both in response speed and function, as both PFR and FFR occur autonomously and in a matter of seconds following a frequency change, whereas Regulation Service signals are centrally dispatched by the ISO, and providers often require closer to 30 seconds to respond.

The NYISO does not procure FFR or PFR. The NYISO is required to meet PFR requirements through NERC's BAL-003-1, also called its frequency response obligation. NYISO meets this requirement without procuring PFR or FFR.[33] It is possible that system needs may shift as the resource mix evolves in coming years, and it may become prudent to solicit a rapid frequency response service from NYCA resources. However, current grid conditions in New York enable sufficient frequency response characteristics. The NYISO receives frequency support benefits from belonging to the Eastern Interconnection.[34] This connection, which includes much of the eastern portion of the continent, prevents significant frequency deviations from 60 Hz that may be driven by events such as unit trips. The breadth and resources of the Eastern Interconnection provide the NYCA (and other balancing areas within the Eastern Interconnection) strong capability to avoid dramatic frequency changes following system disturbances, as compared to smaller interconnections.

Procurement in Other Regions of the US

The Electric Reliability Council of Texas (ERCOT) recently implemented a FFR product as a subset of the ERCOT Responsive Reserve Service.[35] The aim of this product is to minimize frequency deviation that might result in a system disturbance, in accordance with NERC standard BAL-001-TRE-1 and BAL-003-1.

---

33 NYISO proforma Large Generator Interconnection Agreement: NYISO OATT 30.14 Appendix 4, Section 9.5.5: https://www.nyiso.com/regulatory-viewer.

34 The Eastern Interconnection extends from Central Canada east the Atlantic coast (excluding Québec), south to Florida and west to the foot of the Rockies (excluding most of Texas). Additional information about interconnections in North America can be found at: https://www.energy.gov/oe/services/electricity-policy-coordination-and-implementation/transmission-planning/recovery-act-0.

35 ERCOT FFR Product: http://www.ercot.com/services/comm/mkt_notices/archives/4423.

The former reliability requirement is solely applicable to frequency controls in the ERCOT region, which is not part of either the Eastern or Western Interconnection.[36] The pursuit of this product may have been largely driven by ERCOT's susceptibility to emergency conditions caused by frequency deviations, which occur, in significant part, because ERCOT is an electrically islanded system with a substantial quantity of intermittent renewable resources.[37] Energy storage and load resources are the likely resource types to qualify and provide FFR due to their rapid response capabilities. So far, roughly 120 MW of energy storage resources have qualified to provide FFR in ERCOT. However, since being implemented, FFR service has not yet been provided during real-time operations. There is a project in progress to make it easier for resources to offer FFR, and there are on-going discussions to address some reasons that are limiting FFR awards in the ERCOT Day-Ahead Market.[38]

The NYISO has not identified any other regions that procure PFR, since spinning generators provide this grid service naturally without a need for additional equipment preparation or scheduling. This circumstance may explain why PFR is not actively procured today.

Renewable Generator Capability to Provide Fast Frequency Response and Primary Frequency Response

Renewable generators generally have the capability to respond very quickly to deviations in frequency. Inverter-based resources in particular have the ability to program their equipment to respond rapidly to frequency changes, which makes them capable of providing FFR. LCRoR hydro can provide PFR in the traditional sense, as it is a spinning resource that has resistance to changes in frequency. Inverter-based renewable resources can be programmed to provide a response that mimics PFR, but this requires backing down their output.

Inertial Response

Description

Inertia is a critical element that supports the stability of the electric grid. Inertia can be characterized as a measure of a generator's resistance to changes in its rotational speed. Similar to PFR, inertial response is an automatic response from synchronously interconnected fossil, nuclear and hydroelectric generators following a system disturbance. Resistance to change in frequency is provided naturally by these synchronous generators, since they have rotating mass with some resistance to changes in rotational

[36] NERC ERCOT-specific requirements: https://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-001-TRE-1.pdf.

[37] ERCOT is "islanded" because it does not have synchronous interties with neighboring electrical systems. ERCOT does have several HVDC connections with neighboring electrical systems.

[38] Ongoing ERCOT initiative to revise FFR rules: http://www.ercot.com/content/wcm/key_documents_lists/191259/BESTF_Update_On_NPRR_863_Phase_2_Scope_FFR.PPTX.

speed. This characteristic offers stabilizing support to the grid because these resources are naturally resistant to frequency disruptions that might occur due to transmission line trips, failures of other generators, or disconnection of loads. Unlike PFR or FFR, synchronous inertial response occurs simultaneously with loss of supply or loss of load. It slows the initial rate-of-change-of-frequency until FFR and PFR are able to respond and stabilize system frequency. In concert with PFR and FFR, inertial response supports system frequency and aims to avoid the tripping of under-frequency load-shedding relays and improves system strength during disturbances. In the future, it is possible that inertial response adequacy could become a concern as higher levels of renewable resources are incorporated into the generating fleet and traditional inertial generators retire.

Procurement in Other Regions of the US

No regions in the US procure inertial response, but some areas have processes to monitor inertia, including the NYISO, ERCOT, PJM, and SPP. ERCOT has a minimum inertia threshold of 100 GW-seconds, and it may redispatch when inertia drops below that level.[39] The NYISO monitors inertia in its planning studies, which have not identified any related reliability needs to date.[40]

Renewable Generator Capability to Provide Inertial Response

While inverter-based resources generally do not provide inertia in the traditional sense, wind turbines in particular have kinetic energy "in the rotating mass of the blades, shaft, and generator that can be extracted to rapidly inject real power into the grid." Wind facilities and other inverter-based resources can be programmed to provide "synthetic inertia," which is increasingly recognized in the industry as synonymous with FFR as response times from providers are growing more rapid. Both inertial response and FFR instruct control equipment to modify output when certain thresholds are crossed with respect to frequency deviations or other system disruptions.[41] Further research and development is needed to determine whether the type of inertial response that inverter-based resources can produce is capable of supporting the needs of the transmission grid. In contrast, since LCRoR hydro resources have spinning turbines, they are capable of contributing to system inertia in the same manner as larger hydroelectric generators.

---

[39] ERCOT inertia threshold: http://www.ercot.com/content/wcm/key_documents_lists/141324/Inertia_Basic_Concepts_Impacts_On_ERCOT_v0.pdf.

[40] NYISO Reliability Planning reports can be found at https://www.nyiso.com/. Navigate to: Library > Reports > Planning Reports > Reliability Planning Process.

[41] Denholm, Paul, Yinong Sun, and Trieu Mai. 2019. *An Introduction to Grid Services: Concepts, Technical Requirements, and Provision from Wind*, CO: National Renewable Energy Laboratory. Page 29. NREL/TP-6A20-72758. https://www.nrel.gov/docs/fy19osti/72578.pdf.

Flexible Ramping

Description

In other regions of the US that have substantial amounts of intermittent resources, there is considerable uncertainty driven by both the output variability from front-of-the-meter intermittent generators, as well as from behind-the-meter intermittent generation, which materializes as load variability.[42] Flexible Ramping product[43], which can be defined as any additional reserve product to ensure ramp capability is made available, has been introduced as a new grid service in some regions. The main objective of a Flexible Ramping product is generally for the optimization software to make available additional upward and downward flexible ramping capability in order to address uncertainties driven by load changes, intermittent output changes, and/or forecasting errors. Most commonly, the Flexible Ramping product aims to cover a range of possible outcomes in net system supply and demand from one 5-minute interval to the next. Some regions procure flexible ramp capability in the day-ahead timeframe as well.

Procurement in Other Regions of the US

System uncertainty caused by integration of intermittent resources has driven certain regions to develop market products for Flexible Ramping. These regions include the California Independent System Operator (CAISO) [44], the Midcontinent Independent System Operator (MISO) [45], and the Southwest Power Pool (SPP). [46] A primary motivation for implementing this product has been to reserve ramping capability for ramp needs throughout the time horizon of the real-time market. The product also aims to avoid price spikes resulting from unit ramp constraints, better incorporate unit opportunity costs into binding intervals, and reduce regulation and reserve shortages. The optimization schedules ramp capability based on a certain confidence level of net load ramp needs occurring 5 to 20 minutes beyond the real-time optimization horizon. Upward and downward ramp capability are typically procured separately.

The NYISO relies on Operating Reserves to provide adequate insurance against system disruptions that might threaten the NYISO's ability to meet load. However, the NYISO will consider the potential need

---

[42] Xu, Lin and Tretheway, Donald. CAISO Flexible Ramping Products Straw Proposal. June 2, 2014. https://www.caiso.com/Documents/StrawProposal_FlexibleRampingProduct.pdf. Page 6.

[43] Also referred to as ramp capability, uncertainty product, or load-following reserve.

[44] CAISO flexible ramping product description: http://www.caiso.com/informed/Pages/StakeholderProcesses/CompletedClosedStakeholderInitiatives/FlexibleRampingProduct.aspx.

[45] MISO flexible ramping product description: https://cdn.misoenergy.org/Ramp%20Capability%20for%20Load%20Following%20in%20MISO%20Markets%20White%20Paper271169.pdf.

[46] SPP flexible ramping product description: https://www.spp.org/documents/29342/ramp%20product%20design.pdf.

for a Flexible Ramping product to balance intermittent resources as part of its continued review of the *Grid in Transition* Report.

Renewable Generator Capability to Provide Flexible Ramping

Any resource that can respond to a dispatch signal within a specified time frame is technologically capable of providing a Flexible Ramping product, which includes renewable generators. The level of output forecast certainty may impact the eligible participation level from renewable resources.

Possible Market Revisions and Items for Future Consideration

The findings of in this report have informed the NYISO's perspective on potential next steps and possible market revisions that could improve efficient and reliable operations while enabling renewable generators to provide a broader range of grid services. The following sections of the report outline a possible revision to the NYISO's Regulation Service market, which is the principal market change that this study has identified as potentially beneficial. This section also addresses when NYISO will consider procuring other grid services that it does not procure today.

Bifurcation of the Regulation Market

The NYISO's current regulation market design is a single, symmetric product, which requires providers to be able to both increase and decrease output at the direction of the NYISO. This study has provided insights into the concept of separating Regulation Service into distinct upward and downward products. This market change would have several potential benefits and presents possible drawbacks.

Increased Accessibility for Renewable Resources

An opportunity to expand access to the provision of ancillary services from renewable generators exists in the creation of separate regulation up and regulation down products. This market change could enable greater participation by renewable generators since these resources can more easily reduce output than increase output, which facilitates the provision of Regulation "down" service more readily than the current bi-directional regulation product. The evaluated renewable technologies have a greater ability to regulate in the downward direction than in the upward direction because they can modify inverter signals to reduce output, similarly to how they respond to curtailment signals from the NYISO for economic or reliability purposes today. Regulating only in the "down" direction also avoids concerns that additional energy might not be available to permit an intermittent resource to increase its output when instructed. In the case of wind facilities, control systems can instruct individual turbines to feather their blades to reduce output or shut turbines down completely if necessary. Solar PV resources can effectuate regulation "down" response through gating mechanisms such that less DC current would be allowed to flow through the inverter to the AC side of the system. LCRoR hydro can divert water from its turbines in order to regulate down. Additionally, regulating in the upward direction would require pre-curtailment of energy output in order to be scheduled.

Economic Factors that Influence Renewable Participation in Ancillary Service Markets

While bifurcation of the regulation market would enable greater participation by renewable generators from a technological perspective, factors other than market structure may have a more significant impact on the level of renewable participation in regulation markets. A disincentive exists for renewable generators to reduce output to provide Regulation Service (or other grid services that require output reduction), since many renewable resources receive government incentives such as Production Tax Credits (PTC)[47] and Renewable Energy Credits (REC)[48]. Both of these incentives are linked to the amount of energy that a renewable resource generates. If a renewable facility were to provide a non-energy service to the grid that required output curtailment, such as Regulation Service, it would forego producing some energy and forfeit the associated government-issued financial incentive. These incentives produce two results that would likely lead to renewable generators being scheduled for Regulation Service infrequently if they participated today: 1) low-priced energy offers, and 2) above-market regulation bids.

For example, a qualifying renewable resource might receive a PTC of $20/MWh, plus the LBMP at its location for each MWh of energy it produces. Therefore, it would need to recover at least the same amount to make providing Regulation Service economic. In 2019 and 2020, Regulation Capacity prices averaged $7/MWh and exceeded $20/MWh in less than 5% of intervals. Historic Regulation Service prices provide some indication that a renewable resource reflecting the opportunity cost of not providing energy in its regulation offer would rarely receive a regulation schedule. In addition, the optimization generally seeks to maximize energy output from renewable resources since their energy offers are very economic. Thus, the optimization would likely rarely schedule renewable generators for Regulation Service, and renewable resources may lack adequate incentive to become Regulation Service suppliers.

Observation of other ISO/RTOs supports the notion that renewable generators may lack adequate financial incentives to install advanced controls and participate in regulation markets. Observations in

47 The PTC compensates qualified renewable facilities per kWh produced: https://www.epa.gov/lmop/renewable-electricity-production-tax-credit-information.

48 "RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource." : https://www.epa.gov/greenpower/renewable-energy-certificates-recs.

CAISO, ERCOT, and SPP, all of which have separate regulation "up" and "down" products, reveal minimal trends in renewable participation, which is likely driven, at least in part, by insufficient economic incentive.

Additionally, certain facilities receive the federal Investment Tax Credit (ITC),[49] which incentivizes quantity of installed MW rather than energy output. The ITC, PTC, and REC incentive structures do not encourage or require facilities to install advanced controls capable of responding to very granular dispatch signals necessary for grid services such as Regulation Service.

Additional Potential Benefits of Bifurcating the NYISO's Regulation Market

Currently, Regulation Service providers are required to be able to move both up and down at the instruction of the NYISO in order to balance the system. In addition to potential impacts on renewable participation, separation of Regulation Service into "up" and "down" products would lead to a variety of impacts on markets, grid operations, and consumers. The transformation of the current regulation product into two products would potentially expand participation from renewable generators, but it would also have implications for other resource types that currently provide Regulation Service. Current Regulation Service providers sometimes encounter limitations in scheduling capability due to an inability to regulate up or down. For example, generators that are scheduled at either their minimum generation ("mingen") or Upper Operating Limit (UOL) are not eligible to provide the current symmetric Regulation Service because they are not able to move in both directions. The change to a two-product design would enable resources that are scheduled at mingen to regulate up, while resources scheduled at UOL would become eligible to regulate down.

The bifurcation of Regulation Service into distinct up and down products would also offer the NYISO and its stakeholders an opportunity to perform a holistic examination of the regulation market structure and make improvements that could increase flexibility and improve reliable grid operations. For example, enhancements could be made to enable the optimization to recognize transmission constraints when scheduling Regulation Service providers in real-time, thereby enhancing the deliverability of Regulation Service to the grid. Additionally, this effort could include reassessing the Regulation Capacity and Movement structure to determine if there might be opportunities for increased market efficiency.[50]

---

[49] The ITC compensates qualifying renewable facilities on a per-kW basis: https://programs.dsireusa.org/system/program/detail/658.

[50] 2020 State of the Market Report Section F, page A-163: https://www.nyiso.com/documents/20142/2223763/NYISO-2020-SOM-Report-final-5-18-2021.pdf/c540fdc7-c45b-f93b-f165-12530be925c7?t=1621341531140.

Potential Cost Impacts of Bifurcating the Regulation Market

Bifurcation of the Regulation Service market would be expected to reduce consumer costs, as it would expand the pool of eligible suppliers. This increase in supply may include some renewable generators, but it is likely that the majority will consist of generators that were previously precluded from providing Regulation Service due to the constraint of either being scheduled at mingen or UOL. The NYISO has conducted a consumer impact analysis for this project[51], which highlights some estimates of consumer cost impacts that might result from bifurcating the Regulation Service market. Costs to consumers would be expected to decline overall as a result of this market change, since the shift in supply would likely drive a reduction in high-priced intervals, including shortage price intervals, and reduce price impacts from tradeoffs with producing energy. The current Regulation Service market is small in relation to the energy market, on the order of $15-$20M annual cost compared to annual energy market costs that have ranged from roughly $4B to $7B in recent years. Thus, while this effort would be expected to reduce consumer costs, the benefits are expected to be minimal in the context of total NYISO market costs.

The possibility of bifurcating the regulation market requires significant analysis to determine whether the benefits would outweigh the costs of implementation. Not only would this change require substantial software revisions, but it would also likely have impacts on optimization efficiency. Discussions with other ISOs and RTOs that procure distinct Regulation "up" and Regulation "down" products indicated that procurement of separate regulation products has led to software run-time increases due to the added complexity of the solution. Potential revisions to the NYISO's Regulation Service product are also discussed in the 2019 Reliability and Market Considerations for a *Grid in Transition* Report.[52]

Potential Procurement of Additional Grid Services

Over the course of the research for this report, the NYISO examined several of the grid services that it does not procure today, some of which are procured by other ISO/RTOs. The NYISO believes that the ancillary services it currently procures fulfill the reliability needs of its current system. It is possible that with the transition of the generating fleet to a greater concentration of intermittent sources, new or revised grid services might be needed or add value. The NYISO will continue to evaluate the need for changes to ancillary services as part of its Grid in Transition effort. The NYISO will also explore potential

[51] Grid Services from Renewable Generators Consumer Impact Analysis: https://www.nyiso.com/documents/20142/23671057/CIA%20-%20Grid%20Services%20from%20Renewable%20Generators.pdf/942d0519-634e-12a3-38d2-553f2af02b00.

[52] The *Reliability and Market Considerations for a Grid in Transition* Report can be found at: https://www.nyiso.com/documents/20142/2224547/Reliability-and-Market-Considerations-for-a-Grid-in-Transition-20191220%20Final.pdf/61a69b2e-0ca3-f18c-cc39-88a793469d50.

changes to developing new ancillary service products if relevant projects are prioritized by NYISO stakeholders.

Summary

The table below summarizes the grid services evaluated in this report and the capabilities of renewable resources to provide them. The capabilities of the evaluated renewable technologies were found to be similar, with two exceptions noted below the table.

Figure 5: Summary of Grid Service Procurement and Capabilities from Renewable Generators

	NYISO Procures	Renewable Generators Eligible to Provide under NYISO Rules	Renewable Generator Technology Capable of Providing
Voltage Support Service	✓	✓	✓
Black Start Capability	✓		
Operating Reserves	✓	*	
Regulation Service	✓	✓**	✓**
Fast Frequency Response			✓
Primary Frequency Response			✓
Inertial Response			✓
Flexible Ramping			✓

* With the exception of LCRoR hydro, the renewable technologies considered in this study are not eligible to provide Operating Reserves due to conflict with an NPCC rule, as discussed further in the "Operating Reserves" section.

** Among the technologies evaluated in this study, only LCRoR hydro is eligible to provide Regulation Service, as discussed in the "Regulation Service" section.

Conclusion

The NYISO has found that renewable generators have the technological capability to provide a variety of grid services. While the NYISO does not procure all of these services today, such as Fast Frequency Response, Primary Frequency Response, Inertial Response and Flexible Ramping, it is possible that the NYCA's ancillary service needs will change in the coming years.

Among the services that the NYISO currently procures, which consist of Voltage Support Service, Black Start Capability, Operating Reserves, and Regulation Service, both reliability rules and technological limitations play a role where renewable generators are precluded from participating. Renewable generators are eligible under current NYISO market rules to provide Voltage Support Service, which has some observed participation today. Black Start Capability has some technological requirements that renewable generators are not currently equipped to satisfy, but improvements to renewable generators that might permit them to provide Black Start Capability are in development. With respect to Operating Reserves, an NPCC requirement restricts participation from wind and solar generators due to the uncertain duration of energy output. LCRoR hydro facilities can qualify to provide Operating Reserves.

The NYISO recognizes that bifurcating the Regulation Service market into separate products for the upward and downward directions would expand the ability of renewable generators to participate. While this potential market change may enhance the ability of renewable and other generators to provide Regulation Service, it is important to consider other relevant costs and incentives in determining whether bifurcating this market is likely to provide significant benefits. Economic incentives that renewable resources receive when they produce energy (including the ITC, PTC, and RECs) will likely deter renewable generators from providing a regulation "down" product that would often require reduction in energy output.

Grid Services from Renewable Generators was included as a project that its stakeholders could prioritize for market design in 2022, and it would have further developed the concept to bifurcate the Regulation Service market into "up" and "down" products. The project did not receive significant stakeholder support, but it may be offered for consideration in next year's Project Prioritization process if there is stakeholder interest.

A variety of factors, including intermittent resource penetration, will impact the evolution of grid service needs in the coming years. The integration of renewable resources in other regions has introduced additional complexities to maintaining grid reliability, which has led to the implementation of products such as Flexible Ramping and Fast Frequency Response. Despite renewable capability and eligibility to provide certain grid services in other ISO/RTO areas, participation from renewable generators in services that require curtailment of energy is low to zero in all examined regions. It will be informative to continue observing market, resource, and any reliability rule changes both in New York and across the country as the NYISO continues to assess potential changes to its ancillary service products.