New York ISO
Independent System Operator

5-Minute Transaction Scheduling

A Report by the
New York Independent System Operator

October 2020

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Purpose

The purpose of this paper is to evaluate the feasibility of scheduling external transactions on a 5-minute basis and to identify considerations that would need to be addressed to implement 5-minute transaction scheduling. The New York Independent System Operator, Inc. (NYISO) first provides a background on current bidding and scheduling practices for external transactions. This information provides the necessary background to understand the key concepts that would need to be addressed during the market design process, and areas which would require further analysis and discussion before the NYISO could implement 5-minute transaction scheduling with its neighbors.

Background

The potential benefits of more frequent transaction scheduling include providing additional scheduling flexibility to respond to changes in system conditions, improving convergence between NYISO's Real-Time Commitment (RTC)[1] and its Real-Time Dispatch (RTD),[2] and promoting more efficient use of interregional transmission facilities. In NYISO's 2017 Market Assessment with 50% Renewables, more frequent transaction scheduling was identified as a market concept that could help the NYISO to manage real-time uncertainty due to the entry of large amounts of renewable resources whose output fluctuates.[3] In the NYISO's 2019 Grid in Transition report, the NYISO noted that more frequent transaction scheduling would contribute to its ability to meet future grid challenges, such as expected increases in net load variability that may arise with high levels of intermittent renewable and distributed energy resources.[4] More frequent transaction scheduling could (1) provide pricing and investment signals necessary to incent development of resources capable of resolving dynamic system needs, (2) expand the set of resources available to balance the system, and (3) expand the capability of the New York Control Area (NYCA) and neighboring systems to efficiently provide power and procure power. In order to realize

[1] RTC employs 15 minute scheduling intervals and looks forward approximately 2.5 hours in developing least production cost schedules. RTC's operation is explained in greater detail below.

[2] RTD employs 5 minute scheduling intervals and looks forward approximately 1 hour in developing a least production cost dispatch. The RTD LBMP is ordinarily the price that is used in real-time settlements (there are some exceptions for External Transactions). RTD's operation is explained in greater detail below.

[3] See *2017 Market Assessment with 50% Renewables*, available at the following link: https://www.nyiso.com/documents/20142/1404721/2017%20Market%20Assessment%20with%2050%20percent%20Renewables%20Report.pdf/9780266a-f5e2-6049-f4f0-105322a2be92

[4] See *Reliability and Market* Considerations *for a Grid in Transition*, available at the following link: https://www.nyiso.com/documents/20142/2224547/Reliability-and-Market-Considerations-for-a-Grid-in-Transition-20191220%20Final.pdf/61a69b2e-0ca3-f18c-cc39-88a793469d50

these benefits, both willing market participants and improvements to transaction scheduling are required. This paper will focus on necessary improvements to transaction scheduling practices.

Transaction scheduling is the mechanism used by NYISO to schedule energy transfers, or interchange, between neighboring control areas. External transactions involve the purchase and sale of energy imported, exported, and wheeled-through the NYCA to establish scheduled interchange. In addition to internal generation, interchange is used to meet demand within NYCA. Additionally, internal suppliers may seek to export energy to external control areas. NYISO has ties with four control areas: ISO-New England (ISO-NE), PJM Interconnection, LLC (PJM), Hydro-Quebec and Ontario's Independent Electric System Operator (IESO).

NYISO currently economically schedules external transactions on either an hourly or intra-hour (15 minute) basis. Prior to 2011, all external interfaces were scheduled hourly. Starting in 2010, under NYISO's Enhanced Interregional Transaction Coordination (EITC) initiative, the NYISO pursued more frequent transaction scheduling. Fifteen minute scheduling with neighboring control areas was first activated at the Chateauguay interface with Hydro-Quebec on July 27, 2011. Between July and November 2012, NYISO activated 15-minute scheduling at all of its interfaces with PJM. The next external transaction improvement NYISO developed was Coordinated Transaction Scheduling (CTS). CTS Bids are based on the expected price spread between two neighboring markets. If the expected price spread equals or exceeds the minimum required price spread specified in a CTS Bid, then the external transaction may be scheduled if there is room on the interface. The NYISO first activated CTS with PJM on November 4, 2014. The NYISO activated CTS with ISO-NE on the Northern NY AC interface (or Sandy Pond Proxy) on December 15, 2015.

Today, binding external transaction schedules are determined by NYISO's RTC software depending on the scheduling frequency available at each interface. These schedules are treated as fixed interchange in RTD. The different types of transactions and scheduling bid types are discussed below.

It is important to understand the current state of transaction bidding and scheduling within the NYISO energy market before discussing the considerations necessary to facilitate 5-minute transaction scheduling. Through a discussion of NYISO's current practices, the key processes and mechanisms which would need to be modified in order to support a 5-minute transaction construct within NYISO's real-time market (RTM) are identified. The background topics which are discussed below include:

- Type of transaction and scheduling bid types
- Proxy buses
- Ramp capacity limits
- Electronic-Tags (E-Tags) and checkout

- Day-Ahead Market (DAM) scheduling
- RTM scheduling
- Settlements

Following the evaluation of NYISO's current processes is a discussion of the potential modifications that would be necessary to support 5-minute transaction scheduling in NYISO's energy market.

Current External Transaction Bidding and Scheduling Practices

Types of Transactions and Scheduling Bid Types

There are several different categories of transactions which can be used to distinguish differences between the bidding and scheduling of transactions: LBMP, CTS, wheel-through, and bilateral. For all types of transactions, the point of injection is referred to as the source, which indicates where the power is coming from. The point of withdrawal is referred to as the sink, which indicates where the power is going to. Please see the Appendix for more details on transaction types and scheduling bid types.

- LBMP import and export transactions: Transactions to import or export energy between an external interface and the NYCA. The manner in which the bid curve is structured varies based on the direction of the transaction (e.g. import or export). Import bids are referred to as decremental bids, representing the quantity of MWs that a transaction bidder is willing to sell at various price points. Export bids are referred to as sink price cap bids, representing the quantity of MWs that a transaction bidder is willing to purchase at various price points.[5]
- CTS transactions: CTS is a transaction scheduling mechanism available at CTS-enabled PJM and ISO-NE interfaces in the RTM. CTS allows the scheduling of energy based on the projected price differences between the market areas.
- Wheel-through transactions: Transactions seeking to purchase transmission service with both the source and sink outside of the NYCA. A wheel-through bid is economically evaluated against the congestion cost of the transaction, which is determined by the difference between the LBMP congestion components at the sink and the source.
- Bilateral transactions: Transactions with a direct energy contract between two parties, such that the price of energy is not a part of the NYISO settlement. Bilateral transactions include import, export, and internal.

Proxy Buses

For external control areas, the NYISO has selected a proxy bus outside of the NYCA to represent the location in the adjacent control area at which LBMP prices are calculated. These external proxy bus locations are chosen based on their electrical properties and ability to simulate an accurate distribution of

[5] See Appendix section *Scheduling Bid Types* for more information on the various types of bids.

flows across all tie lines that connect the NYCA and its neighbor. For scheduling external transactions, the external proxy bus represents the generator bus for importing transactions or load bus for exporting transactions. The proxy buses for each external control area are identified in the Appendix and in Section 4.4.4 of the Services Tariff.

Ramp Capacity

NYISO's DAM and RTM consider ramp capacity at its external interfaces. Ramp capacity is the amount of change in Desired Net Interchange (DNI) that generation located in the NYCA can support at any time. Ramp capacity limits are calculated for all NYCA interfaces collectively (referred to as NYCA ramp) and at specific interfaces with neighboring control areas (interface-specific ramp limits).[6] Ramp capacity limits are set for scheduling changes at the top of the hour in the DAM and every 15 minutes in the RTM. Ramp capacity limits are established to ensure that NYISO is able to effectively maintain reliability as generation and interchange schedules change.

NERC Electronic-Tags (E-Tags)

The North American Electric Reliability Corporation (NERC) requires that an E-Tag be created by the Market Participant for each external interface transaction bid, in order to identify transactions to all appropriate control areas. E-Tags are submitted by a Market Participant through a centralized database which automatically notifies NYISO and the applicable external control area of the transaction or tag.

Under NYISO's existing market rules, a transaction offer will only be evaluated in the RTM if at the time of market close (75 minutes prior to the dispatch hour), the transaction bid's E-Tag Status is marked as Valid. The NYISO will only approve the E-Tag request if the information in the E-Tag is consistent with the bid that was submitted in the NYISO's Joint Energy Scheduling System (JESS). After the RTM bidding window closes, a Market Participant may not further adjust the E-Tag. For intra-hour transactions, the NYISO or a neighboring Balancing Authority[7] may update an E-Tag multiple times in response to changing economic schedules and/or the checkout process.

[6] For example, at the Hydro-Quebec Chateauguay-Import/Export interface, the RTM ramp capacity limit is 700 MW at the top of the hour, and 200 MW over the course of the rest of the hour. In other words, the maximum amount of change in scheduled flows at that interface would be 700 MW at the top of the hour, and 200 MW for schedules every quarter hour. NYISO's External Interface Interchange Ramp Capacity Limits are available from the NYISO website. For details on NYISOs Ramp Capacity limits, see: https://www.nyiso.com/documents/20142/3694424/External_Interface_Interchange_Ramp_Limits.pdf/00782f62-bcfc-703e-bf00-15904977647d

[7] *See* Section 35.2.1 of the OATT.

Economic Scheduling, Evaluation and Checkout

Real-Time Market transaction bids which have passed NYISO's initial validations are next economically evaluated by RTC. Following the economic evaluation step, NYISO verifies that the transaction is acceptable with the relevant Balancing Authority through a process known as checkout. During the checkout process, the NYISO and other external control areas confirm the information in the E-Tag, including the source, sink, and MW of the transaction schedule. If the checkout process passes, the transaction is accepted and will flow at the agreed upon level. For hourly transactions, the evaluation and checkout process occurs once an hour, with checkout occurring approximately 30 minutes prior to the dispatch hour and following the posting of binding transaction schedules determined by RTC_{15}. For intra-hour transactions, the evaluation and checkout process occurs every 15 minutes, with checkout occurring approximately 15 minutes prior to the dispatch interval.

Day-Ahead Market (DAM) Scheduling

Day-Ahead transaction scheduling begins with MPs submitting bid data into JESS. Finalized Day-Ahead bids must be submitted by 05:00AM on the day prior to the operating day. After completing a validation process, bids entered into JESS are passed along to the Market Information System (MIS), which feeds relevant data to be evaluated in the Security Constrained Unit Commitment (SCUC) as an input to generate day-ahead commitment schedules. SCUC uses four passes with the objective function of each pass to minimize the total production cost of supplying power to meet load, providing sufficient Ancillary Services, committing Capacity to meet Load Forecast, meet Local Reliability Rules, and meet all Bilateral Transactions submitted in Day-Ahead. SCUC produces schedules and LBMPs for each hour of the operating day. External Transactions are economically evaluated based on data entered into JESS, and the resulting day-ahead schedules are subject to verification by external control areas. Schedules created by SCUC are passed back to MIS, which passes approved External Transactions to internal software that NYISO personnel use to monitor ongoing transactions in both the Day-Ahead and Real-Time scheduling and dispatch processes.

Real-Time Market (RTM) Scheduling

NYISO's RTM include two separate programs, RTC and RTD.

Real-Time Commitment (RTC)

RTC re-evaluates all accepted DAM bids that passed NYISO's day-ahead checkout with external RTOs, and evaluates all new real-time transactions. Market Participants may modify transaction bids that were previously scheduled in the Day-Ahead Market for economic evaluation in RTC, after the Day-Ahead schedule is published and no later than 75 minutes before each dispatch hour. The RTC runs every fifteen

minutes and looks ahead two-and-a-half-hours while simultaneously co-optimizing energy, operating reserves, and regulation service schedules for internal resources and external transactions on a least cost production basis over its optimization horizon. Each RTC run contains a designation indicating the time at which results are posted, "RTC_{00}", "RTC_{15}", "RTC_{30}", and "RTC_{45}". The posting of results for each RTC run occurs fifteen minutes before the actual operating period.

For intra-hour transactions, each RTC run (RTC_{00}, RTC_{15}, RTC_{30}, and RTC_{45}) evaluates bids and produces binding transaction schedules for periods beginning fifteen minutes after its scheduled posting time and produces advisory schedules for the remainder of the optimization period. For hourly external transactions, RTC_{15} establishes binding transaction schedules for the next one-hour period and produces advisory schedules for the remainder of the optimization period.

Coordinated Transaction Scheduling

During the real-time optimization, a CTS bid will be compared to the delta between the forecasted proxy bus prices, depending on the direction of energy flow. To facilitate CTS in real-time, NYISO incorporates forward looking prices provided by both PJM and ISO-NE's real-time scheduling processes into the RTC. On a rolling 15-minute basis, coinciding with each RTC posting, the NYISO sends the binding and advisory schedules for each external proxy to PJM and ISO-NE. Each external control area then sends their forecasted interface prices to NYISO to inform the next RTC run. The prices which are used during the RTC evaluation are referred to as projected[8] prices because the final settlement LBMP for CTS transactions is based on RTD proxy bus LBMPs.

Due to the format in which price information is exchanged between PJM and ISO-NE, the bidding structure for CTS transactions varies slightly between PJM and ISO-NE. The projected price point that PJM sends NYISO is a single forecasted proxy price. Market Participants may submit up to an 11-point bid curve to the NYISO for transactions at the PJM interface. The CTS bid is then combined with the PJM price, allowing RTC to evaluate it simultaneously with all other types of NYISO bids. All PJM-interfaces are CTS-enabled.

With respect to ISO-NE, NYISO receives a supply curve from ISO-NE with price-quantity pairs representing ISO-NE's forecasted prices for different levels of interchange. Due to the complexity which would arise from the need to evaluate the supply curve from ISO-NE and multiple-point bid curves from individual Market Participants, Market Participants are only able to submit a single-point bid curve (but

[8] Additionally, the terms "forecasted", "expected", or "look-ahead" are used as a way to describe what prices are being used to determine the transaction schedules.

they can submit several transactions for evaluation). The CTS bid is then combined with the ISO-NE supply curve points, allowing RTC to evaluate it simultaneously with all other types of NYISO bids. The Sandy Pond interface is the only CTS-enabled interface with ISO-NE.

RTC Transaction Timeline

Figure 1, below illustrates an RTC timeline for two rolling RTC runs, RTC_{15} and RTC_{30}. As noted above, each RTC run indicates the posting time, which is fifteen minutes before the actual operating period for intra-hour transactions. Therefore, for RTC_{15} described below, the operating period begins at 2:30, which is referred to as time "T". The relevant bidding, posting, and dispatch timesteps for external transactions are described below:

- 12:45: RTM bidding window closes.
- 1:55 – 1:57: ISO-NE and PJM send forward looking prices to NYISO to be used in the RTC_{15} run to evaluate CTS bids.
- 2:00 (T-30): RTC_{15} executes.
- 2:15 (T-15): RTC_{15} posts the following information:
  - Binding schedules for 15 minute transactions for the 2:30 – 2:45 interval
  - Binding schedules for hourly transactions for the 3:00 – 4:00 hour
  - Advisory schedules for 15 minute transactions for intervals between 2:45 and 5:00
  - Advisory schedules for hourly transactions for the 4:00 – 5:00 hour
- 2:15 (T-15): Checkout (CO) begins for intra-hour transactions for the 2:30 interval
- 2:30: Checkout (CO) begins for hourly transactions for the 3:00 hour

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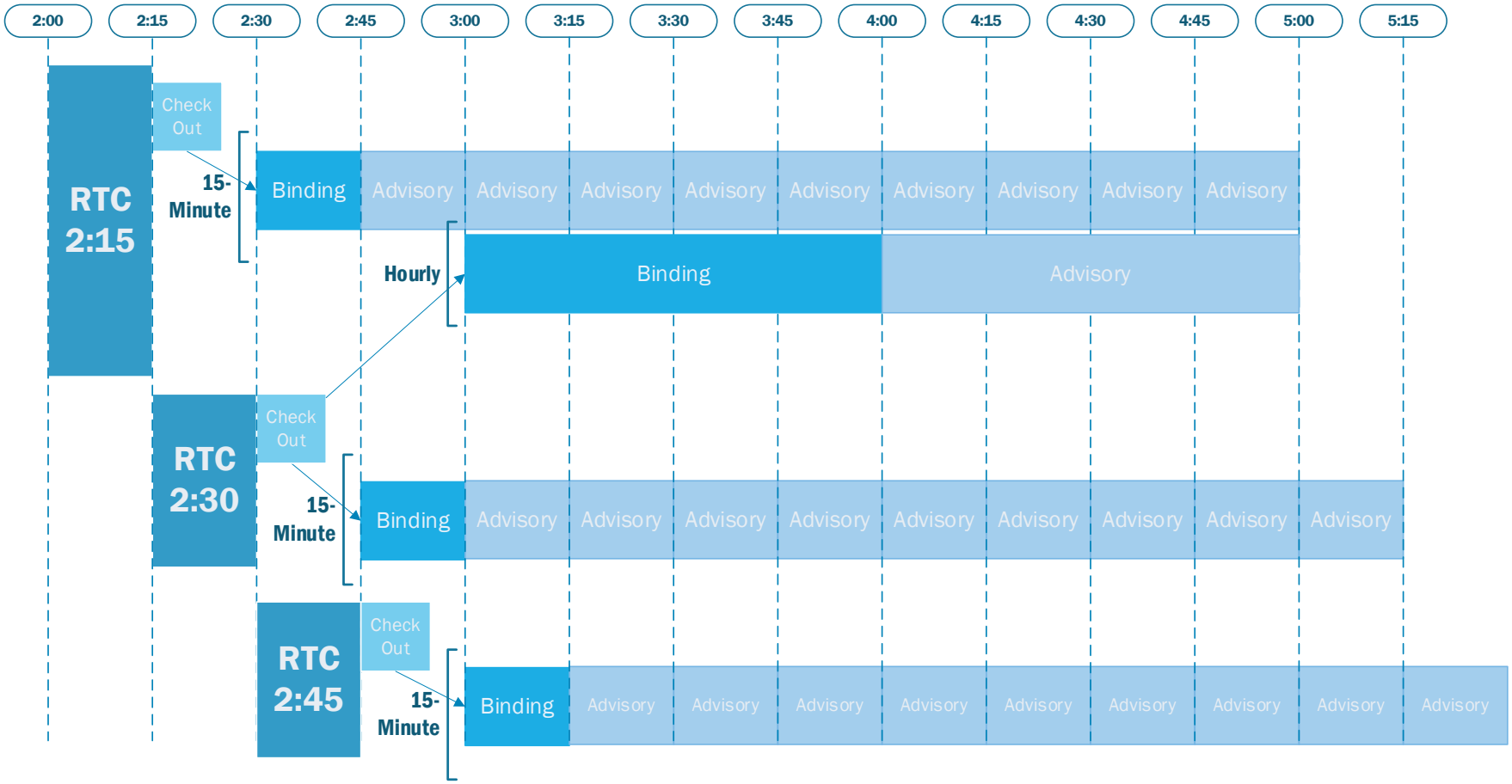


Figure 1: RTC Timeline

Real-Time Dispatch (RTD)

The RTD runs nominally every five minutes, sending base point signals to internal suppliers, and calculating real-time market LBMPs and clearing prices for operating reserves and regulation service. The RTD uses the unit commitment decisions and external transaction schedules from the RTC. The RTD treats transaction schedules established by RTC and confirmed through the checkout process as fixed interchange, and does not re-evaluate any transactions. For internal generators, RTD produces binding schedules for the next five minutes, and advisory schedules for the remaining 15-minute periods of its one hour optimization horizon.

Settlements for Transactions

DAM settlements for transactions are based on the DAM proxy bus LBMP and the DAM MW schedule, calculated at an hourly level. The RTM settlement is calculated at the 5-minute level. In addition to settlements within the NYISO energy market, Market Participants that schedule external transactions are also responsible for settlements with the neighboring control area.

The RTM settlement for transactions is based on the binding RTC scheduled MW, accounting for changes made during checkout, and the RTD proxy bus LBMP, inclusive of any potential external interface congestion calculated in RTC.[9] External interface congestion is a separate category of congestion from internal NYCA congestion in that is it due to constraints at external proxy generator buses. External interface congestion may be caused by several factors, such NYCA ramp limits, interface ramp limits, and transfer limits. Thus, external interface congestion is only present at external proxy generator buses. External interface congestion is determined by RTC, due to the fact that the binding transaction schedules are established by RTC and transaction bids are not re-evaluated in RTD.

There are several pricing rules which determine how external interface congestion is included in the RTD LBMP. For intra-hour transactions, external interface congestion is calculated on a rolling basis with each execution of RTC. For hourly transactions, external interface congestion is calculated in RTC_{15}. At an unconstrained proxy bus, with no external interface congestion calculated in RTC, there will be no external congestion costs included in the RTD LBMP. At competitive proxy generator buses, if external interface congestion is calculated in RTC, it will be added to the RTD LBMP.

At non-competitive proxy generator buses, special pricing rules are in place to limit the potential exercise of market power and/or market manipulation when the applicable RTC LBMP (rolling or RTC_{15})

[9] The rules for determining prices at the NYISO's external proxy buses are set forth in Services Tariff Section 17.1.6.

is negative. In these instances, external interface congestion will only be added to the RTD LBMP if the RTC LBMP is greater than zero. When the RTC LBMP for a non-competitive proxy generator bus is negative, external transactions will settle at the lower of the RTD LBMP or zero. This ensures that incentives remain for traders submitting offers to import and/or bids to export to offer competitively.

Considerations for More Frequent Transaction Scheduling

Scheduling transactions on a more frequent basis would provide several benefits, especially considering the expected increases in net supply and load variability that may occur with high levels of intermittent renewable resources. To facilitate more frequent transaction scheduling, the NYISO examined the feasibility of evaluating transactions on a 5-minute basis, and identified several key considerations. The initial list set forth below is not exhaustive, as additional market design and operational considerations may arise in the NYISO's discussions with affected stakeholders, or in practice. The broad topic areas are listed below and are discussed in detail below.

- Technical implementation and feasibility
- Ancillary Services
- Proxy bus pricing
- Utilization of 5-Minute transaction scheduling

Considerations

Technical Implementation

The NYISO has identified two technically feasible software options to allow the economic scheduling of transactions on a 5-minute level in NYISO's RTD software, which are described below:

- Build out a transaction model in the RTD, similar to the model that is already in place in SCUC and RTC. RTD would need to be enhanced so it is able to evaluate multiple transaction bids, submitted by different Market Participants as dispatchable at each proxy generator bus (respecting all bus limits). Today, RTD treats interchange as a fixed value provided by RTC. RTD cannot adjust the external transaction values it receives. Other examples of how RTD would need to become more flexible include of the ability to evaluate and enforce interface ramp constraints and external scheduling limit constraints. Building out a transaction model in RTD that is similar to SCUC and RTC would be a significant and complex undertaking.
- Leverage the existing generator dispatch model in the RTD to evaluate and schedule transactions at selected external interfaces where NYISO enables 5-minute scheduling. The NYISO may be able to leverage recent efforts that it has pursued to implement Distributed Energy Resources (DERs) to its advantage. Under the NYISO's DER aggregation model, bids from multiple DERs are aggregated to a single transmission node for evaluation and scheduling within the market software. The DER method would support

multiple Market Participants bidding at the same generator bus in RTD, as occurs in RTC today with multiple external transaction bids at a single proxy generator. With respect to ramp constraints, the generator ramp rate could potentially be leveraged to model the interface-specific ramp limits. The allowed flexibility would then need to be included in the determination of the appropriate NYCA ramp limit. Leveraging the DER model is currently NYISO's preferred technical approach to achieving 5-minute scheduling at its external proxy buses, because it helps address known software and implementation complexities.

Technical Feasibility of Scheduling Transactions in RTD

A complexity with the RTD is that RTD's first time step can vary in length between 5, 10 and 15 minutes, depending on the time between when it initializes and the subsequent time step of the look-ahead period. The subsequent advisory time steps of the RTD are all 15-minutes in duration, and RTD-CAM runs have additional time step lengths to consider. A component of the technical implementation that NYISO will need to address before it can implement 5-minute scheduling is how to handle transaction schedules during RTD-CAM modes, and how to manage transaction schedules when 5-minute scheduling is not available, including circumstances where 5-minute scheduling ceases to be available unexpectedly due to problems in the NYCA or in a neighboring control area.

E-Tagging and Checkout

Currently, NERC E-Tags for all hourly and most intra-hour transactions are created with an E-Tag type of "Normal," and the checkout process occurs manually either hourly or every 15 minutes. For intra-hour transactions at the HQ interface, transactions are created with an E-Tag type of "Dynamic," and the checkout process occurs once an hour, prior to the dispatch hour. Five minute scheduling would require the use of the "Dynamic" checkout process (rather than "Normal") wherever it is permitted. While this would be an extension of an existing NYISO process, it would require developing new procedures with neighboring control areas and NYISO operator tools to manage 5-minute interchange. Dynamic checkout would need to be performed in compliance with applicable NERC standards for E-tagging.

Technical and Operational Limitations at External Interfaces

A neighboring control area needs to be able to support incorporating NYISO's 5-minute interchange schedules into its real-time systems. This effort may prove more complicated for neighboring control areas that employ a real-time security constrained economic dispatch. As an example, the feasibility of moving to 5-minute transaction scheduling for CTS-enabled interfaces might require the exchange of forecasted prices more frequently and/or changes to the bidding window that locks 75 minutes before the beginning of each operating hour. Additionally, at controllable external interfaces (such as Scheduled Lines or D.C. ties), the operational ability of the intertie to respond to changing 5-minute basepoints without non-convexities such as operational deadbands due to infeasible operating ranges for tie line

equipment[10] would be essential for the benefits of 5-minute transaction scheduling to be realized. These technical and operational limitations may inform the feasibility of evaluating 5-minute transactions for each bid type.

Ancillary Services

Stakeholders have expressed interest in external transaction bids to supply ancillary services (primarily to provide operating reserves) to the NYCA. Currently, only Generators and Demand Side Resources located within the NYCA are eligible to provide Operating Reserves, consistent with New York State Reliability Council (NYSRC) requirements.[11] All resources within NYCA are able to be monitored by NYISO to ensure compliance with reliability criteria.

There are regulatory and reliability considerations that would need to be addressed before external resources could be permitted to be scheduled to provide operating reserves in the NYCA.[12] Specifically, NYISO would need to evaluate the reliability impacts of holding reserves outside of the NYCA, such as NYISO's ability to monitor the availability and deliverability of external resources. Transaction scheduling at a 5-minute level would be a minimum pre-requisite for external resources to be able to provide operating reserves. However, the implementation of 5-minute transaction scheduling does not guarantee that NYISO would allow the scheduling of operating reserves at its external interfaces at any time in the future.

Proxy Bus Pricing

The current pricing rules for calculating the RT LBMP at an external proxy generator bus is based on the sum of the RTD LBMP and any external interface congestion calculated in RTC. These rules would need to be re-considered for both competitive and non-competitive proxy buses, specifically the interplay between external interface congestion formed in RTC and the RT LBMP that is used for settlements. With respect to non-competitive proxy buses, existing rules are in place at these proxy buses to ensure that traders submitting offers to import and/or bids to export have incentives to offer competitively.[13]

[10] The NYISO's dispatch model is not equipped to handle such non-linear problems. Introducing such a change will introduce performance and solution quality risks.

[11] NYISO's locational reserve requirements and applicable reliability rules can be found on the NYISO website at the following link: https://www.nyiso.com/documents/20142/3694424/nyiso_locational_reserve_reqmts.pdf/ab6e7fb9-0d5b-a565-bf3e-a3af59004672.

[12] Information on NERC and NPCC standards and requirements related to inter-Balancing Authority reserves can be found in the following NERC Reliability Standards at: https://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-002-3.pdf and the NPCC Regional Reliability Directory: https://old.npcc.org/Standards/Directories/Directory%205%20-%20Reserve_20200426.pdf.

[13] *See, e.g.*, Services Tariff Sections 17.1.6.3.2 and 17.1.6.3.3.

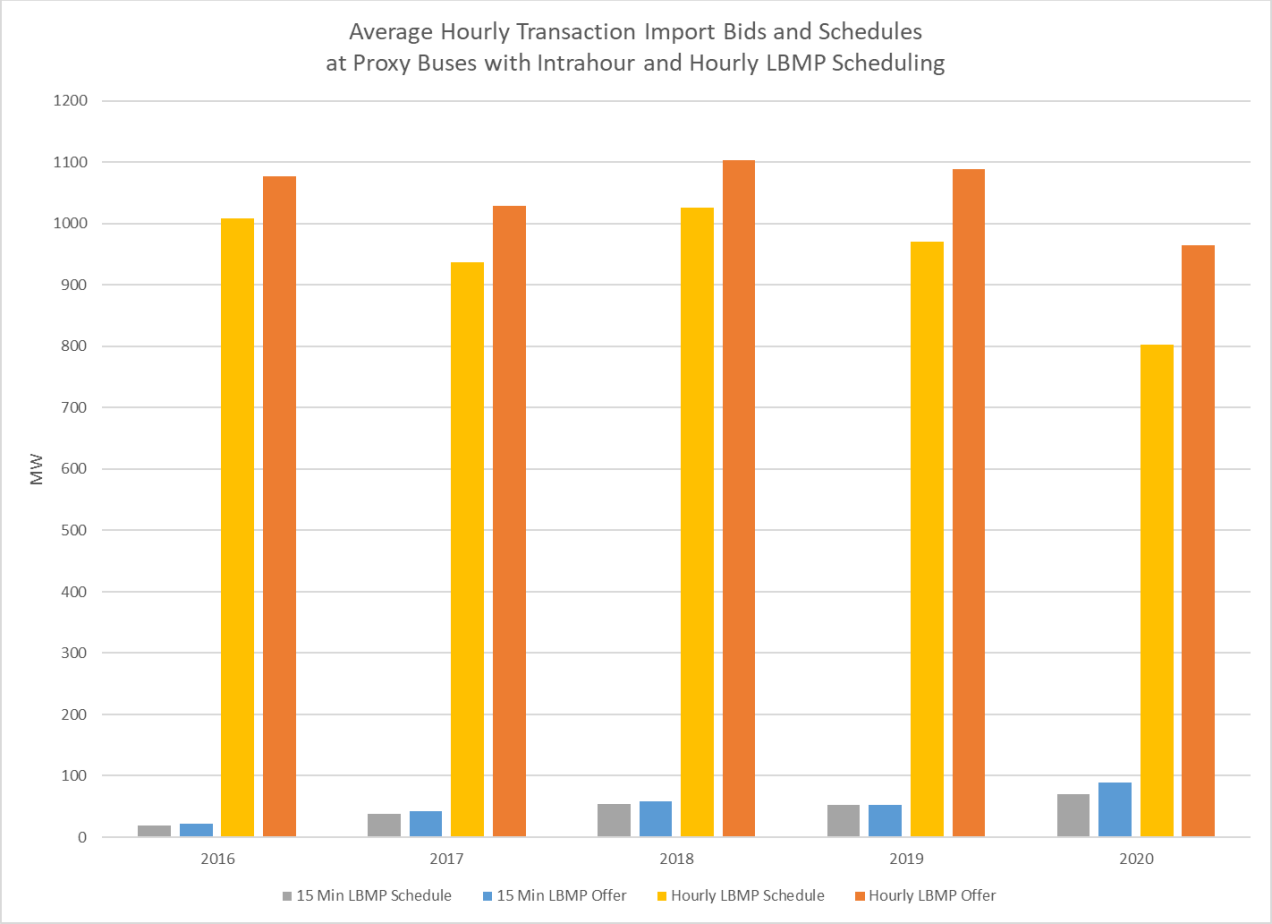
Consistent with the existing pricing rules, special pricing rules would need to be in place for non-competitive external proxy buses that effectively protect NYCA loads and suppliers from non-competitive behavior that might occur in a 5-minute transaction scheduling environment.

Utilization of 5-Minute Transaction Scheduling

The full benefits of 5-minute transaction scheduling will only be realized if there are Market Participants that take advantage of this flexibility with their real-time offers. While there has been interest from Market Participants in utilizing this feature, it is unclear if providing a 5-minute scheduling capability would result in bidding behavior and utilization that would provide a reasonable justification to pursue this effort. NYISO's Market Monitoring Unit (MMU), Potomac Economics, regularly provides an evaluation of CTS performance in its quarterly and annual State of the Market reports, analyzing the liquidity of CTS bids.[14] To provide an understanding of bidding and scheduling of intra-hour and hourly LBMP transactions, the NYISO evaluated five years of bidding and scheduling data, which are presented in the following graph.[15] This graph presents the average hourly bid and schedule for intra-hour and hourly transactions in each year.

[14] Annual and quarterly State of the Market reports can be found in the Document Library on the NYISO website: https://www.nyiso.com/library. Quarterly reports can be found under Corporate Reports – Market Monitoring Quarterly Reports and the annual reports can be found under Corporate Reports – State of the Market report.

[15] Data from 2020 is for the period of January 1 – October 1, 2020. This analysis did not include an evaluation of export bids as there are not a high enough volume of offers for a statistical analysis.



Coordination with Neighboring Control Areas

NYISO has consulted with neighboring control areas to determine their levels of interest in pursuing this effort. A brief summary of the NYISO's discussions with each of its neighbors is included below. IESO, ISO-NE, and PJM each recognized the potential benefits of more frequent transaction scheduling; however, each of the ISOs/RTOs indicated that any involvement in this effort would be a longer-term priority. HQT has expressed a near-term interest in pursuing this effort.

Control Area	Potential for Development of 5-Minute Frequent Transaction Scheduling
Hydro-Quebec	Discussions between HQ-TransEnergie and NYISO have been ongoing since the EITC project in 2010. HQT would be interested in moving forward with more frequent transaction scheduling in the near-term.
IESO	IESO has expressed long term interest in more frequent transaction scheduling. Currently, scheduling at the IESO interface is only permitted hourly. NYISO and IESO would need to determine if it would be appropriate to transition to intra-hour (15 minute) scheduling before moving to 5-minute scheduling.
ISO-NE	ISO-NE recognizes the potential benefits of more frequent transaction scheduling, while acknowledging the significant technical work that would be required for design,

	coordination, and implementation. ISO-NE explained that it has other higher-priority projects to complete, so it is not able to work on this effort in the near-term.
PJM	PJM is willing to engage in high-level discussions with the NYISO to be able to determine the feasibility and priority of this effort.

The purpose of this report is to identify and understand the technically feasible and market design concepts which need to be considered when developing 5-minute transaction scheduling at any of the NYCA borders. Due to the level of effort and complexity that 5-minute scheduling would require, interest from external control areas is imperative to realizing the benefits and value of the project.

Real-Time Make Whole Payments

External transactions are not eligible to receive Bid Production Cost Guarantee (BPCG) payments in the RTM. Therefore, external transactions bear latency risk for price changes between time when the schedule is established by RTC and the actual flow, as transactions are ordinarily settled on RTD LBMPs. The NYISO has received feedback from some Market Participants that this risk is a barrier to bidding more flexibly in the RTM. This feedback is an important consideration when evaluating the potential utilization of 5-minute bidding and scheduling by Market Participants. Certain Market Participants primarily take positions in the day-ahead market, and bid as price takers in the RTM to avoid the uncertainty of price changes between RTC and RTD. By moving the scheduling of transactions into RTD, it is expected that the existing RTC to RTD risk would be reduced, as transaction flows and pricing would both be determined in RTD.

Fees

NYISO's Market Monitoring Unit (MMU), Potomac Economics, provided an evaluation of CTS performance in the 2019 State of Market (SOM) report, specifically with a focus on CTS bids and profits. This analysis noted a high liquidity of CTS bids at the ISO-NE border compared to the PJM border. The 2019 SOM report concluded that the difference in the volume of bids between PJM and ISO-NE can be attributed to the per MWh fees charged by both PJM and NYISO at their common border for imports and exports. The MMU concludes that transaction fees present a significant economic barrier to achieving the potential benefits from the CTS process. Since the 2015 SOM, Potomac has recommended eliminating transaction fees at the PJM-NYISO border. The NYISO has identified this as a future market project in recent and past project prioritization efforts. The MMU's observation on the reason for lower liquidity of bids would likely hold true for 5-minute transaction scheduling, given that transaction fees would still apply. This concern is an important consideration when evaluating the potential utilization of 5-minute transaction scheduling at the PJM border. Transmission Services Charges (TSCs) are the primary

component of the transaction fees.

Conclusion

NYISO recognizes the potential benefits of more frequent transaction scheduling, especially as more intermittent generation comes online. This paper serves to outline the key considerations that would need to be addressed during the market design process if more frequent transaction scheduling is identified as a market project in the future, while highlighting the technical and regulatory complexities which may arise. Implementing 5-minute scheduling would require a collaborative interregional effort to ensure that the benefits of more frequent transaction scheduling are realized. The key market design and operational considerations identified in this report will be vital to developing a path forward when completing a market design for more frequent transaction scheduling.

Appendix

Transaction Types

There are several types of transactions for which a 5-minute transaction scheduling construct would be applicable.

- LBMP import and export transactions: Transactions to import or export energy between an external interface and the NYCA. LBMP transactions are settled within the NYISO energy market, with Market Participants submitting transactions bids to import (sell) or export (buy) energy. LBMP transactions are settled based on LBMP at the sink or source proxy bus.
- CTS transactions: For CTS imports, the NYISO proxy bus is considered the source, and the import will generally be accepted when the NYISO's forecasted LBMP at the proxy bus is greater than the neighboring RTO's forecasted LMP by an amount that equals or exceeds the CTS bid. For CTS exports, the NYISO proxy bus is considered the sink and the export will generally be accepted when the neighboring RTO's forecasted proxy bus LMP is greater than the NYISO's forecasted proxy bus LBMP by an amount that equals or exceeds the CTS bid.
- Wheel-through transactions: Transactions with a source and sink outside of the NYCA. A wheel-through bid is economically evaluated against the congestion cost of the transaction, which is determined by the difference between the LBMP congestion components at the sink and the source.
- Bilateral import and export transactions: Transactions with a direct energy contract between two parties, such that the price of energy is negotiated directly between parties and not a part of the NYISO settlement. Bilateral transactions are responsible for paying Transmission Use Charges (TUCs) to reflect the cost of moving power between the sink and the source. Bilateral import and export transactions submit $/MW bids which are economically evaluated against the proxy bus LBMP.

Scheduling Bid Types

The format of a transaction bid depends on the type of transaction: import, export, wheel-through, or CTS. For intra-hour transactions, Market Participants must submit bid(s) to cover an entire hour and may submit either a single bid curve for the entire hour or individual bid curves for each quarter hour.

Decremental Bids for Imports

A decremental bid curve is used to submit a bid for an LBMP or bilateral import. The bid curve represents the total quantity of MWs that a Market Participant is willing to sell at various price points ($/MW) with a maximum of eleven MW and $/MW pairs. Each pair represents the total amount of MWs that the MP would be willing to sell if the LBMP is at or below the given $/MW value. The source of a decremental import bid will be an external generator proxy bus and the sink will be the NYISO proxy/reference bus or an internal load bus.

Sink Price Cap Bids for Exports

A sink price cap bid is used to submit a bid for an LBMP or bilateral export. The bid curve pair represents the desired increments of energy that a Market Participant is willing to purchase at various price points, with a maximum of three MW and $/MW pairs. The $/MW bid must be ascending from the first point to the last point. The amount of MWs that can be scheduled are additive, such that for each pair with a $/MW price less than the clearing price, the total transaction scheduled could be up to the sum of all applicable pairs. The source of a sink price cap export bid will be the NYISO proxy/reference bus or an internal generator bus and the sink will be an external proxy load bus.

Wheel-Through Bids

A wheel-through bid is structured similar to a decremental bid, in that up to an eleven point bid curve represents the numbers of MWs that the transaction bidder is willing to buy at the importing proxy bus and sell at the exporting proxy bus and incremental costs for each MW point. Whereas the price points for a decremental bid for an external import transaction is evaluated against the proxy LBMP for energy, a wheels-through bid is evaluated against the difference in the congestion cost between the two external proxies.

CTS

A CTS bid represents the number of MWs that a bidder is willing to sell as long as the forecasted price difference between the NYISO proxy bus price and neighboring interface proxy bus is greater than or equal to the dollar bid. The forecasted price difference is based on forward looking prices produced by the real time optimization processes for each control area.

Proxy Buses

The following table[16] indicates the current scheduling frequency and the scheduling bid types available at each external control area proxy bus. For the Hydro-Quebec interface at Chateauguay, there are two separate proxy buses, one at which only imports and exports to/from NYISO can be scheduled and one at which only wheel-through can be scheduled.[17] For the CTS-enabled proxy buses with PJM and ISO-NE, only wheels-through transactions are scheduled on an hourly basis; all other transactions must be on a 15-minute basis.

[16] Source: MST 4.4

[17] There are two separate proxy buses at the Chateauguay interface to facilitate the management of two simultaneous constraints at that interface: 1) total transfer capability and 2) ramp limits. For more information, please see Technical Bulletin 158: https://www.nyiso.com/documents/20142/2931465/TB-158.pdf/f3814272-7a77-95ae-c427-ad8709ca98ec.

Proxy Generator Bus	PTID	Scheduled Line	Designated Scheduled Line	Non-Competitive	CTS Enabled Proxy Generator Bus		Scheduling Frequencies		
					Requires CTS Bids	Permits CTS Bids	Hourly Scheduled	Variably Scheduled	Dynamically Scheduled (Not Presently Available)
Hydro Quebec									
HQ_GEN_IMPORT	323601			✓			✓	✓	
HQ_LOAD_EXPORT	355639			✓			✓	✓	
HQ_GEN_CEDARS_PROXY	323590	Dennison Scheduled Line		✓			✓		
HQ_LOAD_CEDARS_PROXY	355586	Dennison Scheduled Line		✓			✓		
HQ_GEN_WHEEL	23651			✓			✓		
HQ_LOAD_WHEEL	55856			✓			✓		
PJM									
PJM_GEN_KEYSTONE	24065					✓	✓* (See Notes)	✓	
PJM_LOAD_KEYSTONE	55857					✓	✓* (See Notes)	✓	
PJM_GEN_NEPTUNE_PROXY	323594	Neptune Scheduled Line	✓			✓	✓* (See Notes)	✓	
PJM_LOAD_NEPTUNE_PROXY	355615	Neptune Scheduled Line	✓			✓	✓* (See Notes)	✓	
PJM_GEN_VFT_PROXY	323633	Linden VFT Scheduled Line	✓			✓	✓* (See Notes)	✓	
PJM_LOAD_VFT_PROXY	355723	Linden VFT Scheduled Line	✓			✓	✓* (See Notes)	✓	
PJM_HTP_GEN	323702	HTP Scheduled Line	✓			✓	✓* (See Notes)	✓	

Proxy Generator Bus	PTID	Scheduled Line	Designated Scheduled Line	Non-Competitive	CTS Enabled Proxy Generator Bus		Scheduling Frequencies		
					Requires CTS Bids	Permits CTS Bids	Hourly Scheduled	Variably Scheduled	Dynamically Scheduled (Not Presently Available)
HUDSONTP_345KV_HTP_LOAD	355839	HTP Scheduled Line	✓			✓	✓* (See Notes)	✓	
ISO New England									
N.E._GEN_SANDY_POND	24062				✓		✓** (See Notes)	✓	
NE_LOAD_SANDY_PD	55858				✓		✓** (See Notes)	✓	
NPX_GEN_CSC	323557	Cross Sound Scheduled Line	✓				✓		
NPX_LOAD_CSC	355535	Cross Sound Scheduled Line	✓				✓		
NPX_GEN_1385_PROXY	323591	Northport Norwalk Scheduled Line					✓		
NPX_LOAD_1385_PROXY	355589	Northport Norwalk Scheduled Line					✓		
Ontario									
OH_GEN_PROXY	24063						✓		
OH_LOAD_PROXY	55859						✓		

Notes:

* At specifically identified Proxy Generator Buses ("* See Notes"), only Wheels Through (the NYCA) are scheduled on an hourly basis.

** At specifically identified Proxy Generator Buses ("** See Notes"), only wheels through the NYCA or a neighboring Control Area are scheduled on an hourly basis.