NEW YORK INDEPENDENT SYSTEM OPERATOR

A536: Real-Time Scheduling

Overview

Concept of Operation

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1   INTRODUCTION

1.1   Goal Statement

The purpose of this document is to summarize the rules, bidding parameters, time lines, and constraints for the commitment and dispatch functions of the real-time scheduling (RTS) system. The document covers the following subjects:

- Resources available to RTS

- Bidding parameters of those resources

- Functions that schedule those resources

- Calculation of prices

- Posting of information

- Monitoring and mitigation

The RTS time frame extends from 5 minutes in the future to 2½ hours in the future. During this period, generating units may be started (committed) or shut down (decommitted); or the output of energy resources may be adjusted. Commitment and decommittment decisions are made every 15 minutes by the real-time commitment (RTC) process. Decisions to adjust the output of internal energy suppliers (dispatch) are made every 5 minutes by the real-time dispatch (RTD) process, as is the calculation of energy and ancillary services prices. The real-time control of energy resources (regulation), provided by AGC every six seconds, is outside the scope of RTS, except that RTS must select providers of the regulation ancillary service. External transactions are scheduled hourly, however RTS will support both hourly and quarter-hourly transactions.

1.2   Business Need

The current real-time scheduling process revolves around the Security Constrained Dispatch (SCD) and Balancing Market Evaluation (BME) programs. SCD nominally executes every 5 minutes and BME once an hour. These two programs BME and SCD must be replaced to support new market features (15-minute scheduling, shorter elapsed time from close of market to scheduled interval, two settlement for ancillary service, etc.).   It is anticipated that all new market features made possible by the new RTS will move the New York wholesale energy market toward the FERC standard market design. Equally important, the RTS will provide the expansion capability needed to accommodate an ever-growing market, in part by implementing new dispatching algorithms, and in part by upgrading the computer platform on which the dispatch runs.

In moving toward the FERC standard market design, the RTS will provide greater convergence in prices used to make commitment decisions, the prices used to make dispatch decisions, and real-time prices. Price convergence will be the result of:

- Consistent modeling of reserve requirements in commitment and dispatch processes

- Shorter time interval between real-time commitment and real-time dispatch

- A load model that will provide estimates of the load profile at times during the hour

- Real-time energy pricing that will recognize the actual, rather than scheduled, performance of resources

1.3   Definitions, Acronyms, and Abbreviations

Term	Description
10_{00}	10-minute units started by RTC_{00}
10_{15}	10-minute units started by RTC_{15}
10_{30}	10-minute units started by RTC_{30}
10_{45}	10-minute units started by RTC_{45}
30_{00}	30-minute units started by RTC_{00}
30_{15}	30-minute units started by RTC_{15}
30_{30}	30-minute units started by RTC_{30}
30_{45}	30-minute units started by RTC_{45}
AGC	Automatic generation control
BME	Balancing Market Evaluation
DMNC	Dependable maximum net capability
EDRP	Emergency demand response program
EST	Economically-scheduled external transaction
Ex-ante pricing	Estimate of prices made before the time period being priced. Ex-ante prices assume that projected conditions (load, system configuration, etc.) materialize, and that providers perfectly follow schedules determined by the optimization processes.
~~Ex-post pricing~~	~~Estimate of prices made after the time period being priced. Ex-post prices consider actual, rather than projected, conditions (load, system configuration, etc.), and actual, rather than scheduled, behavior of providers.~~
PST	Pre-scheduled external transaction
RTC	Real-time commitment
RTC_{00}	Real-time commitment that posts on the hour
RTC_{15}	Real-time commitment that posts at 0:15 after the hour
RTC_{30}	Real-time commitment that posts at 0:30 after the hour
RTC_{45}	Real-time commitment that posts at 0:45 after the hour
RTD	Real-time dispatch
RTD-CAM	Real-time dispatch – corrective action mode
RTS	Real-time scheduling (RTC, RTD, and RTD-CAM)
SCUC	Security constrained unit commitment
SCD	Security constrained dispatch
SNET	Short notice external transaction
$SNET_{00}$	Short notice external transactions scheduled by RTC_{00}
$SNET_{15}$	Short notice external transactions scheduled by RTC_{15}
$SNET_{30}$	Short notice external transactions scheduled by RTC_{30}
$SNET_{45}$	Short notice external transactions scheduled by RTC_{45}
UOL	Upper operating limit
UOL_E	Emergency upper operating limit
UOL_N	Normal upper operating limit

1.4   Other Documents

This document provides an overview of the RTS system. Other documents provide more detail. These other documents are:

- A536_COO_ARCHITECTURE

  Discusses processes and information flow of the RTS and identifies suitable hardware configurations to support those processes and flows.

~~A536_COO_HUMAN MACHINE INTERFACE~~

~~Discusses the human-machine interface needs of ISO personnel: operations, market services, market monitoring, etc.~~

- A536_COO_Bidding

  Discusses the bidding characteristics for supply as well as external economic and prescheduled transactions.

- A536_COO_MIS IMPACT

  Discusses the interaction of market participants with the new features of the New York energy market.

- A536_COO_POSTING

  Discusses the posting of information (schedules, prices, etc.) produced by the RTS.

- A536_COO_RTAMP

  Discusses the automated real-time mitigation of internal resources.

- A536_COO_RTDCAM

  Discusses the emergency scheduling functions.

- A536_COO_SCHEDULING

  Discusses the commitment, scheduling, and pricing of energy, ancillary services, and external transactions in real-time. Bidding parameters are also described.

- A536_COO_SETTLEMENT

  Discusses the changes in settlement rules, including bid production cost guarantees, associated with the RTS.

~~A536_COO_SNET~~

~~Discusses the automated checkout of transaction schedules with neighboring control areas that will be required to support 15-minute transaction schedules.~~

2   Controllable Entities

RTS schedules energy, external transactions, and ancillary resources to meet native load, support external transactions, and provide control, while maintaining system reliability. The controllable entities available to RTS are internal generators and demand-side resources, imports, exports and wheels, and providers of ancillary services.

2.1   Internal Resources

Internal generating units or demand side resources may supply energy and/or ancillary service.   Internal resources may be dispatchable or self-scheduled. Self-scheduled resources in turn may be fixed or flexible.

- **Dispatchable**: the resource follows a 5-minute base point, or, if providing regulation, follows a 6-second base point. These resources may provide ancillary services.

- **Self-Scheduled Flexible**: the resource is self-committed but has a dispatchable range. The resource follows a 5-minute base point within the dispatchable range, or, if providing regulation, follows a 6-second base point. These resources may provide ancillary services.

- **Self-Scheduled Fixed**: the resource is self-committed and has no dispatchable range. These resources may not provide ancillary services.

2.2   External Transactions

External transactions (imports, exports, and wheels) may be ~~pre-scheduled (PST) or~~ economically scheduled (EST~~)~~. ~~In either case, the transaction would) and~~ will be ~~evaluated and~~ scheduled hourly~~. Pre~~.   Economically scheduled transactions ~~may incorporate~~will have a single MW schedule ~~changes at 15-minute intervals; economically scheduled transactions may not change schedule during the~~for the entire hour~~. Pre-scheduled~~.   Economic transactions are ~~approved solely on availability of capacity and ramp. Pre-scheduled transactions are evaluated hourly. Transactions are~~ scheduled if energy prices estimated by RTC are within the limits of the bid.

~~Short notice external transactions (SNETs) are also being considered, although not for implementation in the initial~~ A limited form of pre-scheduled transactions (PST), on an hourly basis are being implemented to accommodate external ICAP deliverability rules. Full pre-scheduling is being considered as a future enhancement to RTS~~ but will not be included in the initial implementation.~~ A pre-scheduled transaction may specify a different MW schedule for each 15-minute interval within a given hour. Pre-scheduled transactions are approved solely on availability of capacity and ramp.

Short notice external transactions (SNETs) are also being considered as a future enhancement to RTS but will not be included in the initial implementation. If implemented, it is anticipated that a SNET request must be received and approved 30 minutes before flowing. SNET requests, like pre-scheduled transactions, would not be economically evaluated.

3   Bidding

Hourly bids are required from suppliers of energy or ancillary services. Bids may be submitted up to ~~one hour~~75 minutes before the hour being economically evaluated.   That is, bids to supply energy and ancillary service for the hour 12:00 to 12:59:59 are required no later than ~~11:00~~10:45. Similarly, hourly bids are required for economically evaluated external transactions (imports, exports, and wheels). Bids for external transactions may also be submitted up to ~~one hour~~75 minutes before the hour being scheduled.

Requests that are not economically evaluated must be received, ~~and approved, one hour~~75 minutes before the hour being scheduled.   These requests include self-scheduled internal energy resources and pre-scheduled external transactions. Pre-scheduled transaction requests must also be approved ~~one hour~~75 minutes before the hour being scheduled.   It is anticipated that short notice external transactions, if and when available, must be requested and approved at least 30 minutes prior to flowing.   Requests that require approval must be submitted sufficiently ahead of the deadline to allow time for any analysis that must precede approval.

3.1   Energy

Bids to supply energy come from generation internal to the NYCA and demand-side resources internal to the NYCA. Bids to import, export, or wheel energy may be pre-scheduled or economically evaluated. The ability to request external transactions with short notice is also being considered.

3.1.1   Internal Generation

Parameters related to energy bidding are illustrated in Figure 1~~Figure 1Figure 1~~ and include minimum generation level and cost, blocks of incremental energy, and various operating limits.
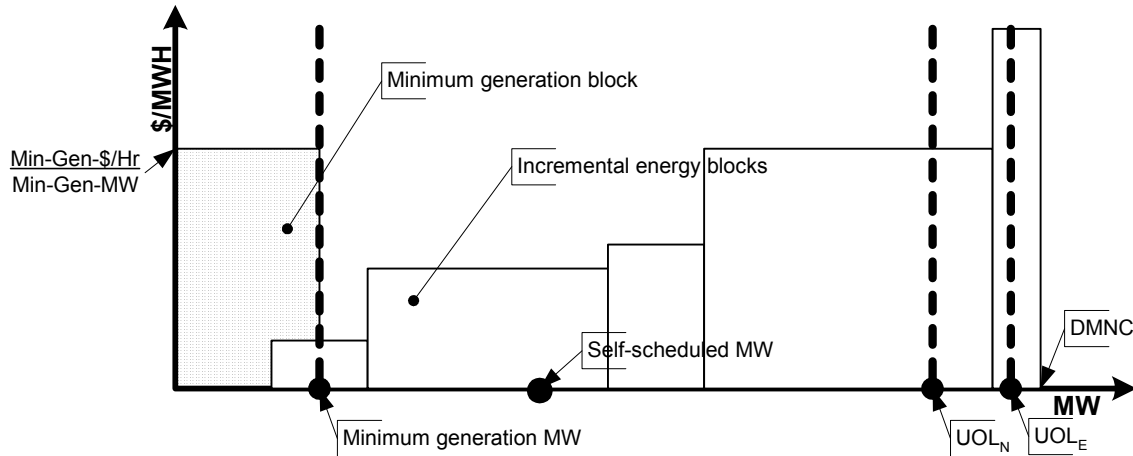
Figure 1. Energy Bidding Parameters

New features include the ability to specify both normal and emergency upper operating limits. Self-scheduled resources will be able to specify output level independently of upper and lower operating limits.   Also, the incremental energy cost curve will be specified using up to 12 constant cost blocks; currently the incremental energy cost curve may contain up to three blocks or 5 piece-wise linear segments.   A unique start up cost may be defined for each hour of the day.   Alternately, start up cost may be defined as a function of the number of hours since shutdown.

3.1.2   Internal Demand-Side Resource

Upon demonstration of ability, qualified demand-side resources may offer energy and/or ancillary service, as do traditional generating resources.   Bidding parameters will be identical for all internal resources.

3.1.3   RT Pre-Scheduled External Transactions

Except for a limited form of hourly pre-scheduling to accommodate external ICAP deliverability rules, pre-scheduled external transactions will not be accommodated in the initial deployment of the RTS. Requests for pre-scheduled transactions, imports, exports, and wheels, must be received and approved one hour before flowing. Duration of the requested transaction may be from one hour to the remainder of the day; and may contain schedule changes at 15-minute intervals, on the quarter hour.   No bid price is associated with pre-scheduled transaction requests.

3.1.4   RT Economically Scheduled Transactions

Bids for economically scheduled transactions must be submitted one hour before flowing.   Duration of the transaction must be one hour.   The transaction must start and stop on the hour and have constant magnitude for the hour.   Schedule changes during the hour will not be accommodated.   Additionally the bid (sink price cap or decremental bid) associated with the transaction must be constant for the entire hour.

3.1.5   Short Notice External Transactions

Short notice external transactions will not be accommodated in the initial deployment of the RTS. If and when short notice external transactions are made available, it is anticipated that requests for such transactions must be received and approved at least 30 minutes prior to flowing.

3.2 Ancillary Service

Internal generating units and qualified demand-side resources may supply ancillary service as indicated in the table below~~.~~ For reserve, the resource defines a ramp rate; the scheduling process will select the amount of ancillary service~~. Suppliers~~. There will ~~use a~~be no real-time ~~bid, including an~~ availability ~~price,~~bids for offers to supply reserves (neither 10-~~minute~~minute or 30-minute, synchronous or nonsynchronous ~~and 30-minute nonsynchronous reserve. There will be no real-time bid for offers to supply spinning reserve (either 10-minute or 30-minute).~~). For regulation, the resource would additionally specify a maximum amount of regulation ancillary service that may be selected by the scheduling software. For the purposes of providing reserves, demand-side resources shall be treated as off-line.

Status	Start-Up	10-Spin	10-NS	30-Spin	30-NS	Regulation
On-Dispatch	10-minute	✓		✓		✓
	30-minute	✓		✓		✓
Self-Scheduled Flexible	10-minute	✓		✓		✓
	30-minute	✓		✓		✓
Self-Scheduled Fixed	10-minute					
	30-minute					
Off-line	10-minute		✓			
	30-minute				✓	
On-Dispatch	10-minute	✓		✓		✓
	30-minute	✓		✓		✓

4 Scheduling

4.1 Real-Time Commitment (RTC)

Shown in Figure 2~~Figure 2Figure 2~~, the RTC is a multi-period security constrained unit commitment and dispatch model that co-optimizes to simultaneously solve load, reserves and regulation. Each RTC run optimizes over ten quarter hour periods for a total optimization horizon of 2½ hours. Each RTC run receives a label in terms of our description of the model that indicates the time at which the results of the run are posted. These results apply to the 2 ½ hour period that starts 15 minutes after the RTC results post, e.g., $RTC_{1:15}$ posts at time 1:15 and optimizes from time 1:30 through 3:59:59. RTC will run every 15 minutes.

Unit starts and stops will be controlled by RTC in most cases. The exception is the commitments made by RTD-CAM. The RTC runs that post at 15 minutes past each hour determine the economically evaluated external transactions scheduled for the following hour , i.e., $RTC_{1:15}$ determines the economically evaluated external transaction schedules for time 2:00 through 2:59:59 (a time period beginning 45 minutes after posting). RTCs that post on the hour, and 30 and 45 minutes after the hour, will treat all transactions as ~~fixed injections or withdrawals. This will require some form of pre-processing to ensure transaction feasibility. In the event of an infeasible schedule, the pre-processor will not select specific transactions to be cut but rather will indicate the number of MWs that need to be cut in order to maintain feasibility. It is expected that operations staff will continue to~~protected. RTC may reduce specific transactions to maintain feasibility, but will not pass those curtailments to IS+. Instead, RTC will issue alarms to the operator indicating the amount of MWs of transactions that needed to be cut in order to maintain feasibility. The operator will then use the IS+ tools to curtail the appropriate transactions~~ ~~ if desired.

The objective of RTC is to minimize the total as-bid cost (production cost) over the optimization timeframe. The solution requirements are:

- Meet forecast load

- Meet all reserve requirements by product type and location

- Meet the regulation requirement

The solution must satisfy a set of constraints. The constraints modeled in RTC include:

- All transmission constraints (base case, contingency, thermal, voltage, stability))

- Generation bidding parameters (ramp rates, startup times, minimum down times, minimum generation levels, Upper Operating Limits,)

The costs that are being minimized in the optimization include but are not limited to:

- Generation startup costs

- Generation minimum generation costs

- Generation incremental energy costs

- Import generation costs

- Export schedule benefits

- Wheel through schedule benefits

- Dispatchable load schedule benefits

- Reserve schedule availability costs (Lost opportunity costs are implicitly captured through other costs)

- Regulation schedule availability costs (Lost opportunity costs are implicitly captured through other costs)
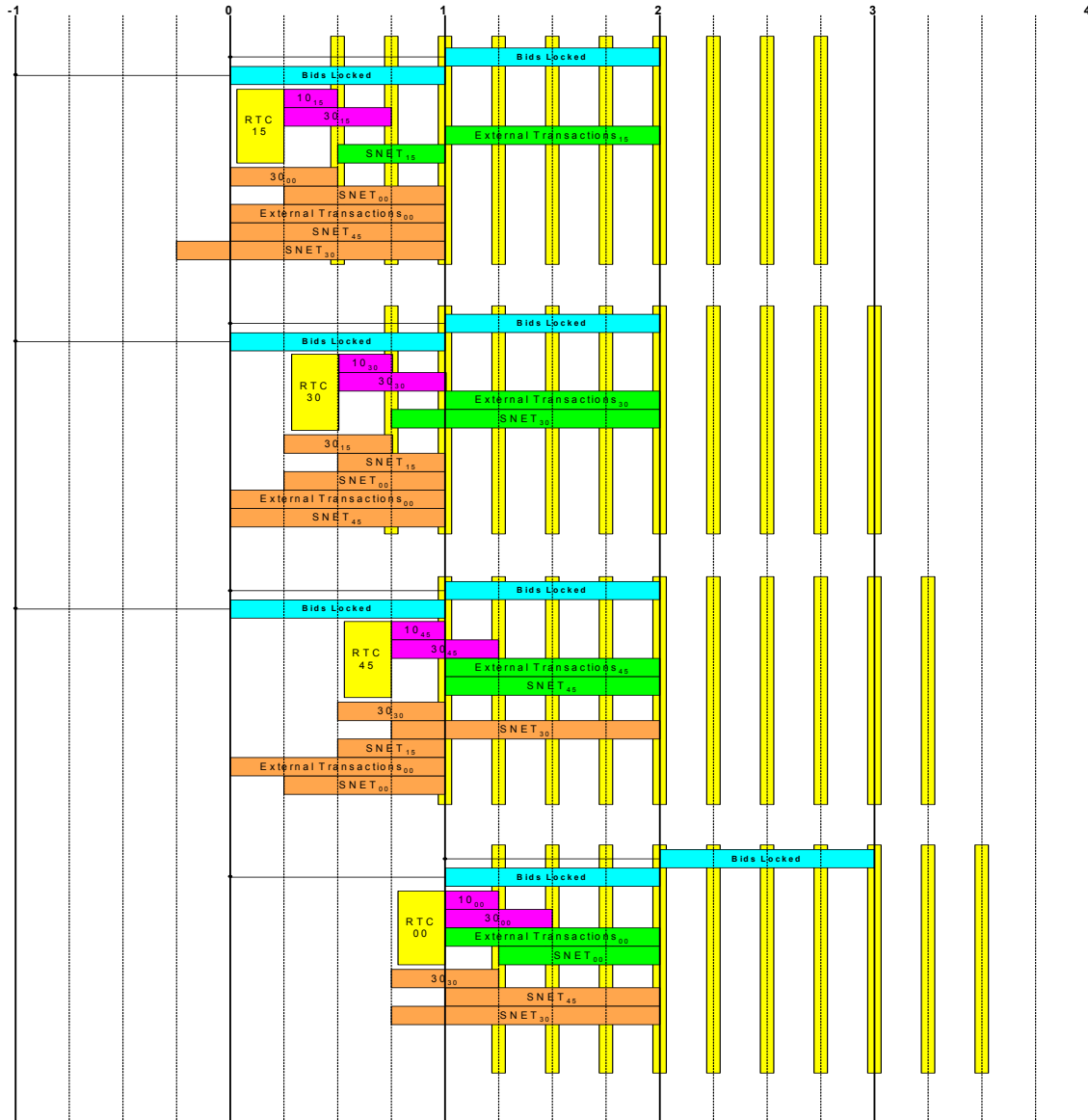
Figure 2. Real Time Commitment Process

4.1.1   RTC$_{15}$

RTC$_{15}$ runs during the interval :00 (:mm) to :15 of the current hour and posts its results by :15 after the hour, RTC$_{15}$ does the following:

- Decides which 10-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :30:00 (:mm:ss) of the current hour.

- Decides which 30-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :45:00 of the current hour.

- Decides which 10-minute gas turbines and 30-minute gas turbines are to be shutdown so they are disconnected from the network by :30:00 of the current hour.

- Schedules economically bid external transactions for :00:00 through :59:59 of the next hour.

- Schedules pre-scheduled transactions for the period :00:00 through :59:59 of the next hour.

~~Schedules SNETs for the period :30:00 through :59:59 of the current hour.~~

4.1.2 RTC$_{30}$

RTC$_{30}$ runs during the interval :15 (:mm) to :30 of the current hour and posts its results at :30 after the hour, RTC$_{30}$ does the following:

- Decides which 10-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :45:00 (:mm:ss) of the current hour.

- Decides which 30-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :00:00 of the next hour .

- Decides which 10-minute gas turbines and 30-minute gas turbines are to be shutdown so they are disconnected from the network by :45:00 of the current hour.

- Reaffirms the economically bid external transactions scheduled by the previous RTC$_{15}$ for :00:00 through :59:59 of the next hour.

Reaffirms pre-scheduled transactions for the period :00:00 through :59:59 of the next hour.

- ~~Reaffirms SNETs for the period :45:00 of the current hour through :59:59 of the next hour~~ .

4.1.3 RTC$_{45}$

RTC$_{45}$ runs during the interval :30 (:mm) to :45 of the current hour and posts its results at :30 after the hour, RTC$_{45}$ does the following:

- Decides which 10-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :00:00 (:mm:ss) of the next hour.

- Decides which 30-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :15:00 of the next hour.

- Decides which 10-minute gas turbines and 30-minute gas turbines are to be shut down so they are disconnected from the network by :00:00 of the next hour.

- Reaffirms the economically bid external transactions scheduled by the previous RTC$_{15}$ for :00:00 through :59:59 of the next hour.

- Reaffirms pre-scheduled transactions for the period :00:00 through :59:59 of the next hour.

~~Reaffirms SNETs for the period :00:00 through :59:59 of the next hour.~~

4.1.4 RTC$_{00}$

RTC$_{00}$ runs during the interval :45 (:mm) of the previous hour to :00 of the current hour and posts its results at :00 of the current hour, RTC$_{00}$ does the following:

- Decides which 10-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :15:00 (:mm:ss) of the current hour.

- Decides which 30-minute gas turbines are to be started so they are synchronized to the network and running at their minimum generation level by :30:00 of the current hour.

- Decides which 10-minute gas turbines and 30-minute gas turbines are to be shut down so they are disconnected from the network by :15:00 of the current hour.

- Reaffirms the economically bid external transactions scheduled by the previous RTC_{15} for :15:00 through :59:59 of the current hour.

- Reaffirms pre-scheduled transactions for the period :15:00 through :59:59 of the current hour.

Reaffirms SNETs for the period :15:00 through :59:59 of the current hour.

4.2   Real-Time Dispatch (RTD)

RTD is a multi-period security constrained dispatch model that co-optimizes to simultaneously solve load, reserves and regulation. Each RTD run optimizes nominally over a period of 1 hour. RTD makes no unit commitment decisions. It simply dispatches the resources available to it on a least-as-bid cost basis. RTD will run every 5 minutes. Figure 3Figure 3Figure 3 shows six RTD executions that occur over a 30-minute time frame. Import, export and wheel through transactions are considered as fixed injections and withdrawals by RTD.
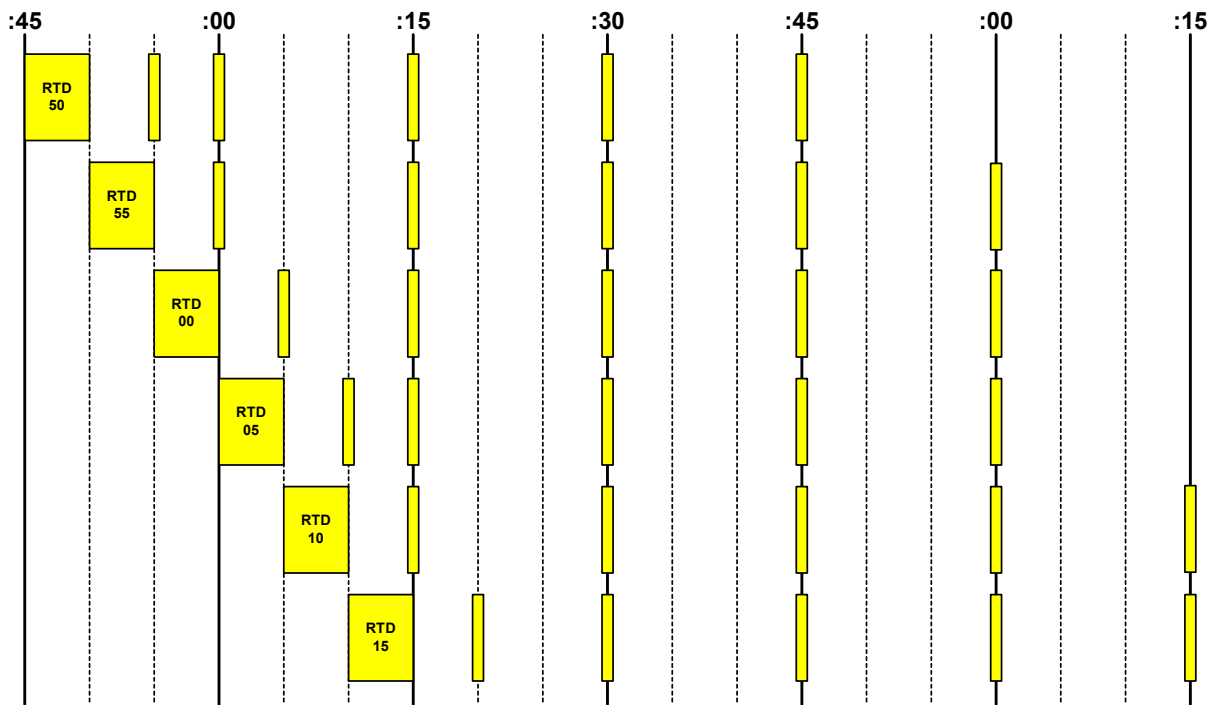

Figure 3. 30 Minutes of RTD Process

Each RTD run receives a label that indicates the time at which the results of the run are posted. For example, $RTD_{1:15}$ posts at 1:15. Each RTD calculates desired conditions for five times in the future: 5 minutes in the future and the next four quarter hours, aligned with the quarter hours. There may therefore be 5, 10, or 15 minutes between first and second times considered by RTD. The later four times always align with RTC time periods.

The objective of RTD is also to minimize the total as-bid cost (production cost) over the optimization timeframe. The solution requirements are:

- Meet forecast load

- Meet all reserve requirements by product type and location

- Meet the regulation requirement

The solution must satisfy a set of constraints.   The constraints modeled in RTD include but are not limited to:

- All transmission constraints (base case, contingency, thermal~~, voltage, stability)~~)

- Generation bidding parameters (ramp rates, minimum generation levels, Upper Operating Limits, etc.)

The costs that are being minimized in the optimization include :

- Generation incremental energy costs

- Dispatchable load schedule benefits to the extent there a 5-minute dispatchable loads

- Reserve schedule availability costs (Lost opportunity costs are implicitly captured through other costs)

- Regulation schedule availability costs (Lost opportunity costs are implicitly captured through other costs)

4.3   Real-Time Corrective Action (RTD-CAM)

RTD-CAM is the mechanism to reschedule NYISO units after unexpected, event driven emergency conditions that could not have been foreseen by the RTC and RTD. RTD-CAM includes the following:

- Reserve pickup -- reestablish the NYISO net interchange schedule after major system events caused by the loss of transmission lines or generators

- Reserve restoration -- reestablish reserves following a reserve pickup

- Max Gen pickup – increase generation in selected locations at emergency rates

- Base points ASAP, no commitments – calculate base points to correct line, contingency or transfer overloads and/or voltage problems caused by unexpected system events

- Base points ASAP, commit as needed -- calculate base points and commit 10-minute units to correct line, contingency or transfer overloads and/or voltage problems caused by unexpected system events

5   Pricing and Settlement

Highlights of pricing and settlement are described below.

5.1   Internal Energy

The two-settlement (day-ahead and real-time) of energy supplied by internal resources will be retained, as will penalties for significant under-generation.   The ability for off-dispatch energy resources to "chase price" will be eliminated.

Real-time energy prices will be determined every five minutes~~, after each dispatch interval (ex-post) and will account for actual conditions encountered and actual performance of suppliers. This marks a significant change from (ex-ante) as is the~~ current practice, where real-time prices are determined before each dispatch interval ~~(ex-ante)~~ using an estimate of conditions that will be encountered and schedules calculated for suppliers.

Real-time bid production cost guarantee will be given to on-dispatch resources.   Self-scheduled resources will not be given a real-time bid production cost guarantee.

5.2　Ancillary Service

A full two-settlement system (day-ahead and real-time) will be applied to reserve and regulation ancillary service. Both day-ahead and real-time clearing prices of regulation and reserve ancillary service will incorporate a marginal lost opportunity cost. This is intended to make internal resources indifferent to providing energy, reserve or regulation.

Resources chosen to provide ancillary service, that fail to provide the service when called upon, will be obligated to "buy-out" of their obligation. Otherwise, charges to under-performing resources associated with replacement energy will be eliminated. There will be no penalties to providers of 30-minute reserve.

5.3　Price of External Transactions

Transactions pre-scheduled in real-time will settle at the price determined hourly by RTC_{15} if the interface is binding, or at RTD prices, determined every five minutes, otherwise. Similarly, economically-scheduled import transactions will settle, or balance in the event of transactions scheduled day-ahead, at the price determined by RTC_{15} if the interface is binding, or at RTD prices otherwise.

A bid production cost guarantee will be given to imports. Initially, exports and wheels will have no bid production cost guarantee. A bid production cost guarantee may be extended to exports and wheels at a later time.

6　Posting

Information to be posted originates either in RTC, RTD or RTD-CAM. Results of each RTD, nominally every five minutes, will post for a time 5 minutes in the future with advisory information posted for an additional four quarter-hours. When RTD-CAM is activated, the posted results will be the same as those of RTD, except that in some situations RTD-CAM will make commitment decision and those will be posted as well.

The decisions made by each RTC to commit internal generating units and demand side resources will be posted: 15 minutes ahead for 10-minute units and 30-minutes ahead for 30-minute units. Decommitment decisions will also be posted. Additionally, schedules and associated prices of external transactions from RTC_{15} will be posted.

7　Automated Real-Time Mitigation

The mitigation plan calls for the mitigation of an internal energy resource when the resource's conduct (the asking prices for start-up, minimum generation, or incremental energy) is inconsistent with what would occur in a workably competitive market. The mitigation plan also requires that such conduct have an impact before mitigation can be applied. Thresholds of the "conduct" and "impact" tests are established in the mitigation plan and, where appropriate, are a function of localized market concentration. It is expected that all aspects of the mitigation plan will be automated in the RTS. These include the conduct test, impact test, and special thresholds in the event of localized market concentrations.