Appendix B: Reliability Gap Analysis

NYISO Reliability Gap Assessment

Scott Harvey and NYISO Staff [36]

This white paper identifies a number of areas of potential future reliability gaps assuming a high level of intermittent resources operating in New York Independent System Operator (NYISO) and outlines recommendations to address these gaps.

The potential areas of future reliability gaps assuming a high level of Intermittent and/or limited energy supply resources are expected to include:

1. Maintain Ability to Balance Load and Generation
2. Maintain Ten-Minute Operating Reserves
3. Maintain Total Thirty-Minute Operating Reserves
4. Maintain Ability to Meet Daily Energy Requirements
5. Maintain Reliable Transmission Operations
6. Maintain Black start Capability
7. Maintain Voltage Support Capability
8. Maintain Frequency Response Capability
9. Maintain Resource Adequacy
10. Ability to Manage Supply Resource Outage Schedules

1. Maintain Ability to Balance Load and Generation

Potential Reliability Gap # 1: The NYISO may be challenged to meet NERC control performance requirements balancing high levels of intermittent generation with system demand that may be difficult to forecast in real-time operations.

NYISO Plan for Gap # 1: The NYISO will continue to track applicable NERC Balancing Area Control Performance Standards and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Increasing statewide regulation procurement requirements
b. Investigate benefits of separate regulation "up" and "down" service
c. Increasing statewide ten and/or thirty-minute operating reserve requirements
d. Investigating the need for ramping requirements in NYISO markets
e. Improving the NYISO's Real-Time Energy Market Dispatch
f. Accounting for increased real-time load forecast uncertainty

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g. Promoting more frequent interchange scheduling with neighboring regions

Background:

The following sections focus on forecasting and scheduling issues that will also impact the ability of the NYISO to balance load and generation with a resource mix that includes much more intermittent resource output than today.

It is generally recognized today that meeting New York load with high levels of intermittent resource output, particularly solar and wind generation, will require the NYISO to have sufficient flexible, dispatchable and potentially fast ramping supply to balance variations in intermittent resource output. These variations will include not only short-term variations in output during the operating day as a result of changes in wind speed and cloud cover but also a sustained ramp up of solar output at the beginning of the day as the sun rises and a sustained ramp down of solar output at the end of the day as the sun sets.

This potential reliability gap concerns the ability of the NYISO to balance load and generation within the time frame of the real-time dispatch and regulation markets with a resource and output mix that includes much more intermittent resource output than today. NERC tends to view this issue as simply a matter of the availability of resources able to provide load balancing. The challenges the California ISO has encountered in balancing load and generation show that the issues the NYISO will need to address as its resource mix changes will be more complex than this, involving not only the amount of flexible generation available to balance load and generation but also the ability of the balancing software, particularly RTD, to recognize the need to balance load and generation in the appropriate time frame and potentially changes in the way regulation instructions are determined by AGC.[37]

The availability of sufficient ramp capability to balance variations in intermittent resource output will need to be addressed in five time frames. These are the time frame of the regulation balancing instruction, the time frame of the real-time dispatch, the time frame of the intra-day unit commitment decisions, the time frame of the day-ahead market, and the time frame in which investments in resources able to provide balancing will be made. The NYISO's current processes have both strengths and limitations in each of these times frames. Some of these limitations can likely be addressed with minor refinements of existing reliability processes and tools, but addressing others may require more fundamental changes in the current processes and tools.

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37 The challenges the California ISO has encountered in balancing load and generation as the level of intermittent resource output has risen over the past few years are discussed in a wide variety of documents. We think the following provide helpful context for understanding the challenges the New York ISO will need to address California ISO, Market Performance and Planning Forum, December 7, 2016 pp. 17-23; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55, California ISO, Final Flexible Capacity Needs Assessment for 2019, May 21, 2018; and discussion in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 22-37.

If the NYISO develops methods that will allow it to effectively dispatch resources to balance net load this will address the concerns NERC focused on with whether there will be enough resources on line to balance these variations in net load. A key complication that comes up in the context of this issue, and under several additional topics below, is the likely low level of energy prices during times when intermittent resource output is high, which will make it very expensive to keep thermal generation on line generating power at their minimum load output to provide upward ramp capability. Similarly, low or negative energy prices would also make it very expensive to rely on thermal or hydro resources to provide down regulation (because the resources would need to be scheduled at an output above minimum load in order to be able to regulate down). These expected future market conditions will tend to make it desirable to shift to separate up and down regulation products, at least during the hours of high intermittent resource output. In addition, potential future changes to market rules to allow solar and wind to provide down regulation may help reduce the cost of regulation while meeting the reliability needs to balance generation and load.

a. Increasing NYISO Regulation Procurement Requirements

Regulation (e.g. the capability of generation to respond to six second dispatch instructions through Automatic Generation Control (AGC)) plays a secondary role in balancing load and generation for the NYISO today. One of the challenges facing the NYISO as its resource mix evolves is whether regulation can continue to play this secondary role, with most of the variations in net load balanced by the real-time energy dispatch, or if the NYISO will need to make fundamental changes in its design reflecting a greater reliance on regulation.

As the level of intermittent resource output has increased, the California ISO has encountered increasing difficulty in balancing variations in intermittent resource output with its real-time dispatch. This difficulty in using the California ISO's economic dispatch to balance variations in intermittent resource output has been due in part to net load forecast latency which is discussed below. When variations in intermittent resource output cannot be balanced in the economic dispatch, this has resulted in an increased reliance on regulation to balance generation and load, potentially requiring that greater amounts of regulating capability be scheduled.[38]

The NYISO will need to be prepared to address similar challenges in balancing load and generation within the five minute time frame of the dispatch interval as the level of intermittent generation in New York rises. One option for addressing net load balance variations could be through a substantial increase in

38 See California ISO, Market Performance and Planning Forum, December 7, 2016 pp. 17-23; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55.

the amount of regulation capability that would be scheduled and available for real-time operations. Such an approach would need to address a number of complicating factors. Not only would substantial regulating capacity be needed to balance net load if RTD is unable to consistently carry out this function, but the inability to rely on the dispatch of generation to restore regulation would mean that the regulating resources would need to have sufficient energy and dispatch range to meet sustained net load imbalances. In addition, the commitment of thermal resources to provide additional regulation capability would increase the amount of emitting generation operating at minimum load.

Moreover, the reliance on much larger amounts of regulation capability to balance load and generation would greatly diminish the value of real-time time prices in incenting performance and raise issues with the current design of the regulation balancing function. If an increased level of generation, storage and/or regulating load were used to provide regulation capability, then the NYISO would need to evaluate whether changes would be needed in the deployment of regulation to take account of congestion impacts, to minimize the cost of meeting load, and to maintain sufficient regulation capability (i.e.to avoid drawing down energy or capacity limited regulation resources) above what is currently done by AGC today.

Low energy prices during periods when intermittent resource output is on the margin will also make it more expensive to provide regulation from thermal resources. These cost changes could be addressed with a shift to separate up and down regulation products, so that thermal resources would not have to be dispatched up above minimum load in order to provide regulation down, which could instead be provided by intermittent resources that could reduce output, and a shift to non-generation resources for regulation, either batteries or controllable demand.

It is possible that as the reliance on regulation to balance net load and generation increases in the Northeast region, the NYISO, Ontario Independent Electricity System Operator (Ontario IESO) and ISO–NE could make greater use of the existing framework for taking account Area Control Error (ACE) diversity within the region, (ACE Diversity Interchange)[39]. The potential gains from taking account of ACE diversity will be limited by the extent of transmission constraints within and between the ISOs, which appears to be the current impediment to use of the existing program. The current challenges entailed in taking advantage of ACE diversity within the region while managing transmission constraints could however become even greater with larger differences between actual and forecasted net load that need to be balanced with regulation.

b. Increasing statewide ten-minute spin and/or thirty operating reserve requirements

39 See NPCC, Regional Reliability Reference Directory # 5 Reserve, Section 5.11 ACE Diversity Interchange, October 11, 2012.

The key time frame for balancing variations in intermittent resource output is the real-time dispatch. It will be important to have enough resources on line or able to come on line quickly both the balance unpredictable variations in intermittent resource output and to balance large mostly predictable changes in intermittent resource output, such as the morning and evening solar ramp.

The MISO and California ISO moved forward in 2016 with implementation of ramp capability dispatch designs in an effort to maintain their ability to balance load and generation with rising levels of intermittent resource output. As is discussed below, these designs are still works in progress in both the California ISO and MISO. While there are lessons to be learned from the MISO and California ISO implementations, there is not yet a clear design in operation that the NYISO should emulate.

On the other hand, the first step towards a ramp capability product in the MISO was an increase in the spinning reserve requirement above the NERC minimum, followed by the introduction on May 1, 2012 of a lower shortage price for the dispatch of capacity scheduled to provide spinning reserves.[40] The recently proposed PJM ORDC would similarly increase the reserves cleared in the market in the hope that this would make more dispatch capacity and ramp capability available to balance real-time variations in intermittent resource output. Like the changes in the MISO spinning reserve target, PJM does not propose that the target quantities be set taking into account the potential for variations in net load during those specific system conditions nor take account of locational transmission constraints that might impact the dispatch of the generation providing the additional reserves.[41]

In a similar manner, the NYISO could utilize an increased ten-minute spinning operating reserve requirements that would be simultaneously optimized in real-time with much lower penalty prices than those currently applied to spinning reserves to provide for additional dispatch capability and that increased total ten and thirty-minute operating reserve requirements will allow for that on-dispatch capability to be maintained throughout the day. The exact proportion of increases in ten-minute spin, ten-minute total, and thirty-minute operating reserves would need to be studied so that the most effective and efficient use is made of available supply resources to meet real-time load.

c. Investigating the Need for NYISO Ramping Requirements

The MISO and California ISO have developed the ramp capability dispatch concept for use as a tool to help balance both predictable and unpredictable variations in intermittent resource output.[42] These

40 See MISO March 1, 2012 filing in FERC Docket ER12-1185, the discussion in Potomac Economics, 2012 State of the Market Report for MISO Electricity Markets, June 2013 p. 31 and 2015 State of the Market Report for MISO Electricity markets, Analytical Appendix, p. A-56.

41 See PJM March 29, 2019 filing in FERC Docket ER19-1486

42 The real-time dispatch of the California ISO, like the New York ISO, is based on a multi-interval optimization design that looks out an hour. This also helps the California ISO balance predictable variations in net load.

designs in effect commit and dispatch resources in real-time so as to make additional spinning reserves available for use in future intervals to balance variations in intermittent resource output.

These designs differ from a simple increase in the spinning reserve requirements in five important respects.

1. The capacity providing ramp capability is dispatched for energy at a much lower shadow price than the shortage price typically used for spinning reserves.
2. The ideal amount of additional ramp capability depends on the magnitude of the potential variations in intermittent resource output, given system conditions at that time of day, rather than on the size of potential generation or transmission contingencies typically used to establish spinning reserve requirements.
3. The locational requirements for these reserves need to reflect the constraint patterns impacting the balancing of intermittent resource output rather than those associated with a large generation or transmission contingency.
4. The energy market cost of resources providing ramp capability would ideally be taken into account in scheduling additional ramp capability, as resources scheduled to provide ramp capability would be dispatched for energy much more often than spinning reserves will be activated following contingencies.
5. The ramp capability designs not only attempt to provide additional ramp capability to balance large decreases in intermittent resource output, they also attempt to provide downward ramp capability to accommodate large increases in intermittent resource output at lower cost, and with fewer curtailments.

Each of these elements is discussed further below.

Shortage price

The current NYISO shortage price for spinning reserves is $775. If this shortage price were applied to an increased spinning reserve requirement, the ramp capability used to meet the increased spinning reserve requirement would not be available to balance load and generation unless energy prices exceeded $775. With a ramp dispatch design, the goal is to maintain additional ramp capability when its cost (shadow price) is low, and to use this ramp capability to balance load and generation when the cost savings from using the ramp capability in the current dispatch interval is high. Hence the MISO uses a penalty price of $5 for reductions in ramp capability below the target level and the California ISO uses a demand curve for reductions in ramp capability with values ranging from near 0 (when there is a large amount of ramp capability available relative to the target) to $247 (when there is relatively little available).[43]

43 These penalty prices are discussed further in in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 97-99.

Reserve Quantity

The MISO ramp dispatch implementation targets having enough ramp capability to meet predicted ramp needs (the forecast change in net load) plus a margin for net load forecast uncertainty.[44] The current MISO design uses the same target quantity for ramp capability to meet net load forecast uncertainty over the day.[45] The California ISO, which has a much higher level of both behind the meter and wholesale energy market solar generation than the MISO, has attempted to implement a design in which the ramp capability target to cover net load forecast uncertainty varies from hour to hour and is continuously updated based on system conditions.[46] Our review of the performance of the MISO and California ISO implementations of ramp capability dispatch designs leads to the conclusion that in markets with high levels of intermittent resource output the setting of the ramp capability target will need to evolve to designs in which the ramp capability target takes account of the current level of intermittent resource output, a high target when intermittent resource output is expected to be high (and hence could fall by a lot) and a lower target when intermittent resource output is expected to be low (and hence can't fall much lower).

Locational Requirements

NYISO locational reserve requirements are based on assessment of generation and transmission outage contingencies. There is no assurance that these locational definitions will be appropriate for balancing large future variations in intermittent resource output on the NYISO transmission grid. A critical weakness in the initial implementations of the ramp capability dispatch in both MISO and the California ISO has been the failure to take sufficient account of the impact of transmission constraints on the dispatch of generation scheduled to provide ramp capability.[47]

Energy Market Cost

The NYISO's scheduling of spinning reserves does not take account of the energy offers associated with

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44 The MISO uses a single interval dispatch, so absent modeling future ramp needs through the ramp capability dispatch design, the dispatch for the current interval would not take account of predictable ramp needs in future intervals. The New York ISO, like the California ISO and Ontario IESO, utilizes a multi-interval optimization design for its real-time dispatch so its base dispatch takes account of predictable ramp needs in future intervals. Unlike the California ISO, however, the New York ISO real-time dispatch does not model each future dispatch interval in 5-minute increments but models them in a combination of 5, 10 and 15-minute increments that can lead to blind spots in the identification of predictable ramp needs in future intervals.

45 See the discussion in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018. Pp 87-92. Our initial scoping/cost benefit analysis of the ramp capability dispatch for MISO used targets that varied in a few broad hourly blocks over the hours of the day. See MISO, Stakeholder 5th Technical Workshop, Ramp Capability in MISO Markets, April 14, 2012 pp. 49-50.

46 This is discussed in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 74-87. This paper contains references to the relevant California ISO documents.

47 This is discussed in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 92-97.

the capacity providing reserves. This is a reasonable design because spinning reserves are rarely dispatched out of market in response to contingencies. This is not the case for generation capacity providing ramp capability. This capacity may be dispatched for energy a significant percentage of the time it is scheduled, and part of reasons for scheduling this capacity is to avoid the need to dispatch very high cost resources to balance variations in intermittent resource output. This goal may not be achieved if the scheduling process does not take some account of the energy cost of the resources scheduled to provide ramp capability.

Downward ramp capability

Unlike spinning reserves, ramp capability dispatch designs maintain the availability of both downward and upward ramp capability.[48] Balancing either predictable or unpredictable increases in intermittent resource output is less challenging than balancing reductions in intermittent resource output because increases in intermittent resource output can in principle be balanced by dispatching down intermittent resource output to manage transmission constraints and to avoid over generation until other supply resources can be ramped down. The NYISO was one of the first ISOs to introduce the economic dispatch of intermittent (wind) resource output and this design has since been implemented in most other ISOs. This design has proved reasonably effective in balancing load and generation when intermittent generation increases rapidly. While California ISO operators had concerns with their ability to dispatch down intermittent resource output a few years ago, those concerns have been relieved over the past few years by the level of intermittent resources participating in the California ISO dispatch.[49]

This ability to balance increases in intermittent output, however, depends on both intermittent resources and flexible resources participating in the economic dispatch rather than submitting inflexible price taking offers.

Analysis of transmission constraint patterns during high ramping hours will be important in order for the NYISO to avoid outcomes in which ramp capability is counted as available in assessing system conditions and committing generation but cannot be dispatched to balance variations in intermittent resource output because of transmission constraints. Analysis of the temporal pattern of ramp capability use is needed to avoid incurring the cost of maintaining incremental ramp capability in hours in which the

48 It is particularly important for the scheduling, and compensation, of downward ramp capability to take account of the offer price of downward ramp capability. Output that can be dispatched down at extremely negative prices provides little value to power consumers in balancing variations in intermittent resource output.

49 It is still the case that only a subset of intermittent resources participate in the California ISO's real-time dispatch but the level of participation has been sufficient to allow the California ISO to balance rapid increases in intermittent resource output within the real-time dispatch. Instances of downward power balance violations have remained low for more than 2 years, see California ISO, Market Performance and Planning Forum, July 10, 2019 p.33. This low level of downward power balance violations over the past couple of years may in part reflect hydro conditions in California, which is an issue the California ISO must manage but the New York ISO does not face to a material extent.

probability of the additional ramp capability being needed is low (and hence the benefit from maintaining additional ramp capability low relative to this cost).

The NYISO should continue to track the ongoing refinements to ramp capability dispatch designs in MISO and California ISO and assess whether such a design should be implemented in New York in a manner that would help balance variations in intermittent resource output. In addition, the NYISO should undertake ongoing analysis of the locational and temporal patterns associated with significant variations in intermittent resource output in the NYISO. This information will be a critical element of any ramp capability design that may be implemented in the NYISO and this information will likely help inform other changes in NYISO operating practices or markets that would help more efficiently and reliably accommodate higher levels of intermittent resource output . A good understanding of likely transmission constraint patterns during high ramp hours will be beneficial to the NYISO in balancing generation and load whether the NYISO implements a ramp capability dispatch similar to California ISO or MISO or develops a different approach. Similarly, the ability to predict periods of high variability in net load will be beneficial to the NYISO whether or not it implements a ramp capability dispatch similar to the California ISO or MISO. Moreover, the ability to account for transmission constraints and predict periods of high net load variability are key elements of ramp capability dispatch designs and the California ISO experience has shown how complex the necessary analysis of net load forecast uncertainty can be with high levels of solar generation, particularly behind the meter solar generation.[50]

Another operational issue impacting the real-time dispatch (and the look-ahead real-time unit commitment) that the NYISO will need to address is the potential for operators to respond to ramp issues by adjusting the load forecast in RTC and RTD with the intent of creating more ramp capability.[51] While it is

50 The California ISO initially sought to estimate the variability of net load using recent data for exactly the same time of day. However, such an approach runs into the statistical constraint that a lot more data is required to reliably estimate the variability of a distribution than to reliably estimate its mean. The California ISO found that its estimate of the variability of net load, and hence of the need for ramp capability, varied tremendously over short periods of time as a few extreme outcomes moved in and out of the sample used for forecasting. Using data over the same hour rather than the same 5-minute time period on prior days provides more data points and stability in the estimates, but also leads to larger forecast error in hours at the beginning and end of the day when solar output can be changing relatively rapidly over some hours. Moreover looking further back in time to add data points with the goal of improving the estimate of net load variability, adds days to the sample but adds days with increasingly different sunrise and sunset times, particularly during the times of year when days are lengthening or shortening relatively rapidly from day to day. And accounting for these factors impacting the variability of solar generation is further complicated if the solar generation is behind the meter and the ISO forecasters cannot observe the change in solar output but only the change in net load.

These complications are not unsolvable but they create complex analytical challenges that are reasons that it would be desirable to begin addressing these analytical issues well before the time comes when it is necessary for the New York ISO to implement a ramp capability dispatch. Further discussion of these issues can be found in California ISO, Department of Market Monitoring, 2016 Annual Report on Market Issues and Performance, May 2017 pp. 110-111; Warren Kazenstein, California ISO, "Flexible ramping constraint discussion," Market Surveillance Committee Meeting, February 11, 2016. Roger Avalos, California ISO, Department of Market Monitoring, "Briefing on Flexible Ramping Product," Market Surveillance Committee meeting, July 15, 2015. California ISO, Department of Market Monitoring, Comments on Demand Curve in the Flexible Ramping Product Draft Technical Appendix," June 15, 2015, as well as in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp, 74-87

51 These adjustments can cause the software to commit additional generation, which can increase the amount of ramp capability available for dispatch, and to back down regulating units, which can provide more upward ramp capability in subsequent intervals.

important for operators to have the ability to adjust the net load forecasts flowing into RTC and RTD when the net load forecast is not reflective of expected with system conditions, these operator adjustments can create additional issues if these adjustments chronically result in uneconomic commitments and interchange schedules and thereby lead to distorted relationships between RTC and RTD prices and schedules.

d. Improving the NYISO's Real-Time and Day-Ahead Energy Market Processes

The NYISO's real-time dispatch design, real-time unit commitment processes and day-ahead market will all affect the NYISO's ability to efficiently and reliably balance load and generation in real-time with a much higher level of intermittent resource output.

Real-Time

The NYISO will need to focus on two potential gaps in the current market design that would potentially impact the performance of the real-time dispatch in balancing variations in intermittent resource output. The first potential gap, discussed above, is the need for the NYISO either to increase its spinning reserve target or to adapt a ramp capability dispatch design in order to have enough ramp capability available to balance load and generation in real-time with higher levels of intermittent resource output. The second potential gap is the continued need for the energy market to provide strong incentives for participation in the real-time dispatch.

Participation in the Real-Time Dispatch

The NYISO's real-time dispatch design is well suited to balancing variations in net load. Like the MISO and Ontario IESO, the NYISO's real-time dispatch simultaneously optimizes the dispatch of energy and scheduling of ancillary services in real-time. Also like MISO, the NYISO applies demand curves to the dispatch of energy that reduce the supply of ancillary services in real-time, the forward commitment process (RTC) or the day-ahead market.[52] This design enables the NYISO's real-time dispatch to be more flexible than the current California ISO design in balancing generation and load in real-time, and is the kind of design the California ISO has recognized a need to shift to over the next few years.[53] There are three caveats to the continued ability of the NYISO to use its existing market design and real-time dispatch to balance increases in intermittent resource output using the real-time dispatch that the NYISO should keep in mind in analyzing potential reliability gaps. First, the ability of the NYISO to effectively use its economic dispatch to balance variations in net load depends critically on flexible resources having a sufficient

52 The changes PJM recently filed with FERC in docket ER19-1486 would implement a similar design in PJM.

53 See most recently Don Tretheway, California ISO, "Day-ahead market enhancements – flexible ramping product," Market Surveillance Committee Meeting, January 25, 2019.

economic incentive to participate in the NYISO economic dispatch, rather than submitting price taking bids corresponding to their day-ahead market schedules, and to offer their full ramp capability, and perhaps make investments to increase their ramp capability. The NYISO's market design generally provides strong incentives for flexible resources to participate in its economic dispatch.[54]

However, the incentive to respond to marginal incentives in the energy market is not present for resources that are committed uneconomically and are made whole with uplift payments. Energy market prices will not provide efficient incentives for participation in the economic dispatch or investments in greater operational flexibility if a large proportion of unit commitments are uneconomic (with the outcome that incremental energy margins do not contribute to profits but only reduce uplift payments) and resources earn profits by inflating their minimum load and start up offers, rather than by responding to the economic dispatch. It is therefore important for the NYISO to track the extent to which flexible resources are committed economically in real-time and made whole with bid production cost guarantee payments and attempt to correct any market design elements that are materially contributing to a need for bid production cost guarantee payments for such flexible resources.

The NYISO's ability to maintain efficient marginal incentives in the energy market and avoid materially increased reliance on bid production cost guarantee payments will depend in part on the structure of future contracts used to subsidize investment in intermittent resources. If the structure of future contracts creates incentives for many intermittent resources to offer their output at or near the current NYISO bid floor of -$1000 per megawatt hour, the potential for very negative prices will adversely impact the economics of many NYISO operating decisions, including the economics of committing thermal resources providing spinning reserves, upward balancing, frequency response and reactive power. [55] Highly negative real-time prices also have the potential to materially weaken energy market performance incentives because they would increase the likelihood that dispatchable resources would typically be receiving bid production cost guarantees to recover real-time commitment costs and hence would have little potential to profit from better real-time operating performance.[56]

In addition, the potential for real-time prices to fluctuate rapidly between positive prices and extreme negative prices, particularly prices near -$1000 per megawatt hour, have the potential to adversely impact

54 The California ISO has adjusted elements of its market design over the past five years to be more like the New York ISO market design with the goal of encouraging flexible resources to more fully participate in the California ISO's economic dispatch.

55 Intermittent resource output is typically offered in NYISO and other ISO markets at prices well above the NYISO's -$1000 bid floor, with tax and regulatory incentives generally incenting offers in the -$15 to -$150 range. There are, however, instances in which tax and regulatory incentives result in supply being offered at extreme negative prices, which can create difficult to resolve market and operational problems. It is important that future regulatory, contract and tax subsidies be implemented in a manner that avoids creating inefficient incentives for supply to be offered at extreme negative prices that do not reflect the social cost of curtailing the output.

56 The California ISO has maintained a bid floor of -$150 and Ontario IESO requires wind resources to offer supply at prices no lower than -$5.

the degree to which flexible resources would participate in the real-time dispatch and/or day-ahead market and would potentially have a variety of adverse market and reliability impacts that are difficult to completely anticipate.

Second, the application of hybrid (Fixed Block) pricing to dispatchable resources that are committed and kept on line in order to provide reserves (as ordered by FERC in EL18-33) could result in substantial inconsistencies between settlement prices and the economic dispatch. These inconsistencies could incent flexible resources to self-schedule their output rather than participating in the economic dispatch, incent intermittent resources to submit price taking, rather than economic offers, and incent dispatchable resources to increase their minimum operating level.[57] The NYISO is considering ways to minimize such inconsistencies as it tests methodologies to incorporate the commitment costs of fast-start resources into the calculation of real-time prices.[58] These incentive issues will need to be addressed before the level of intermittent resource output in New York rises to a level that will at times require dispatchable fast start resources to be on line to provide reserves and ramp despite being uneconomic in the energy market.

Third, the ability of the NYISO to manage increases in intermittent resource output is subject to the issues regarding net load forecasting discussed in subsection (e) below. The real-time dispatch will only be effective in balancing rapid increases in potential intermittent resource output if the increases are foreseen in the net load forecast that is utilized for the real-time dispatch.

Intra-day Unit Commitment

One step back from the real-time dispatch is the time frame in which the NYISO commits quick starting generation and schedules net interchange over the operating day. The New York's RTC currently makes these commitment and interchange scheduling decisions to meet a deterministic load forecast at least-cost. As the amount of intermittent resource output in New York increases, this net load forecast will be less accurate than it is today. The NYISO may need to modify RTC to account for load forecast uncertainty so it will commit generation and schedule interchange to maintain sufficient ramp capability to balance load and generation in RTD.

The MISO and California ISO have met this challenge by including target levels of upward and downward ramp capability in the objective function of their look-ahead unit commitment tools.

57 These inefficient incentives could be addressed, in part, by implementing constrained off payments to flexible resources that are dispatched inconsistently with settlement prices, but this resolution could result in very substantial uplift costs because of the large potential difference between the price of energy set by the fast start pricing design and the incremental dispatch price for constrained off intermittent resource output. A better approach would be to limit the extent to which resources that are on line to provide reserves or ramp capability can set energy prices, but it will take time to design such an approach and get it approved by FERC.

58 See NYISO, Enhanced Fast-Start Pricing, ICAPWG May 30, 2019 at this link: https://www.nyiso.com/documents/20142/6785167/053019%20MIWG%20-%20Enhanced%20Fast%20Start%20Pricing.pdf/dab2227c-e7ef-f7bf-194c-fdc8180809cd

The California ISO's look-ahead unit commitment tool (RTPD) is modeled after the NYISO's RTC, so the two programs have very similar functionality. We believe that the NYISO's RTC can readily be modified to implement ramp capability targets. The key challenges for the NYISO would be to: 1) determine appropriate ramp capability targets that reflect the expected variability of net load over the day and at different times of year; 2) develop workable locational ramp capability targets; and 3) set appropriate penalty prices for using ramp capability to balance load in the current dispatch interval. The NYISO's Reserves for Resource Flexibility project seeks to evaluate these challenges, by studying the future need for the NYISO to procure additional 10 and 30 minute Reserves beyond minimum requirements. As part of this project, the NYISO is exploring methods to calculate and predict net load forecast uncertainty.[59] The NYISO could potentially leverage this work in the future to help set ramp targets for different time horizons, such as one or two hours ahead for RTC.

While RTC can be modified to take account of net load forecast uncertainty and the need for ramp capability in RTD in making commitment and interchange scheduling decisions, the reduced accuracy of the net load forecasts used in RTC will lead to less efficient unit commitment and interchange scheduling decisions.[60] Moreover, there are a number of market issues that will tend to require more complex optimization decisions in the NYISO's intra-day unit commitment processes, which will tend to extend solution time and increase the latency of the load forecasts used to make unit commitment decisions. One approach the NYISO could take to mitigate these impacts would be to move commitment decisions for quick start units into RTD,[61] so they would be less impacted by the latency in the net load forecast and potentially to also move some interchange scheduling into RTD.

A third challenge confronting the NYISO's intraday unit commitment programs will be the need to manage the output of energy-limited resources over the operating day, including the need to schedule interchange and commit thermal generation to maintain energy balance. These challenges are discussed under topic 4 (Maintain Ability to Meet Daily Energy Requirements) below.

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59 See NYISO, Reserves for Resource Flexibility, ICAPWG May 6, 2019 at this link: https://www.nyiso.com/documents/20142/6474763/5_9_2019_Reserves_for_Resource_Flexibility_FINAL.pdf/f5b74852-2b18-9233-a8fa-bfc488ed1238

60 Increased load forecast error would tend to increase bid production cost payments to resources committed in real-time, undermining market incentives. There may be a longer term need for financially binding intra-day commitment schedules. This is related to the discussion of the possible role of intra-day markets in supporting the efficient balancing of intermittent resource output, see, for example Arthur Henriot, "Market Design with Centralized Wind Power Management: Handling Low-predictability in Intraday Markets," Energy Journal Vol 35, # 1 2014 pp. 99-118, Kristof De Vos and Johan Driesen, "Balancing Management Mechanisms for Intermittent Power Sources – A Case Study for Wind Power in Belgium," Karsten Neuhoff, Carlos Batile, Gert Brunekreeft, Christine Vasilakos Konstantinidis, Christian Nabe, Giorgia Oggioni, Pablo Rodilla, Sebastian Schwenen, Tomasz Siewierski and Goran Strbac, "Flexible Short-Term Power Trading: Gathering Experience in EU Countries," Berlin 2015; and Frieder Borggrefe and Karsten Neuhoff, "Balancing and Intraday Market Design: Options for Wind Integration, Berlin January 2011.

61 This would be moving back to the functionality that was present in SCD at NYISO start-up, enhanced with the look-ahead capability of RTD.

Day-Ahead Market

As the level of intermittent resource output in New York increases, the NYISO may at some point need to begin explicitly modeling the need for upward ramp capability in the day-ahead market. The MISO began including a requirement for upward ramp capability in its day-ahead market in 2016. The California ISO is in the process of developing such a requirement.[62] We believe the NYISO day-ahead market design and engine are well suited to implementing day-ahead ramp capability targets as they become needed. As with RTC, the key issues with meeting flexibility targets in the day-ahead market will be to 1) set appropriate ramp capability targets over the day, and 2) develop locational requirements.

A related set of day-ahead market reliability gaps concern the design of the NYISO forecast load pass and the reliability commitment. While the NYISO reliability commitment design has worked very well over the past 20 years, providing an assurance that sufficient resources will be available to meet real-time load while having minimal impact on day-ahead market commitments and prices, this design may need changes to better maintain reliability in a market with substantial net load forecast uncertainty and potentially limited incentive for the operators of intermittent resources to participate in the day-ahead market.

The MISO and California ISO have experienced relatively limited participation of intermittent resource operators in the day-ahead market, in part because of the structure of the contracts that subsidize those resources output.[63] While virtual supply offers tend to compensate for intermittent resource output that is not offered in the day-ahead market, many virtual supply bidders lack direct insight into the likely output of specific resources and instead must submit offers that approximate the expected impact of the intermittent supply on real-time prices.[64] More accurate scheduling of likely intermittent resource output may be needed as the level of intermittent resource output in the NYISO increases and it becomes more expensive to have excess thermal capacity on line in real-time. In addition, as the level of intermittent resource output rises, it will become more important to explicitly account for the potential variability and unpredictability of intermittent resource output in the forecast load commitment. These changes may require that the NYISO not only account for ramp needs in the day-ahead market but make associated changes in the design of the forecast load pass in the day-ahead market, including potentially providing

62 See most recently, California ISO, "Day-Ahead Market Enhancements Phase 2: Flexible Ramping Product," February 28, 2019 and Don Tretheway, California ISO, "Day Ahead Market Enhancement Status and Next Steps," May 2, 2019.

63 See, for example, California ISO, Market Performance and Planning Forum, April 18, 2019 pp. 30-31; Potomac Economics, IMM Quarterly Report: Winter 2019, March 19, 2019 p. 26.

64 In some cases, the virtual bidder is the load serving entity to which the intermittent resource is under contract and the load serving entity has access to information regarding the expected output of the resource. This is not necessarily the case however, depending on the structure of the contracting process for subsidized intermittent resource output.

market based compensation and assigning financial commitments to resources scheduled to meet load in the forecast load pass.[65]

Another potential reliability gap is the hour-long time frame of the day-ahead market schedules combined with the limited look-ahead capability of RTC. If long-starting resources are used to balance load during the evening solar ramp, it will be important that they come on line when they are needed during the hour, and not all come on line at the beginning of the hour when their operation could require dispatching down intermittent resource output at low or negative prices. The California ISO has been considering the implementation of 15-minute scheduling intervals in its day-ahead market to address these issues,[66] but has encountered challenges solving that many discrete intervals in the time frame of the day-ahead market that have led to the deferral of such a design.[67]

An alternative approach would be to lengthen the time horizon of intra-day commitment scheduling tools that solve in 15-minute intervals and to use them to determine the commit time for slower starting resources. This approach might be combined with changes to the NYISO two settlement rules that would insulate resource from two settlement charges for the difference between their day-ahead market schedule and real-time commitment schedule times.

Another set of changes impacting the design of the NYISO day-ahead market are those that will make it more expensive, potentially at times much more expensive, to have more than the minimum number of thermal units on line during low priced periods when intermittent resource output is high. This may create a need for the NYISO to optimize not only the supply of regulation, spinning reserves and ramp across a limited set of on line resources — but also to coordinate this with the commitment of resources needed to provide voltage support and perhaps frequency response.

The NYISO's day-ahead market software will provide a framework for evaluating unit commitment decisions but changes may be needed to both the optimization capabilities of these designs (including granularity, ability to account for energy and voltage limits, frequency response needs, replacement reserves and locational capacity requirements with carefully considered penalty price designs) and in the optimization horizon.

65 Hence, the best way to address these issues is by utilizing contract structures that combine subsidies with efficient incentives to participate in the day-ahead market.

66 An important motivation for the California ISO to evaluate the use of 15-minute schedules has been the potential ability to schedule cascade hydro resources in the U.S. Pacific Northwest and western Canada to meet the evening solar ramp if these resources could be scheduled day-ahead with sufficient granularity.

67 See, Don Tretheway, California ISO, "Day Ahead Market Enhancement Status and Next Steps," May 2, 2019.

e. Managing Net Load Forecast Uncertainty

As the level of intermittent resource output within the NYISO increases, the NYISO's ability to balance load and generation will be impacted by the latency of the net load forecast used in RTD. An important factor impacting the ability of the California ISO to balance load and generation with a resource mix that includes large amounts of intermittent resource output, particularly behind the meter solar generation, has been the latency in the net load forecast that is used in the real-time dispatch. The total load forecast latency arising from the length of the dispatch interval, RTD solution time, and the total calculation time for the net load forecast in the California ISO real-time dispatch can amount to 20-minutes or longer. The consequence is that there can be substantial generation available to balance net load in RTD that is not instructed to adjust its output in the direction needed to balance load and generation because of these time lags. Not only do these time lags mean that it could take 20 minutes or more before the real-time dispatch signal begins to move in the direction needed to balance load and generation, the dispatch signal can remain out of balance for even longer periods as the net load forecast continues to lag changes in real-time output.[68]

This net load forecast latency has contributed to situations in which the California ISO is unable to balance load and generation over sustained periods because the RTD dispatch is based on net load forecast that is 20 minutes out of date and does not show the imbalance, with the result that regulating capacity is completely utilized, with the regulating resources pinned at the upper limit of their regulating range.[69] The NYISO needs to be prepared to deal with the impact of load forecast latency in its real-time dispatch as the level of solar generation, particularly behind the meter solar generation, increases in New York.

Such an increase in load forecast latency would also impact the NYISO's CTS scheduling, which could become even more challenging as the level of intermittent resource output rises in New York and in adjacent regions such as ISO-NE.

One option for the NYISO in managing the impact of load forecast latency in RTD would be to pursue the approach the California ISO has been taking over the past year, seeking to reduce the amount of latency

68 This load forecast latency and the resulting net load forecast error, combined with high ramp needs, has led over time in the California ISO to a very high level of manual load forecast adjustments by California ISO operators (load bias or load conformance adjustments in California ISO terminology). These ad hoc manual adjustments have become large and frequent, impacting 60-80% of all RTD intervals and averaging hundreds of megawatts 2016, 2017, and 2018 see for example California ISO, Department of Market Monitoring, 2017 Annual Report on Market Issues and Performance, June 2018, Figures 9.15 and 9.11 and California ISO, Department of Market Monitoring, Q4 2018 Annual Report on Market Issues and Performance, February 13, 2019, Table 2.2,. Similar large ad hoc manual adjustments to the load forecast are being made in California ISO's intra-day commitment software and the operators are also making ad hoc adjustments to when updated load forecasts flow into RTD. Cascading operational impacts such as these from increasing net load forecast latency and error would have the potential to create substantial challenges for the New York ISO in reliably operating the New York transmission system.

69 California ISO, Market Performance and Planning Forum, December 18, 2017 pp. 4-13; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55

in the load forecast. This could involve both changes in load forecast methodology and incremental reductions in RTD solution time.[70] Another option would be an approach that has not been taken in California but could be considered in New York which would be to require roof top solar vendors to provide aggregated regional output data to the NYISO in real-time as opposed to the 15-minute frequency granularity that is received today.

While minor improvements in net load forecasting and RTD solution time such as those entailed by the approaches outlined above may be sufficient to keep load forecast latency within an acceptable range given the characteristics of the NYISO resource mix, there is no assurance that such an approach will be successful. Moreover, while load forecast latency could be reduced by modifying RTD to solve faster, there will be conflicting needs for RTD to look out further in time and potentially make additional optimization choices (such as short-term unit commitment), which would tend to increase RTD solution time and increase load forecast latency. Hence, other approaches to managing the impact of net load forecast latency on the NYISO's ability to balance load and generation may be required, including approaches that could involve more substantial changes in real-time dispatch tools and dispatch methods that would take a number of years to develop. For example, the forecast latency arising from RTD solution time could be addressed by abandoning multi-interval optimization in the real-time dispatch and shifting to an RTD design that solves a single interval dispatch extremely quickly, in less than a minute, as is the case in ERCOT.[71] Simplified fast solving methods might also be developed for adjusting the current net load for any intermittent resources being dispatched down so that the overall net load forecast latency might be reduced to a minute or two.

f. Promote More Frequent Interchange Scheduling with Neighboring Regions

When CTS was being developed it was hoped that the implementation among PJM, NYISO and ISO-NE would contribute to balancing sustained variations in intermittent resource output. However, it has proven challenging to develop sufficiently accurate load and price forecasts to achieve these benefits in the time frame of the CTS implementation in RTC.

It is noteworthy in this context that an important component of the California's ISOs strategy for

70 For recent California ISO discussions of forecast error and latency, as well as California ISO efforts to reduce forecast latency, see California ISO, Market Performance and Planning Forum, June 11, 2018 pp. 23-32; Amber Motley, California ISO, "Flexible ramping product requirements and load forecast discussion," Market Surveillance Committee Meeting, June 7, 2018; California ISO, Market Performance and Planning Forum, February 20, 2018 pp. 29-34; California ISO, Market Performance and Planning Forum, December 18, 2017 pp. 4-13; California ISO, Market Performance and Planning Forum, May 16, 2017 pp. 43-51; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55.

71 Alternatively a more complex RTD design could perhaps be developed in which real-time dispatch instructions are determined in a single interval optimization with upper dispatch limits and penalty prices input into that single interval dispatch from a multi-interval optimization that would postures resources to be able to respond to known ramps in future intervals. Such a design would attempt to retain the benefits of multi-interval optimization in posturing generation to be able to balance generation and load during predictable ramps while also maintaining the ability to solve quickly and respond to unexpected changes in net load.

balancing high levels of intermittent resource output has been to reduce the latency of interchange scheduling with adjacent balancing areas by implementing the western EIM, enabling interchange to be adjusted on a 5-minute basis. The NYISO, ISO-NE and Ontario IESO balancing areas are all even smaller than the California ISO balancing area and they may need to achieve the critical scale for balancing intermittent resource output by developing methods for integrating the regional dispatches among the NYISO, New England ISO, Ontario IESO and Hydro-Québec in a more coordinated manner than has been possible with the CTS design.

We noted above the potential for increased use of the existing ACE diversity interchange framework in the context of regulation. Additional coordination methods that might be considered in the timeframe of the real-time dispatch include: 1) changes in the CTS design with ISO-NE that would operate like a regional energy imbalance market with a single 5-minute energy dispatch and could eventually be extended to coordination with Ontario IESO and Hydro-Québec, or 2) shifting the NYISOs CTS scheduling for the next 15-minute interval from RTC, into RTD's multiple interval optimization.[72] Both approaches to improved coordination would involve substantial changes so would take a number of years to implement, if they ca be proven workable. Implementation of such a regional 5-minute dispatch that would take account transmission constraints within the entire region might also enable the northeast balancing areas to make better use of the ACE diversity interchange design.

2. Maintain Ten-Minute Operating Reserves

Potential Reliability Gap # 2: The NYISO may be challenged to maintain ten-minute operating reserves and meet NERC disturbance control performance requirements in response to variations in the levels of intermittent generation.

NYISO Plan for Gap # 2: The NYISO will continue to track ten-minute operating reserves and applicable NERC Balancing Area Disturbance Control Standards and implement necessary operational and market changes in order to maintain acceptable control performance. *Such changes are detailed in the following section and include:*

a. Increasing statewide ten and/or thirty-minute reserve procurement requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Account for increased real time load forecast uncertainty
d. Evaluate the sustainability of 10-minute and 30-minute reserves

Background:

72 With such an approach, RTC could continue to be used for the forward evaluation of interchange schedules that would be exchanged with other markets, but the scheduling of interchange for the next 15-minute interval would be shifted into NYISO's RTD.

We noted above that the scheduling of additional spinning reserves or ramp capability could play an important role in enabling the NYISO to balance load and generation as the New York resource mix evolves towards a substantially greater reliance on intermittent resource output. However, these increases in the level of intermittent resource output used to meet load on the NYISO transmission system also have the potential to impact the way the NYISO meets its spinning and total reserve targets in a number of ways that will need to be considered by the NYISO in parallel with these changes.

First, there may be a need for changes in the way the NYISO identifies and schedules reserves to balance the system following "contingency events." As the NYISO resource mix changes, the largest short-term unexpected reductions in generation within the NYISO may be a result of changes in intermittent resource output rather than conventional generation outage contingencies. This evolution in the resource mix will create the need for the NYISO to identify and protect against these events.

Second, these same changes in the resource mix will result in typically low energy price levels over many hours of the day, making it more expensive, potentially much more expensive, to keep thermal resources with minimum stable operating levels on line to provide contingency reserves or to maintain the ability to balance load and generation when intermittent resource output falls. These price and cost changes will create a strong incentive for the NYISO to meet its spinning reserve targets with resources that are able to provide reserves without generating material amounts of energy, This will in turn require the NYISO to evaluate its ability to rely on spinning reserves provided by a variety of resources other than thermal generation and to identify any limitations on the proportion of reserves or balancing energy that can reliably be provided by particular types of resources.

Third, these changes in the resource mix and associated low energy prices have the potential to lead to market outcomes in which the price of spinning reserves is low, providing little incentive for an increased supply of resources able to provide spinning reserves, but the full cost of spinning reserves, including the commitment costs of reserves provided by thermal generation, is high. Hence, as these changes in the resource mix and wholesale energy price level occur, the NYISO will need to assess whether its reserve pricing design is providing an efficient price signal.

Fourth, these changes in the resource mix and energy price levels have the potential to result in storage resources being used to meet a significant portion of the NYISO's spinning reserve requirement. In addition to the need to assess its ability to rely on varying levels or proportions of storage resources to provide spinning reserves, these changes will make it more important for the NYISO to manage the energy balance of resources providing reserves and meeting energy demand throughout the day.

We discuss each of these potential reliability gaps below.

Contingency Reserve Targets

The level of intermittent resource output on the NYISO system is currently low enough that even large proportional changes in intermittent resource output are small relative to the size of the generation and transmission outage contingencies the NYISO maintains reserves to recover from. This relative balance will likely cease to be the case at some point in the future as intermittent resource output rises and the absolute size of the short-term variations in intermittent resource output become larger.[73] This potential reliability gap is related to the discussion of ramp and energy market balancing in Section 1, but the ramp capability dispatch would schedule additional ramp based on targets and a demand curve. The NYISO might need to undertake an assessment of its ability to recover from a large reduction in intermittent resource output using a combination of spinning reserves and potentially resources providing upward ramp capability that would be enforced at a higher penalty price than its procurement of flexible ramping capacity.

The NYISO will need to track and evaluate the magnitude of potential contingencies or other unpredictable short-term changes in intermittent resource output as the resource mix evolves. In addition, the NYISO will need assess on an ongoing basis and project how the magnitude of these unpredictable supply changes will likely change with prospective changes in the resource mix.[74] This assessment will be used to guide any needed changes in NYISO spinning reserve targets and shortage prices.

The NYISO might also find it necessary or desirable to develop tools that more accurately and dynamically model locational reserve requirements taking into account transmission loadings and unit commitments. Such improvements would potentially allow the NYISO to more accurately model the amount and location of the spinning and total reserves across the system so as to reduce the need to commit additional thermal resources at minimum load in order to provide reserves.[75] The NYISO is currently considering the implementation of Load Pocket Reserve areas in NYC, which could be accomplished more efficiently via a dynamic methodology considering load pocket transmission loadings.

73 An example of additional types of contingencies that might need to be protected against is the tripping of solar generation in connection with faults on the transmission system. NERC identified this risk in 2017 and the level of solar generation on the California ISO grid required that the California ISO schedule operating reserves to protect against a contingency in which 25% of forecast solar output, later reduced to 15%. The California ISO typically carries ½ of its operating reserves as spinning reserves, See California ISO Market Notices of June 12, 2017 and September 14, 2017 and California ISO, Department of Market Monitoring, 2017 Annual Report on Market Issues & Performance, June 2018 pp. 141-143.

74 As the level of intermittent resource output rises, this evaluation will eventually need to be dynamic, with the required level of reserves declining when intermittent resource output is low (and hence there is no potential for large contingencies involving sudden reductions in intermittent resource output). If the New York ISO attempted to maintain a fixed spinning reserve margin that was sufficient to cover large reductions in intermittent resource output even intermittent resource output is low, meeting this reserve target would require committing additional thermal generation and further increasing emissions, in addition to the generation used to meet load when intermittent resource output is low.

75 The California ISO has developed such a tool, referred to as commitment modeling enhancements. These improvements are slated to be implemented in combination with other improvements to the design of the day-ahead market, see http://www.caiso.com/informed/Pages/StakeholderProcesses/ContingencyModelingEnhancements.aspx

Spinning Reserve Resource Mix

At the same time that the size of the NYISO's largest generation contingency may increase, the cost of scheduling spinning reserves on thermal units is likely to rise substantially with the increasing output of intermittent resources. In particular, increased output from intermittent resources with negative incremental costs associated with subsidies tied to megawatt hour output levels, will likely cause middle of the day energy prices to gradually fall until they frequently reach negative levels. These changes in energy prices will make it more and more costly for the NYISO to keep thermal resources on line at minimum load in order to provide spinning reserves (or upward ramping capability).[76]

These cost pressures will require the NYISO to assess how much of its spinning reserve requirement can be concentrated on particular resources that can provide spin without incurring substantial minimum load costs,[77] and to evaluate its ability to rely on various types of storage and other non-generation resources to provide spinning reserves.

The NYISO's simulations reported in the December 2017 *Integrating Public Policy* report projected some increase in day-ahead market spinning reserve prices, but some elements of the reported simulation results suggest that future spinning reserve prices might be materially higher than projected in the report.[78]

The likely high cost of spinning reserves provided by thermal units will also require the NYISO to evaluate its reliability rules relating to the supply of spin from other types of resources and establish appropriate rules. This could, for example, involve rules allowing import supply of spinning reserves from external balancing areas, resource designs in which thermal resources are providing spin but not generating energy (PJM operates CTs in this way), designs in which a combination of batteries and very quick starting thermal resources provide spinning reserves,[79] spinning reserves provided by directly controlled and monitored load, and the provision of spinning reserves by inverter based resources, etc. The NYISO's flexibility to revise its spinning reserve supplier requirements may be limited by rules written by bodies such as the NPCC and NYSRC, which have oversight of reliability rules, so NYISO efforts to close reliability gaps may require working with these organizations to align reliability rules with evolving technology and resource capabilities.

76 This discussion focuses on spinning reserves as targets for 10-minute reserves can be met with off line resources.

77 We believe this is the case, however, we have not reviewed Niagara's ramp rate or its ability to provide spin at low output levels.

78 The price simulations in Figures 58-64 tend to show positive day-ahead market prices and very negative real-time prices.

79 Quick starting resources can provide 10-minute non-spinning reserves under the current New York ISO tariff. This comment refers to the possibility of a supplier providing spinning reserves with a combination of a battery able to provide an immediate response, but only for a short period of time, and a quick starting unit, that could not respond immediately but could come on line before the battery has depleted its storage.

In addition, as the amount of spinning reserves provided by energy limited resources such as energy storage rises, the NYISO may need to evaluate whether: 1) there needs to be a cap on the proportion of spinning reserves provide by particular types of resources; 2) restrictions are needed on the number of successive hours energy limited resources can be scheduled to provide reserves in the day-ahead market;[80] and 3) whether a one hour sustainability requirement for all resources providing spinning reserves is sufficient to meet reliability needs.

Spinning Reserve Price Formation

Absent a substantial change in the NYISO resource mix, resources able to provide spinning reserves without incurring minimum load costs, such as pondage hydro, pumped storage, energy storage and perhaps other types of resources will be able to submit high offer prices for spinning reserves that would and should clear in the day-ahead because they will provide reserves at much lower costs than could thermal units. These higher spinning reserve prices will reduce the uplift payments to thermal resources committed out of merit to provide spinning reserves, and will also provide a price signal for the supply of spinning reserves for resources that do not need to incur minimum load costs in order to provide spinning reserves.

A complicating factor in meeting these evolving resource needs for spinning reserves is that the likely high cost of relying on thermal resources to provide reserves during hours in which energy prices are low or negative will not necessarily be reflected in reserve prices under the NYISO's current market design. Instead, reserve prices could be set by incremental reserve offers, while thermal resources committed to provide reserves incur large uplift costs. These incremental reserve prices would not provide an efficient price signal for investment in resources able to provide reserves without selling a material amount of energy in the spot market.

It is possible that suppliers able to provide spinning reserves from resources that do not incur minimum load costs in providing reserves will submit offers at levels that will clear in the market and displace thermal resources, while sending an appropriate price signal for the supply of spinning reserves. Relying on resource offers to provide an efficient price signal in these circumstances rests on a hope that there will be just enough exercise of market power. This is unlikely to be the case. There is no assurance that suppliers will possess enough market power to raise prices closer to the efficient level, nor assurance that they will not have so much market power that they are able to raise prices when there is no shortage of spinning reserves from such resources. Nor is it apparent that they would even have the ability to figure out the bid level in the day ahead market that would raise prices while displacing thermal resources, given

80 Or alternatively, whether an energy limit needs to be enforced on the scheduling of reserves in the day-ahead market.

the multiple factors that would impact the cost of carrying reserves on thermal units (such as the price of energy at each location). Hence, we do not recommend relying on market participant offers to set reserve prices that send an efficient price signal in this situation.

A better approach would be for the NYISO to refine its demand curve for spinning reserves to send an appropriate price signal for all types of resources able to provide reserves. This will require a demand curve for spinning reserves that extends down to low shortage prices, as a demand curve with high penalty prices will cause thermal resources to be committed out of market with reserve prices set by their incremental reserve offers. As noted above, PJM has recently filed plans to implement such an approach with the FERC, and the NYISO is exploring introducing more steps in its shortage pricing design for reserves and regulation as part of its Reserves for Resource Flexibility project.[81]

A third possible approach would be to develop a pricing methodology that would incorporate the out of merit costs of thermal resources committed to supply spinning reserves into the price of spinning reserves. This would be in the spirit of the hybrid pricing design for fixed block units/fast start pricing but would be even more complex, if it were workable at all, and there is no assurance that a workable design of this type could be developed.

The NYISO will continue to monitor the level of day-ahead and real-time prices and the uplift cost of resources committed to provide spinning reserves and assess the need for changes in reserve shortage values of the price determination rules on an ongoing basis.

Management of Reserves Provided by Energy Limited Resources

As part of a broader need to track the energy as well as capacity balance of the New York electric system, as the level of storage resources used to meet load and provide reserves rises, the NYISO may need to develop more complex tools to track whether the resources scheduled to provide spinning reserves have sufficient energy to meet NYISO reliability needs above and beyond those that will be implemented as part of the current Energy Storage Resource design.[82] As the amount of energy limited resources relied upon to balance net load increases, the NYISO will need to not only assess whether the individual resources scheduled to provide reserves have enough energy to meet NYISO requirements, but to also assess whether the resources available to the NYISO in aggregate have enough capacity and energy to allow reserves to be restored following a contingency in which energy limited resources providing reserves have their reserves converted to energy.

81 See FERC Docket No. EL19-58-000 for PJM's 206 filing of Reserve Market Enhancements, submitted March 29, 2019

82 See the New York ISO Order No. 841 Compliance filing in FERC Docket ER19-467.

Reductions in the amount of thermal generation committed to meet energy demand during some periods of the day may require the NYISO to specify additional, or simply different, locational reserve constraints as commitment patterns change.

The inclusion of more energy limited resources such as batteries in the resource mix providing spinning reserves will also require changes in the way spinning reserves are scheduled and energy dispatched to ensure that resources scheduled to provide reserves have enough energy to sustain their output for the one-hour period required by the NYISO. This will require software that can both model energy limits and make optimal trade-offs between using energy in storage to meet load in the current period and reserving the energy in storage so the storage resource can provide more spinning reserves. While the basic framework of the NYISO's real-time co-optimization of energy and ancillary services within the multi-interval optimization framework of the real-time dispatch is well suited to evaluating these tradeoffs, there may be a need to evolve this design to: 1) model future RTD intervals more discretely and thereby better model ramp needs; 2) explicitly account for net load forecast uncertainty; and 3) explicitly account for energy limit impacts that extend beyond the current RTD horizon.

3. Maintain Total Thirty-Minute Operating Reserves

Potential Reliability Gap # 3: The NYISO may be challenged to meet NPCC Operating Reserve requirements to not be deficient in total balancing areas reserves for greater than four hours in response to longer term variations in the levels of intermittent generation.

NYISO Plan for Gap # 3: The NYISO will continue to track applicable NPCC Operating Reserve Standards performance and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Increasing statewide Total Operating (30-minute) Reserve procurement requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Account for increased real time load forecast uncertainty
d. Evaluate the sustainability of 10-minute and 30-minute reserves

Background:

We have noted several times above that the expected increases over the next 10 years in the level of zero or near zero incremental cost wind and solar output, both within the NYISO and in adjacent regions, potentially combined with output related regulatory and tax subsidies will likely cause middle of the day energy prices to gradually fall. These low energy prices will make it more and more costly for the NYISO, and adjacent balancing areas, to keep resources on line at minimum load beyond those needed to provide required reserves and regulation Low energy prices within the NYISO and in adjacent balancing areas during the middle of the day when intermittent resource output is high has the potential to reduce the ability of the NYISO to restore contingency reserves following outages because there will likely be much lower levels of latent reserves available not only within New York but also lower levels of latent reserves on line in adjacent regions. This market tightness will be compounded to the extent that the NYISO uses energy-limited resources, particularly resources with very limited energy supply such as energy storage, to provide spinning reserves. Not only will the NYISO need resources that will enable it to restore 10-minute reserves following contingencies, the NYISO will also need to replace the energy output of energy limited resources whose reserves have been converted to energy that they will not be able to sustain beyond the required one (1) hour minimum period.

The current reserve shortage design of the NYISO for 30-minute reserves would send an efficient price signal for the supply of resources able to provide 30-minute reserves. Hence, the current market design would incent suppliers able to provide 30-minute reserves to offer their supply in RTC so it could be scheduled to provide reserves, and if necessary energy, following contingencies if reserve prices rose due to a shortage of 10- or 30-minute reserves. Moreover, the supply offers of these resources in RTC would provide visibility to NYISO operators of the energy and capacity supply available to restore reserves.

There can, however, be a potential reliability gap to the extent that the resources that would be able to provide additional energy or reserves following a contingency would need to incur costs prior to real-time in order to be able to operate, such as gas fired generators that might need to schedule and potentially sell back gas or demand response resources that would need to take some advance actions in order to be able to provide reserves.

The NYISO current market design is well suited to addressing this potential reliability gap by scheduling additional 30-minute reserves in the day-ahead market, which need not be provided by on-line resources. Moreover, if the NYISO would be willing to go for an hour or more without restoring reserves following a contingency, the NYISO could develop a reserve product with a longer notification and start up time. The NYISO will need to analyze the potential need for replacement reserves as markets in the Northeast evolve over time and set appropriate 30-minute reserve targets and penalty prices. This will include analyzing the impact of relying on energy-limited resource to provide spinning reserves on the amount of replacement reserves needed to maintain reliability following a contingency.

Importantly, replacement reserves can be procured from off-line resources that would not incur minimum load costs in order to be available to restore reserves following a large contingency. If we anticipate energy prices are low during some hours of the day, the NYISO is likely to find it will be efficient and perhaps even necessary to rely much more on off-line units not only to provide contingency reserves but to restore contingency reserves and replace contingency limited energy reserves that have been converted to energy. This will require the availability of resources that can be brought on line within the relevant time frame and perhaps also require the development of different gas supply arrangements for those resources. One change to be evaluated is the availability of gas for replacement reserves if less thermal generation is operating, and less often operating above minimum load and will gas supply be available when gas fired resources need to come on line in the winter. This assessment will also need to take into account future changes in environmental restrictions on burning oil when gas prices are high or gas supply is curtailed. The NYISO may therefore need to develop rules that will ensure that replacement reserves will be available to restore contingency reserves in a market environment in which there are much less latent reserves available in the NYISO or in adjacent balancing areas.

The NYISO already procures 30-minute reserves based on a demand curve so the current design could be used to procure additional 30-minute reserves in the day-ahead market if real-time spot energy prices fall over time and less replacement capacity can be counted on to be on line in the NYISO or in adjacent regions in real-time.[83] However, any future reliance on energy limited resources to provide spinning reserves, 10-minute total reserves and 30-minute reserves will make it extremely important for the NYISO to develop mechanisms for evaluating and managing the energy balance of resources and the balancing area as a whole, both day-ahead, within the operating day and potentially over multi-day forward periods.

4. Maintain Ability to Meet Daily Energy Requirements

Potential Reliability Gap # 4: The NYISO may be challenged to meet NERC control performance requirements managing high levels of intermittent limited energy storage supply resources to meet daily energy requirements in real-time operations.

NYISO Plan for Gap # 4: The NYISO will continue to track applicable NERC Balancing Area Control Performance Standards and operating reserve criteria and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Developing new capability for operator management of limited energy supply resources

83 Another factor that may materially tighten the capacity balance in the northeast are the changes PJM has filed in the design of its reserve market. PJM currently commits for a 30-minute reserve requirement day-ahead which is not enforced in real-time. This design potentially makes substantial additional capacity available in in real-time, although the actual incremental impact is difficult to assess because it also impacts the scheduling of interchange and virtual bids in the day-ahead market. The tariff changes PJM has filed would apply a $2000 per megawatt penalty price to these reserves in real-time, which would effectively make them no longer available to support increased exports to the NYISO following the loss of a generating unit. The eventual impact of these changes in the PJM reserve market are difficult to assess, both because there may be differences between what has been filed and what will be approved by FERC, and because these changes will impact market participant behavior in PJM, New York, MISO and even utilities in SERC. Hence, it will be a few years before the impact of these changes will be apparent, but there will be an impact to tighten real-time markets in the northeast.

b. Increasing statewide ten and/or thirty-minute operating reserve

c. Account for real time load forecast and renewable uncertainty

Background:

If the NYISO becomes more dependent on the output of limited energy storage resources to balance variations in intermittent resource output and potentially relies on these resources to provide spinning reserves and regulation, the NYISO will need to be able to track the energy balance of these resources over the operating day. This information will enable the NYISO to assess the ability of these resources to provide reserves and to balance variations in intermittent resource output and take this capability into account in its dispatch, interchange scheduling and unit commitment decisions. As the role of storage or other energy limited resources expands, it will become increasingly necessary for the NYISO to develop systems for tracking the energy balance of energy limited resources participating in NYISO's energy and ancillary services markets so the NYISO's market and reliability processes do not count on resources being able providing services or supply that they will not be able to provide because of energy limitations.

In addition, the ability of storage resources and other energy-limited resources to efficiently and reliably contribute to balancing variations in intermittent resource output will require that their output be managed over the day to account for their energy limits. Hence, the NYISO will also need a market design that will allow the NYISO and its market participants to efficiently and reliably manage the energy balance of a significant number of resources with limited storage capability both in the day-ahead market and over the operating day, and potentially over multiple operating days.[84] If increases in the amount of energy limited resources relied upon to balance net load cause the NYISO system to at times become energy constrained over periods of hours or potentially days, maintaining reliability could require that the NYISO do more than simply track the state of charge/available supply of energy limited resources. The NYISO may need to track the overall energy balance and adjust dispatch and interchange schedules to maintain or restore the system energy balance in response to unexpected variations in intermittent resource output, transmission or generation outages, or curtailed imports. These energy limits would not only need to be enforced in the day-ahead market but in intra-day unit commitment and interchange scheduling decisions and in the real-time dispatch.[85]

84 In its Order No. 841 compliance filing, the NYISO described its plans to track the state of charge of Energy Storage Resources (ESRs) over the operating day in both the real-time and day-ahead markets. State of charge monitoring will only be applied to resources that are registered as continuously dispatchable, "must-run" ESRs. Operational experience with ESRs over the next several years should inform enhancements to the proposed design. The NYISO's approach to monitoring and/or managing storage energy levels could later be expanded to other types of energy limited resources, such as hybrid resources, pumped hydro, and certain types of DER.

85 For example, with a little storage on the system and enough thermal output to meet load at the net load peak, storage use can be optimized to reduce the output needed from the highest cost thermal resources. The cost to consumers would be reduced, however, if the storage were used to eliminate the need for some of the thermal generation in the capacity market, in which case the storage output would be needed to meet load over the net load peak. This would require that storage be used in a way that ensured it had sufficient charge to meet load in that net peak

The NYISO today largely relies on market participants to manage the use of their energy-limited resources with their offers prices and occasional communications with ISO operations. One approach that the NYISO could take as the role of storage resources increases would be for the NYISO to continue to rely on market participants to manage their energy limits within the current design.

There are, however, a number of reasons that the current approach to managing energy limits may become unworkable, particularly over the operating day, as the NYISO's reliance on batteries and other energy limited resources increases. First, the current management of energy-limited resources relies in part on interactions between resource operators and NYISO operators. These interactions are workable when applied to a small number of large limited energy resources, as is the case today, but would likely be very unworkable if applied to a large number of small energy limited resources.

Second, the current mechanisms for enabling market participants to manage the output of their energy limited resources using their offer prices, relies on ad hoc processes for avoiding mitigation of these offer prices. These mechanisms would likely also become unworkable if applied to a large number of resources. One way to resolve this problem would be to eliminate mitigation of the offer prices of most energy limited resources, but such an approach would need to be thought through and might require some accompanying market design changes.

Third, the current mechanisms are workable with the relatively long time frames for market participant offer price adjustments at least in part because the current energy limited resources have substantial storage relative to their capacity so their energy limits bind over a relatively long period of time. This makes it workable for them to manage their energy limits with offer prices that change once an hour with a 75-minute lag, and an occasional call to the NYISO operators. The current timing for offer price adjustment would likely not provide a workable framework for the operators of batteries and other energy limited resources whose storage to capacity ratio may only be an hour or two, even when full to manage their energy limits because the resources storage could be depleted before the resource operator would have an opportunity to adjust its offer price. Moreover, "occasional calls to operators" are workable if there are a handful of such resources, not if there are hundreds.

Fourth, in the past, energy limited resources in the NYISO market could manage their energy use while

load hour. This would in effect be a system minimum net charge requirement going into that peak hour. With further reductions in thermal generation, the storage output might be used to meet net load over several hours each day in which net load would exceed the output of thermal generation. This would require that storage be used in a way that ensured it had sufficient charge to meet load over those several hours, which could be ensured with a system minimum state of charge going into those several hours. With even less thermal generation and more reliance on storage, there could be overcast humid days on which thermal generation plus intermittent output would not be sufficient to meet load over the day, so the NYISO would need to enforce a system minimum state of charge for the end of the prior day to ensure that enough energy was available to meet load over the following day. While we have described the scenarios above as if the net load over the peak hour, hours or day were known in advance, this would of course not be the case and the NYISO would also need to account for net load forecast uncertainty, as well as the potential for generation and transmission outages, in setting these system minimum state of charge targets.

meeting market needs by reducing their upper operating limit or by offering supply in high output ranges at high prices. These adjustments were effective in managing energy limits in the past because the NYISO needed to use these resources to meet load over sustained periods so reducing the upper operating limit correspondingly reduced energy usage. With increasing levels of intermittent resource output, however, energy use may not be well related to the upper operating limit because resources may be dispatched up for short periods of time to balance variations in intermittent resource output, then dispatched back down when intermittent resource output rises, or other resources are able to ramp up. Hence, while in the past, if a resource was dispatched to an upper operating limit in excess of its day-ahead market schedule, this would generally result in increased energy usage over the hour. This will be much less certain in the future, as resources would often be dispatched above and below their day-ahead market schedule within the hour, potentially with little impact on the energy usage over the hour.

If resources were to continue to use adjustments to their upper operating limits or their offer prices to manage their energy limits as the NYISO resource mix changes, the upper operating limit or offer price that constrains the dispatch of the resource for energy throughout the hour could also constrain its dispatch up and down to balance intermittent resource output, seriously undermining the ability of the NYISO to use storage and other energy limited resources to balance substantial variations in intermittent resource output.

In maintaining the reliability of the New York electric system as the resource mix evolves, it may not be enough for the NYISO to simply analyze the energy balance over the remainder of the operating day or perhaps a long period given the offers of storage resources and rely on market participants to manage the energy state of storage resources. It may also be necessary for the NYISO to take actions to balance energy over the day. This could involve tradeoffs between using energy limited resource to balance load and generation now and refilling storage with imports later or between committed an internal thermal unit or relying on imports. A difficulty that both Ontario IESO and the California ISO have run into in attempting to evaluate the load and energy balance over the operating day, is the offer prices used for the evaluation of future hours are subject to change. Hence, it could appear economic to defer committing a thermal unit and rely on interchange to meet energy needs at the time when an initial evaluation is made, but then interchange prices could rise dramatically in future hours such that it would have been better to commit the resource. Conversely, imports or gas fired generation output may be available in future hours if there is forward financial commitment but may not be available in the time frame of CTS and RTC absent a financial commitment. If these kinds of issues become significant they might be addressed with some form of forward financial commitment based on advisory prices and schedules in a RTC like tool that scheduled generation and interchange.

The NYISO may therefore need to not only track the energy balance of storage and other energy limited resources, changes in the resource mix may require the NYISO to evolve its market design so that the NYISO takes on more responsibility for managing resource energy balance over the operating day. This role would likely require changes in the day-ahead market, in the role of RTC in scheduling interchange and committing generation during the operating day, and in the real-time dispatch (RTD). The changes impacting each of these time frames are briefly outlined below. In addition, if Energy Storage Resources are relied upon to meet load from the standpoint of resource adequacy, the NYISO will need to be able to evaluate, and be able to maintain, energy adequacy over multi-day periods of low intermittent resource output.

Day-Ahead Market

Software vendors already have the capability to enforce energy limits in the day-ahead market. The California ISO has had such limits in its day-ahead market since 2009, primarily to efficiently schedule the output of pondage hydro resources. The Ontario IESO is also planning to implement energy limits in its day-ahead market. The NYISO plans to implement energy limits for Energy Storage Resources in its day-ahead market.[86] This will be a somewhat more complex optimization problem than modeled in the California ISO software because the NYISO will be optimizing injections and withdrawals for Energy Storage Resources.[87]

Intra-Day Interchange Scheduling and Unit Commitment (RTC)

A need to manage energy limits of the overall NYISO resource mix over the operating day would require even larger changes in NYISO systems because for the NYISO to directly manage energy limits over the operating day in scheduling interchange and making unit commitment decisions would require a real-time unit commitment scheduling and dispatch system that would be able to look out at least over the balance of the operating day and potentially into the next day, to enable the NYISO's unit commitment and interchange scheduling decisions to reflect the NYISO's prospective energy balance. The NYISO's RTC only looks out around 3 hours, not nearly far enough out in time to account for daily energy limits within the program's current optimization horizon.

The Ontario IESO plans to account for intra-day energy limits by extending the horizon of its Enhanced Reliability Unit Commitment program to look out over the remaining hours of the operating day, and into the next day after day-ahead market results have posted. This design will require design compromises in

86 See New York ISO filing in FERC Docket ER19-467, December 3, 2019 and proposed MST sections 4.2.1.3.4, 4.4.1.1 and 4.4.1.2.

87 As observed above, as the level of reliance on storage resources to meet load increases, it may become necessary for the day-ahead market software to enforce minimum system state of charge requirements to ensure that enough energy will be available to the system to meet net load over the following day.

order to maintain a workable solution time, such as analyzing future intervals with hourly granularity. The California ISO has also examined extending the horizon of its look-ahead program, STUC, but these changes have been deferred for now.[88]

It is important for the NYISO to retain the 15-minute granularity of the RTC for interchange scheduling and evaluating commitment of quick start resources. If the NYISO were to take on a role of managing daily energy limits, and sought to optimize energy use over the day, the NYISO could consider approaches such as using an hour time step for the evaluation of the energy limit over periods many hours in the future.

On the other hand, if most of the Energy Storage Resources entering the New York market are short-term low capacity storage resources such as batteries, there may be little economic benefit from managing the storage levels of these resources over the day. If this is the case the NYISO might be able to use RTC with its current look-ahead timeframe for short-term management of resource energy limits, with minimum and maximum energy constraints (or state of charge constraints) for RTC based on day-ahead market schedules, or market participant offers, to manage longer term energy limits.

To the extent there are storage resources with larger storage capacities that need to manage daily energy limits, or resources with other types of daily energy limits (such as gas fired generation with a fixed supply of gas available over the day) the NYISO could utilize its current RTC look-ahead design, combined with minimum and maximum state of charge constraints and energy opportunity costs to manage resource energy limits. Energy limits, state of charge constraints and opportunity costs for the RTC look-ahead could be derived from day-ahead market schedules over the remainder of the day, updated over the day based on actual resource energy use or specified by the resource operator and updated each hour over the day. The schedules and opportunity costs calculated in RTC could then flow into RTD in the form of energy limits and opportunity costs.

Real-Time Dispatch (RTD)

There would also need to a way to reflect resource energy limits in the real-time dispatch, which currently looks out only an hour. There are a number of ways energy limits, state of charge constraints and/or opportunity costs could flow from RTC into RTD with a variety of strengths and weaknesses. While Order No. 841 imposes tariff requirements on the NYISO relating to the way storage resources would be enabled to participate in the NYISO market, it is not assured that either Order No. 841 requirements, nor the proposed storage resource designs of the NYISO or other ISOs will enable low capacity storage

88 http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=866A4566-F461-49F1-95EA-1B758E6BAAC7

resources to profitably participate in NYISO markets or to make a material contribution to balancing variations in intermittent resource output.

Depending on the evolution of the NYISO resource mix, the NYISO might need reliability mechanisms that would commit suppliers to provide specified amounts of energy over the next day, or perhaps multiple days. These changes would influence the gas scheduling (and oil stock) decisions of thermal generators, the use of water in storage and the supply of power from external balancing areas.

5. Transmission Operations and Congestion Management

Potential Reliability Gap # 5: The NYISO may be challenged to meet NERC Transmission Operations requirements when operating under high levels of intermittent generation with system and locational demand requirements that may be difficult to forecast in real-time operations.

NYISO Plan for Gap # 5: The NYISO will continue to track applicable NERC, NPCC, and NYSRC Transmission Operations Standards and implement necessary operational and market changes in order to maintain acceptable performance. Such changes are detailed in the following section and include:

a. Increasing transmission facility constraint reliability margins

b. Increasing locational ten-minute spin and total operating reserve requirements

c. Increasing locational thirty-minute total operating reserve requirements

d. Investigating the need for a locational (zonal) ramping product

e. Account for increased real time load forecast uncertainty

f. Monitor and manage sustainability

Background:

If the NYISO shifts to an operational pattern in which there are few thermal resources on-line during the peak intermittent resource output periods, the NYISO will need to ensure that it can continue to operate the transmission system in accordance with all applicable reliability requirements. As was the case when coal fired generation retired in western New York, the NYISO may find that new transmission constraints will bind that are difficult to manage given the lack of dispatch capability and impacts associated with intermittent resources. In addition, the implications of having reduced amounts of thermal generation on line and able to be dispatched up will need to be evaluated and addressed in the planning process as well as in the day-ahead market and real-time operations.

The NYISO should evaluate the potential variability in solar or offshore wind resource output within constrained regions in eastern New York and assess whether this variability would need to be modeled in contingency analysis to avoid transmission overloads. If there is a reliability need to model these output reductions as contingencies, the NYISO could consider developing systems that would evaluate these contingencies dynamically, linking the size of the contingency being protected against to the level and location of solar or wind output.

The NYISO may need new real-time tools that can analyze the transmission system impact of large reductions in intermittent resource output within constrained regions and dispatch the system to avoid overloads and commit or dispatch generation to ensure that the NYISO will be able to reduce flows following large reductions in intermittent resource output. These issues will include consideration by the NYISO and reliability organizations of modeling changes in intermittent resource output in a manner similar to generation or transmission outage contingencies.

The NYISO will also need to review the modeling of intermittent resources within the planning horizon and how potential levels of intermittent resource output should be accounted for in forward analyses of transmission security.

a. Increasing Transmission Facility Constraint Reliability Margin

In the near-term, the NYISO may have to rely on addressing these transmission operating reliability issues by increasing the reliability margin that the energy market models consider when securing transmission facilities. The constraint reliability margin typically ranges today from 10MW to 50MW. These margins could be increased to account for increased uncertainty in intermittent resource output and load forecast uncertainty.

b. Increasing Locational Operating Reserve Requirements

Another action to ensure that dispatchable resources are available to manage transmission operations would be to establish locational reserve requirements for those areas of the New York State transmission system that are expected to be subject to transmission constraints. There are currently locational reserve requirements for the Eastern New York, Southeast New York, and Long Island Zones, and the NYISO has recently implemented a NYC Zone requirement.[89] Today, the values of locational reserve requirement are based on an expected need for generation response capability to address a locality transmission or generation contingency and a forecast of the zonal demand during the response period (typically a 30-minute period to re-secure the transmission system). Under a future system with high levels of intermittent resources, the values for locational reserve requirements may need to be increased to reflect the generation response uncertainty as well as the load forecast uncertainty in the response period and might

89 See New York ISO filing in FERC Docket ER19-1678 April 26, 2019, accepted by FERC June 21, 2019.

need to also manage resource energy limits so as to maintain sufficient energy within potentially transmission constrained regions.

c. Investigating the Need For a Locational Ramping Product

Similar to the discussion for a ramping product for balancing load and generation, there may be benefits to having a ramping product available on a locational basis to address those areas of the New York State transmission system that are expected to be subject to transmission constraints. Such a locational ramping product could provide an additional means (in addition to that provided by locational reserve requirements) to ensure sufficient locational dispatch capability is available to manage transmission operations.

6. Restoration and Black Start Capability

Potential Reliability Gap # 6: The NYISO may be challenged to effectively restore the system within expected timeframes following a blackout given a system with high levels of intermittent generation.

NYISO Plan for Gap # 6: The NYISO will implement and monitor the effectiveness of established NERC and NYSRC Standards and procedures that require acceptable statewide and NYC restoration and black start capability performance are maintained as system changes occur through time. Such changes are detailed in the following section and include:

a. Annual Review and Update of Restoration Plan
b. Coordination of NYISO and Transmission Owner Restoration Plans
c. Facilitate participation of resources in the Con Edison Restoration Plan

Background:

There are already a number of comprehensive reliability requirements established by the NYS Reliability Council (NYSRC) that require the NYISO to develop and maintain a NYCA System Restoration Plan (SRP) that provides assurance that the NYCA system will be restored in a safe and orderly manner and as promptly as reasonable possible following a major or total blackout. The NYSRC also requires that Each *Transmission Owner* shall establish and maintain a restoration plan that shall be coordinated with the restoration plans of other *Transmission Owners* and shall be part of the NYCA System Restoration Plan. Lastly, the NYSRC requires that the NYISO facilitate the participation of black start capable resources for the Con Edison Restoration Plan.

a. Annual Review and Update of Restoration Plan

Current NYSRC reliability rules already provide for an annual review and update of the NYISO system restoration plan. This review process would provide the framework for the NYISO to analyze the impact of changes in the NYCA resource mix on the system restoration plan and make necessary changes on an ongoing basis. [90]

b. Coordination of NYISO and Transmission Owner Restoration Plans

Current NYSRC reliability rules already provide for coordination of NYISO and Transmission Owner Restoration plans. This coordination will continue to occur in the future and enable collective assessment of the impact of changes in the NYCA resource mix on the system restoration plan.

c. Facilitate Participation of Resources in the Con Edison Restoration Plan

The NYISO will continue to coordinate participation of resources in the Con Edison system restoration plan.

7. Voltage Support

Potential Reliability Gap # 7: The NYISO may be challenged to meet NERC, NPCC, and NYSRC voltage performance requirements for a power system with high levels of intermittent generation.

NYISO Plan for Gap # 7: The NYISO will continue to study voltage performance in both the long-term planning and short-term operating timeframes and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Study voltage performance in long-term planning timeframe (RNA)
b. Study voltage performance in short-term planning timeframe (Operating Studies/Limits)
c. Investigate the potential for new resource types to supply reactive capability

Background:

The provision of voltage support will potentially be impacted in several ways by the prospective changes in the NYISO resource mix. First, with fewer thermal units on line and more output provided by asynchronous resources it may be necessary to at times rely on asynchronous resources to provide voltage support.

Second as energy prices fall during the peak solar hours and at times when wind generation output is high, it will become increasingly necessary to commit thermal resources specifically to provide voltage support, because few thermal resources will be committed based on economics during some periods of the day.

90 The rule can be found in the NYSRC, Reliability Rules and Compliance Manual, April 11, 2019 section 2B2B pp. 26-27 Transmission System Planning Assessments.

Third, low energy prices will make it very expensive to commit thermal generation at minimum load to provide voltage support, with the result that thermal resources committed to provide voltage support will incur large losses on their minimum load output.

With respect to the first change, the potential need for the NYISO to rely more on voltage support provided by asynchronous resources is largely covered by FERC Order No. 827 requirements and the changes in the NYISO large and small generator interconnection agreements that were approved in FERC Docket ER17-61. In addition, the NYISO will assess the need for models, perhaps built into the day-ahead market, to evaluate the need to commit resources for voltage support, rather than continuing to rely on occasional commitments in real-time as is done today.

While FERC Order No. 827 requirements should largely address near term changes in NYISO voltage support needs, the California ISO's experience with operations with high levels of intermittent resource output caused it to include some additional requirements in its Order No. 827 compliance filing, as permitted by the FERC order. These requirements were included in ER17-490. One of these requirements was a prohibition on resources disabling voltage regulation controls when the resource is in operation, without the permission of the ISO. As the NYISO resource mix evolves over time, the NYISO will continue to evaluate the need for rules enabling the supply of voltage support from a wider range of resources or under a wider range of conditions in New York.

With respect to the second change, with less need to commit thermal resources to meet energy demand, and a likely higher cost of committing these resources out of market to provide voltage support, it will become more important to take account of voltage support needs in the day-ahead market solution. Moreover, because voltage support needs are local, the NYISO will need voltage support within specific narrow regions, not necessarily at the locations at which resources able to provide reactive power without incurring substantial commitment costs may be located. Hence, another set of changes the NYISO might implement to better meet these reliability needs would be to model commitments for voltage support in the day-ahead market, so that commitments of other resources would be made taking into account the output and reserves of resources that would be committed to provide voltage support.[91]

A consequence of the third change is that the NYISO may need to consider changes to its compensation design for voltage support to incent the development of resources able to meet New York voltage support needs at lower cost. Uplift payments to thermal units committed out of merit to provide voltage support do not provide a price signal for the development of resources able to provide voltage support at lower cost

91 The development of such a process would not be simple, as it should not only commit resources at least-cost but also avoid distorting the bidding incentives of resources committed for voltage support.

and these uplift payments have the potential to distort the energy and reserve offer prices of thermal resources able to provide voltage support. Hence, in a longer time frame the NYISO may find it desirable to eliminate the current compensation design for voltage support in which all resources receive payments based on accounting allocations of voltage support related costs and shift to a design that would better support competition among a variety of resource types that would be able to provide voltage support. These changes in the compensation design might be accompanied by the use of the planning process to identify the potential to meet voltage support needs at lower cost through installation of more voltage control devices.

8. Frequency Response

Potential Reliability Gap # 8: The NYISO may be challenged to meet NERC, NPCC, and NYSRC frequency performance requirements for a power system with high levels of intermittent generation.

NYISO Plan for Gap # 8: The NYISO will continue to study frequency performance in both the long-term planning and short-term operating timeframes and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Study frequency performance in short-term planning timeframe (Operating Studies/Limits)
b. Investigate the potential for new resource types to supply frequency response capability

Background:

The NYISO's frequency response obligations will be determined by NERC, reflecting changes in the resource mix across the eastern interconnection. Various NERC studies indicate that frequency response will become more of a reliability issues as less thermal generation is on line. The NYISO will likely want to anticipate these requirements. Some of the performance factors that the NYISO will need to review are the potential need to commit generation to meet NERC requirements, rules limiting the circumstances in which plant level controls on synchronous generators can be set to override frequency response (and perhaps requiring notification of the NYISO when plants are operating in this mode), modeling the output range in which synchronous resources can provide governor response, introduce frequency response performance requirements, develop NYISO systems that model the amount of available frequency response and adjust dispatch and commitment to meet NERC targets.

The NYISO's Order No. 842 Compliance filing addresses near term needs for frequency response from both generation and storage resources such as batteries.[92]

92 See NYISO filing in FERC Docket ER18-1620`

9. Maintain Resource Adequacy

Potential Reliability Gap # 9: The NYISO may be challenged to maintain acceptable levels of resource adequacy.

NYISO Plan for Gap # 9: The NYISO will continue to monitor resource supply capability relative to targets (IRM) for the both the long-term planning and short-term operating timeframes and implement necessary operational and market changes. Such changes are detailed in the following section and include:

a. Monitor supply relative to LOLE in long-term planning timeframe (RNA)
b. Monitor supply relative to IRM in shorter-term planning timeframe (ICAP Market)
c. Ensure reliability operating characteristics

Background:

Beyond the time frame of the operating day, the NYISO will need to ensure that there are appropriate financial incentives for investment in resources able to provide balancing services. These investment incentives could in principle be provided through capacity market or energy market incentives but there are a number of practical issues with both approaches that will need to be considered. First, assessment of reliability needs will become more complex as the level of thermal generation is reduced and replaced with the output of intermittent resources and storage. Second, the determination of capacity resource requirements, such as minimum output duration, will become more complex as the level of intermittent resource output and reliance on energy limited storage resource increases. Third, setting requirements for and incenting capacity resource performance will become more difficult as the need for flexible capacity increases. Each of these changes is discussed briefly below.

Reliability Needs

When intermittent resources participate in the capacity market, they result in an economic displacement in the capacity market of the need for traditional resources to the extent the intermittent resources are assigned capacity value. As increasing amounts of intermittent resources are added to the system, their incremental capacity value and hence their ability to displace other resources should be expected to decline due to the common operating characteristics of the intermittent resources and their incremental contribution to reliability in meeting system load requirements. For example, large additions of solar resources may result in the shifting of the observed net peak load (load net of intermittent resource output) into evening hours when solar resources generate little or no output. Changes in the makeup of the resource fleet and the consumption patterns of electricity will require the NYISO to evaluate whether resource adequacy needs, and resource capacity values, continue to be defined by heat wave driven summer peak loads, or will need to shift to resource adequacy needs in alternative situations. The NYISO will need to continue to evaluate each resource's contribution to reliability to ensure the NYISO capacity market is not overstating the incremental capacity value of particular types of resources, leading to an inaccurate displacement in the capacity market of resources that are needed to maintain reliability.

As the NYISO resource mix evolves towards greater reliance on intermittent resource output and energy limited storage resources, assessment of the need for thermal capacity to meet reliability targets will require assessment of ramp needs and energy balance. With respect to ramp needs, the California ISO projects minute by minute future ramp needs, based on historical profiles and future resource mix, as part of its resource adequacy needs assessment. The California ISO analysis also projects the distribution of the maximum daily 3-hour ramp and the distribution of the secondary net load ramp.[93] Assessing the frequency and seasonal pattern for maximum ramps is important in evaluating the ability of the resource mix to meet the ramps. As the level of resource output in New York rises, the NYISO's process for setting the LCR and IRM may need to take account of these ramp capability needs. This would require modeling resource ramp capability and taking account of resource limits impacting the availability of ramp. Some resources may have use limits such as start limits, energy or emission limits, which constrain how often they will be able to provide ramp. There may also be a seasonal pattern to the availability of some resources,[94] which may also limit their value in meeting peak 3 hour ramps during some times of year. In addition, to the extent storage resources are used to provide capacity, and hence displace thermal generation, the NYISO's process for setting the IRM and LCR will need to take account of energy limits over the operating day, and potentially over multiple days.

Accounting for ramp needs and energy limits appears likely to materially impact the kind of analysis that is required to set the LCR and IRM and these changes will become larger as ramp needs and energy limits increase over time.

Resource Requirements

The increasing importance of ramp capability and energy limits in reliably meeting NYISO load will impact many requirements for capacity resources used to balance net load, such as ramp rates, notification and start-up times, minimum load levels, minimum run times, number of starts per day, number of hours the resource can sustain output, seasonal and time of day availability. Setting these requirements will become more complex, not only because of the complexity of modeling how these characteristics impact the IRM and LCR, but also because the need for particular characteristics from incremental capacity

93 See, for example, California ISO, Final Flexible Capacity Needs Assessment for 2020, May 15, 2019 Pp. 12-14

94 This could be the case for demand response based on curtailing load, which might only be consuming power during some times of the year.

resources depends on the aggregate characteristics of the capacity resources that will be used to meet the IRM.

Financial Performance Incentives

The shortage pricing design of the NYISO real-time market should provide a sound framework that can be used to incent the development, investment in, and performance of resources able to balance load and generation in the time frame of the real-time dispatch. The NYISO design in which the scheduling of energy and ancillary services is co-optimized in the real-time dispatch should be effective both in providing balancing and in sending efficient price signals. However, as observed above there is a potential for the structure of the subsidies provided to low emission resources to produce such negative real-time prices that the effectiveness of real-time pricing incentives in the NYISO energy market is greatly diminished by the prevalence of uneconomic real-time commitments and widespread real-time bid production cost guarantee payments. In addition, if a material amount of intermittent resources operate under contracts whose subsidy design incents them to offer supply at extremely negative prices, the resulting extreme level of real-time price volatility could discourage participation the NYISO's real-time dispatch.

Another approach to incenting investment in flexible capacity would be to include flexible capacity requirements in the NYISO capacity market. The California ISO implemented an initial flexible capacity requirement in November 2014, covering the 2015 capacity year.[95] In June 2015, the California ISO began its effort to develop a "durable" flexible capacity requirement with an issue paper identifying the need to refine the initial design to address the need for additional ramping speed to meet rising one-hour ramps and the need for downward flexible capacity.[96] The development of the flexible capacity requirement continued into 2018 with the publication of the Second Revised Flexible Capacity Framework in April 27, 2018.[97] By 2018, the California ISO's view of its flexibility needs had evolved towards concerns with reliance on slow starting generation with long minimum run times and high minimum operating points.[98] The 2018 design document provided for the procurement of three distinct types of flexible capacity, 5-minute flexible, 15-minute flexible and day-ahead load shaping capacity.[99] The effort was suspended in July

95 The California ISO's effort to develop a flexible capacity requirement began in December 2012 with the straw proposal for the initial flexible capacity requirement that was filed with FERC on August 1, 2014 in FERC Docket ER14-2574 and implemented beginning November 1, 2014 to cover the 2015 capacity year.

96 See California ISO, Reliability Services Initiative – Phase 2 and Flexible Resource Adequacy Criteria and Must Offer Obligation – Phase 2: Issue Paper," June 25, 2015.

97 By 2018 the California ISO was no longer concerned with the need for downward ramp as more intermittent resources began submitting economic offers that allowed them to be dispatched down (likely a result in changes in the structure of the subsidies in utility RPS contracts that were intended to incent participation in the California ISO's economic dispatch).

98 See California ISO, Second Revised Flexible Capacity Framework, April 27, 2018, p. 3

99 See California ISO, Second Revised Flexible Capacity Framework, April 27, 2018, p. 4

2018, however, in part because of delays in the timing for developing changes to the California ISO day-ahead market.

The California ISO's experience with this resource adequacy design illustrates how complex such a capacity market approach would need to be if it were relied upon to incent investment in the kind of resources needed to most effectively and efficiently balance variations in intermittent resource output. In particular, the flexibility provided by a resource depends not only on its physical characteristics such as ramp rate, start-time, minimum load level, minimum run time, minimum down times, daily, monthly and annual start limits, energy limits, and emission limits, but also on its offer prices and parameters. Moreover, there is not a single type of flexibility that is needed but rather flexibility is needed in a variety of time frames that might be provided by different types of resources, and the amount of flexible capacity of a given type that is needed depends in part on the characteristics of all of the other capacity.

These considerations will make it very difficult to specify and meet resource flexibility needs through capacity market requirements, difficult for load serving entities to procure through bilateral contracting if they must assemble a portfolio of resources meeting a number of different capacity requirements, and difficult for the NYISO to clear a demand curve. The complexities of managing such a procurement process for multiple flexibility capacity attributes have apparently been a consideration in the California Public Utilities Commission seeking to shift to some kind of central procurement mechanism, which has raised additional design and market questions.

In California, the flexible capacity requirement has been non-binding despite the California ISO's concerns with the availability of sufficient flexible capacity and the California ISO has been engaged for several years in an ongoing review of changes to the flexible capacity requirement to better focus the requirement on procuring the kind of capabilities the California ISO needs to balance load and generation with a high level of intermittent resource output.

10. Ability to Manage Supply Resource Outage Schedules

Potential Reliability Gap # 10: The NYISO may be challenged to manage supply resource maintenance outage scheduling.

NYISO Plan for Gap # 10: The NYISO will continue to monitor its procedures for supply resource outage schedule to determine whether additional operational and/or market changes should be implemented to help maintain operating capability targets throughout the year.

Background:

The NYISO will continue to play a role in coordination generation and transmission outages and will develop load and reliability forecasts that will assist generation and transmission owners in scheduling both long and short-term outages in periods in which they are less likely to adversely impact reliability.

Increases in intermittent resource output may lead to changes in the seasonal pattern of net load variations, making it more difficult for generation owners and the NYISO to schedule generation maintenance at times when the capacity is unlikely to be needed. This has already been happening in the MISO, with the result that the MISO has run into generation shortages during what are normally considered to be off peak portions of the year. This has led the MISO to make changes in its generation outages scheduling process with the dual goal of better coordinating long-term outages and providing better information to generation owners on windows for scheduling short-term outages.[100]

Pay for performance capacity market designs can potentially contribute to improved outage scheduling outcomes by incenting capacity suppliers to avoid outages during reserve shortages, but these designs only take into account capacity needs, they do not reflect resource needed to provide other essential reliability services within a local area, such as voltage support, frequency response, or transmission security. In addition, if periods of potential capacity shortage are a result of a combination of variations in intermittent resource output and the outage schedules of other capacity suppliers, individual market participants may depend on the ISO to coordinate outages in a manner that enables the supplier to schedule outages in periods that reduce the risk of pay for performance penalties.

It is important to recognize that it will not be possible to maintain reliability simply by requiring that all outages be scheduled years in advance as there will be forced outages and other changes in conditions that will never be predictable in such a time frame. Hence, there needs to be a design that achieves several distinct goals for different kinds of resources and outages. First, for resources with very long outages that must be scheduled well in advance and have substantial impacts on the supply balance, such as nuclear refueling outages, a long-term scheduling process will be needed. Second, as the MISO has found, there also needs to be a short-run scheduling process for outages with shorter durations and whose need cannot be predicted far in advance. In addition to evaluating the reliability impact of proposed short-term outages and perhaps implementing additional rules to govern their scheduling, the NYISO may want to assess the MISO's design for providing information to market participants on the projected resource balance over future periods that would be impacted by scheduled outages so that market participants can try to shift outages into favorable period.

100 See MISO January 30, 2019 filing in FERC Docket ER19-915.

Third, the NYISO could consider whether there are changes to its current processes that would better facilitate short-run scheduling of short outages to take advantage of favorable (i.e. low net load) weather conditions (similar to the process for the scheduling of short-term transmission outages to take advantage of favorable conditions).

Fourth, the relative importance of energy and capacity market revenues is important in providing incentives for generation owners to not only schedule outages as permitted by the NYISO but also to complete the outage as quickly as is feasible. If almost all resource revenues are earned in the capacity market and the resource is insulated from capacity market penalties if it schedules the outage sufficiently far in advance, the resource operator will not have efficient incentives to minimize outage length. This will become more of a concern as the level of intermittent resource output rises and the predictability of net load declines as long outages can contribute to reliability problems, even if they are scheduled long in advance if conditions change.