JULY 12, 2013 | MARLBOROUGH, MA

Operating Reserve Training

Welcome and Introductions

Peter Brunette

INSTRUCTIONAL DESIGNER
CUSTOMER SERVICE & TRAINING

Disclaimer for Customer Training

ISO New England (ISO) provides training to enhance participant and stakeholder understanding.

Because not all issues and requirements are addressed by the training, participants and other stakeholders should not rely solely on this training for information but should consult the effective *Transmission, Markets and Services Tariff* ("Tariff") and the relevant *Market Manuals*, *Operating Procedures* and *Planning Procedures* ("Procedures").

In case of a discrepancy between training provided by ISO and the Tariff or Procedures, the meaning of the Tariff and Procedures shall govern.

Objectives

- Explain Reserves in New England Markets
- Understand Reserve Requirements
- Understand how Markets meet those requirements

Agenda

8:30 a.m. – 8:40 a.m.	**Welcome and Introductions** *Peter Brunette, Instructional Designer, Customer Service and Training*
8:40 a.m. – 10:00 a.m.	**Overview of Reserves** *Ronald Coutu, Manager, Business & Technology Solutions,* Business Architecture and Technology
10:00 a.m. – 10:15 a.m.	**Break**
10:15 a.m. – 12:00 p.m.	**Real-Time Reserve Market and Day-Ahead Energy Market** *Ronald Coutu, Manager, Business & Technology Solutions,* Business Architecture and Technology
12:00 p.m. – 1:00 p.m.	**Lunch**
1:00 p.m. – 2:45 p.m.	**Forward Reserve Market** *Ronald Coutu, Manager, Business & Technology Solutions,* Business Architecture and Technology
2:45 p.m. - 3:00 p. m.	**Break**
3:00 p.m. – 3:30 p.m.	**Wrap up** *Ronald Coutu, Manager, Business & Technology Solutions,* Business Architecture and Technology
3:30 p.m. – 4:15 p.m.	**Future Changes to Reserve Market** *Ronald Coutu, Manager, Business & Technology Solutions,* Business Architecture and Technology
4:30 p.m.	**Course ends**

Administrative Details

- Fire escapes
- Restrooms
- Please turn cell phones and pagers to silent
- Do not use laptop, smart phones during class
- Instructors (people who do the work)
- Breaks
- Evaluations (provided in the front pocket of your binder)
- Glossary & Acronyms

Ground Rules

- Please feel free to ask questions during the presentation
- Material is overview/introduction only. If you have specific questions, please see us after the presentation
- Please be sensitive and allow others to ask questions
- Training class is not a Market’s Committee meeting on the Market Rules
- Unresolved questions are put in the “Parking Lot” with answers provided throughout the week
- If during the week you develop some unanswered questions, please feel free to ask the facilitator who will get an answer for you
- Have fun!

Customer Support

- Ask ISO
  - Self-service interface for submitting inquires
  - Accessible through the SMD Applications Homepage
  - Requires a valid digital certificate with the role of Ask ISO/External User
  - Contact your Security Administrator for assistance
- Phone: 413-540-4220
  - Monday through Friday, 7:30 A.M. to 5:30 P.M. Eastern Time
  - Recorded/monitored conversations
- Email: custserv@iso-ne.com

Introductions

- Name
- Organization
- Responsibility
- How long have you been in your job and the electric industry?
- What do you want to get out of this course?

Questions

JULY 12, 2013 | MARLBOROUGH, MA

Overview Operating Reserves

Ron Coutu

MANAGER,
BUSINESS ARCHITECTURE & TECHNOLOGY

Agenda

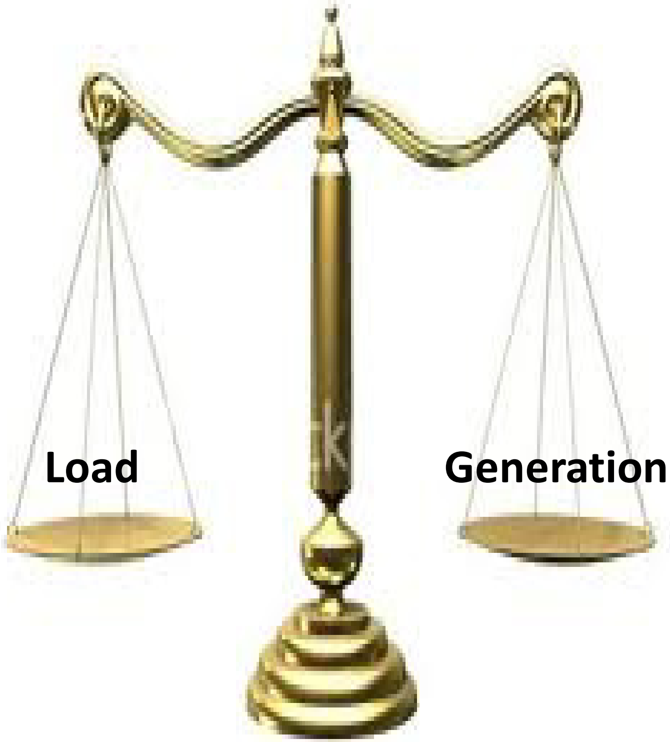
- Overview of Operating Reserves
- Reserves Markets
  - Real-Time Reserve Market
  - Day-Ahead Reserve Market
  - Forward Reserves
- Wrap-Up
- Future Changes involving Reserve Markets

RESERVE MARKET OVERVIEW

Overview of Operating Reserve

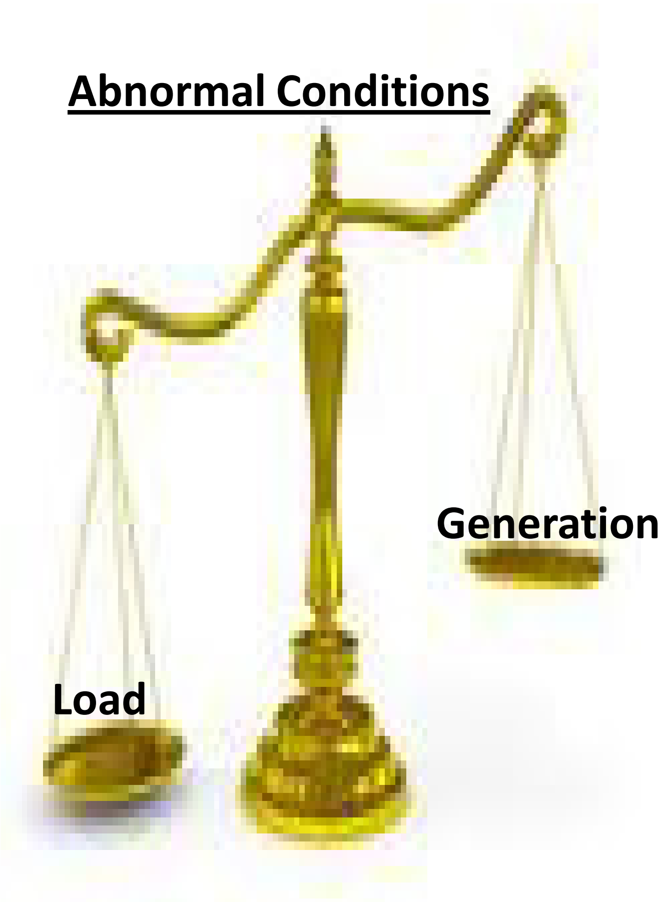
What are Reserves?

<u>Normal Conditions</u>



- So what happens when the system is in balance with generation meeting load and something unexpected happens:
  - Generator "trips" (stops injecting electricity into the system)
  - Other Generators on the system (both inside the ISO Control Area and outside the control area on "free-flowing" ties) respond immediately
  - Operators need to get OUR system back in balance (Generation = Load) QUICKLY

How fast do we need to convert Reserves to Energy?

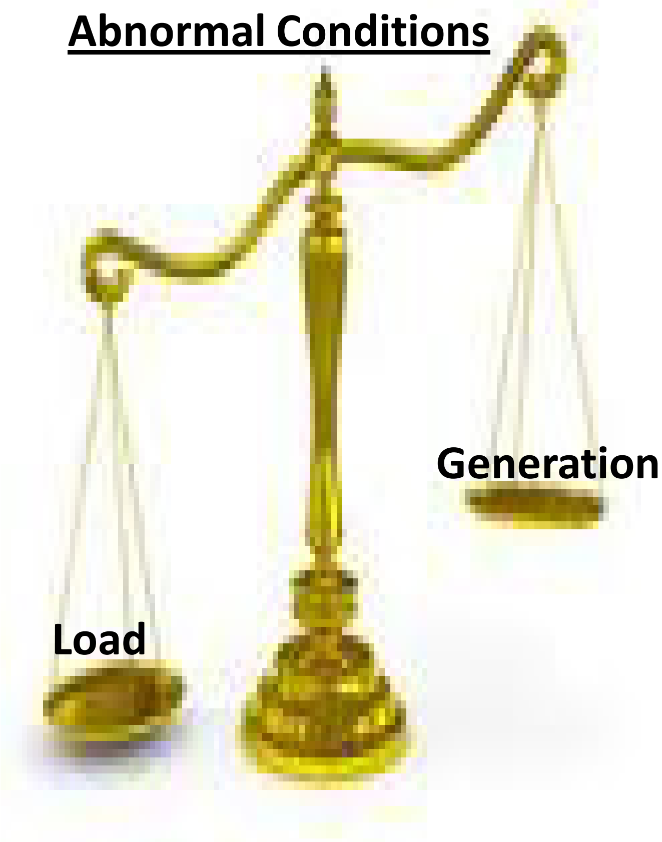


- First ISO tool to respond to this event is Regulation (it respond as quickly as 4 seconds)**
- The Operators need the other resources in the system to respond beyond Regulation to stop leaning on the neighbors when the disturbance is happening
- ** While Regulation might be thought of as a form of Reserves this training will not discuss Regulation

Category of Reserve Providers

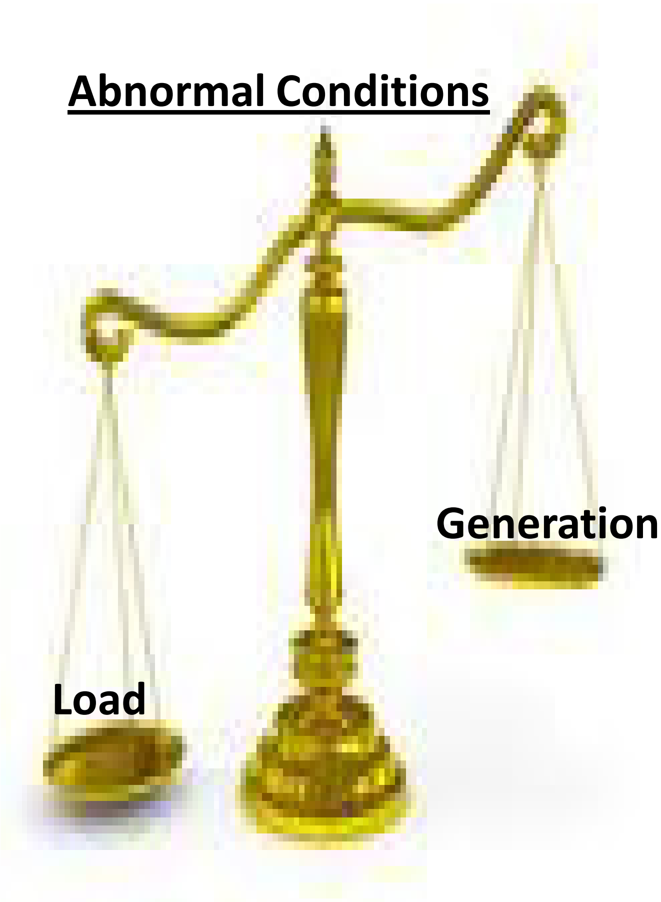
TMSR: "Ten-Minute Spinning Reserve"	TMNSR: "Ten-Minute Non-Spinning Reserve"	TMOR: "Thirty-Minute Operating Reserve"
• Capability of on-line unit to provide increased energy within 10 minutes • Partially loaded on-line generator • Limited by ramp rate and Eco Max • Pump Storage Pumping Asset	• Capability of off-line resources to provide energy within 10 minutes • Off-line generation turbine, diesel or hydro generators • Load interruption – Non-Pump Dispatchable Asset Related Demand (DARD)	• Capability of resources to provide energy within 30 minutes • Can be either on-line or off-line resource • Generally the larger generation turbines • Load Interruption – Non-pump DARD can also qualify

How fast do we need to convert Reserves to Energy? (TMSR and TMNSR)



- Resources providing the TMSR and TMNSR products are dispatched up by the ISO in real time in response to a contingency
  - Under NERC standard BAL-002-1 (R4.1), the ISO must ensure that, upon the loss of a supply source meeting certain criteria, the lost supply is replaced (i.e., the Area Control Error ("ACE") is returned to zero or to the value just prior to the loss of supply) within 15 minutes of the occurrence of the contingency

How fast do we need to convert Reserves to Energy? (TMOR)



- Resources providing the TMOR product are dispatched up by the ISO in real-time when the available TMSR and TMNSR is below or is expected to be below the total system TMR requirement
  - Under NERC standard BAL-002-1 (R4.1), the ISO must restore its total system TMR requirement either:
    1. within 90 minutes from the end of the disturbance recovery period (if the deficiency was caused by a NERC-reportable supply loss) or
    2. within 90 minutes from the time when there was insufficient resources providing the TMR product to meet the total system TMR requirement (if the deficiency was not caused by a NERC-reportable supply loss)

What are Control Area Reserves?

- Reserve Capacity – Capacity over and above what is required to provide energy in the Control Area in order to ensure reliability; this capacity is available for dispatch during system contingencies
- Reserves allow the Control Area to withstand contingencies
  - Reserve capacity requirements are based on largest foreseeable loss of supply
    - Contingency examples: Large generator trips, external line trips

What are Local Reserves?

- Local Reserve Capacity – Capacity over and above what is required to provide energy in the Local Area (Reserve Zone) in order to ensure reliability; this capacity is available for dispatch during Local contingencies
- Local Reserves allow the Local Area to withstand contingencies
  - Reserve capacity requirements are based on largest foreseeable loss of supply or Transmission interface capacity
    - Contingency examples: Large generator trips, line trips

Regulatory Reserve Requirements

- NERC establishes minimum requirements
  - 100% of the 1st Largest Single Source Contingency available in 10 minutes
- NPCC establishes minimum requirements
  - 100% of the 1st Largest Single Source Contingency within 10 minutes and
  - 50% of the 2nd Largest Single Source Contingency within 30 minutes
- ISO requirements include an additional 25% of 10 Minute Reserve to account for generator non performance

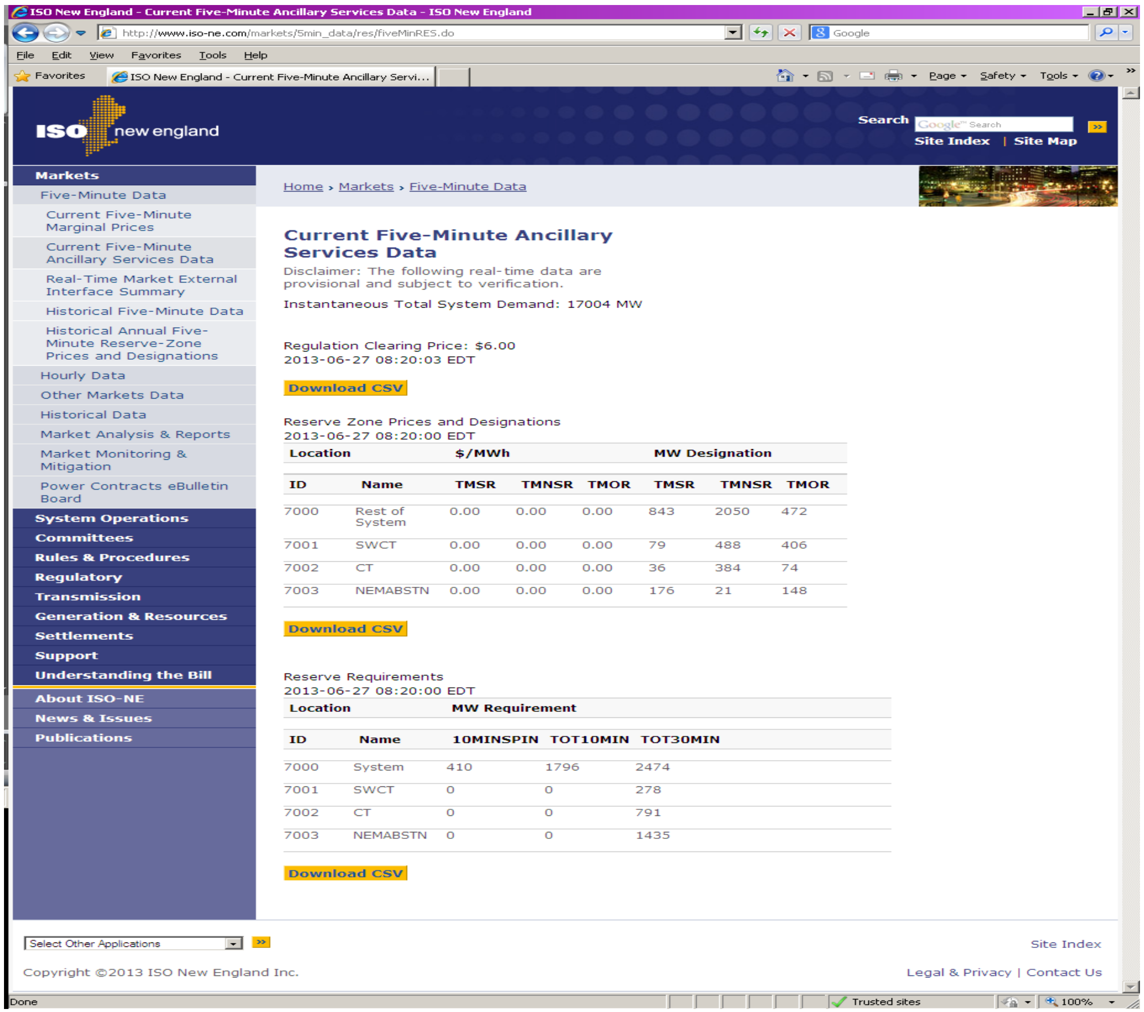
New England Operating Reserve

System Requirements

- Current Operating Reserve Requirements
  - 125% of 1st Contingency MW in 10-Minute Reserve
    - 50% of MW carried as TMSR
    - Breakdown may vary to as low as 25% in TMSR
  - 50% of 2nd Contingency MW in 30-Minute Reserve

- Typical Requirement
  - Requirement is 1800+ MW in 10-Minute Reserve
    - 900 MW TMSR
  - Requirement is the above 1800+ plus additional 750 MW in 30-Minute Reserve creates the Total Operating Reserve Requirement

Where to find Reserve Information on ISO Website?



ISO New England - Current Five-Minute Ancillary Services Data - ISO New England

http://www.iso-ne.com/markets/5min_data/res/fiveMinRES.do

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Markets
- Five-Minute Data
  - Current Five-Minute Marginal Prices
  - Current Five-Minute Ancillary Services Data
  - Real-Time Market External Interface Summary
  - Historical Five-Minute Data
  - Historical Annual Five-Minute Reserve-Zone Prices and Designations
- Hourly Data
- Other Markets Data
- Historical Data
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- Market Monitoring & Mitigation
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Current Five-Minute Ancillary Services Data

Disclaimer: The following real-time data are provisional and subject to verification.

Instantaneous Total System Demand: 17004 MW

Regulation Clearing Price: $6.00
2013-06-27 08:20:03 EDT

Download CSV

Reserve Zone Prices and Designations
2013-06-27 08:20:00 EDT

Location		$/MWh			MW Designation		
ID	Name	TMSR	TMNSR	TMOR	TMSR	TMNSR	TMOR
7000	Rest of System	0.00	0.00	0.00	843	2050	472
7001	SWCT	0.00	0.00	0.00	79	488	406
7002	CT	0.00	0.00	0.00	36	384	74
7003	NEMABSTN	0.00	0.00	0.00	176	21	148

Download CSV

Reserve Requirements
2013-06-27 08:20:00 EDT

Location		MW Requirement		
ID	Name	10MINSPIN	TOT10MIN	TOT30MIN
7000	System	410	1796	2474
7001	SWCT	0	0	278
7002	CT	0	0	791
7003	NEMABSTN	0	0	1435

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Site Index

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Market Rule Governing Sections for Reserves

- MR 1 Section III.2 Real-Time Reserve Clearing Prices
  - III.2.7A Calculation of Real-Time Reserve Clearing Prices
- MR 1 Section III.9 Forward Reserve Market
- MR 1 Section III.10 Real-Time Reserve
  - III.10.4 Forward Reserve Obligation Charges
    - These charges are determined in Real-Time Reserve Section

Manuals that refer to Reserves

- M-11 Market Operations
  - Throughout when discussing Real-Time Market inputs
  - 2.5.9.2 Real-Time Energy Market
    - Section (6) Calculating Real-Time Reserve Clearing Prices
  - 6.4 Real-Time Operating Reserve Requirement Determination
- M-36 Forward Reserves
- M-28 Accounting
  - Section 2 Forward Reserve and Real-Time Reserve Accounting

Operating Procedures associated with Reserves

- Operating Procedure No. 4 – Action During a Capacity Deficiency
  - Discussed on Following Slides
- Operating Procedure No. 8 – Operating Reserve and Regulation
  - Define Products
  - Define Requirements
- Operating Procedure No. 23 – Generator Resource Auditing
  - Section II Off-Line Reserve Auditing
    - Off-Line Reserve Audit (CLAIM10 and CLAIM30)

Questions

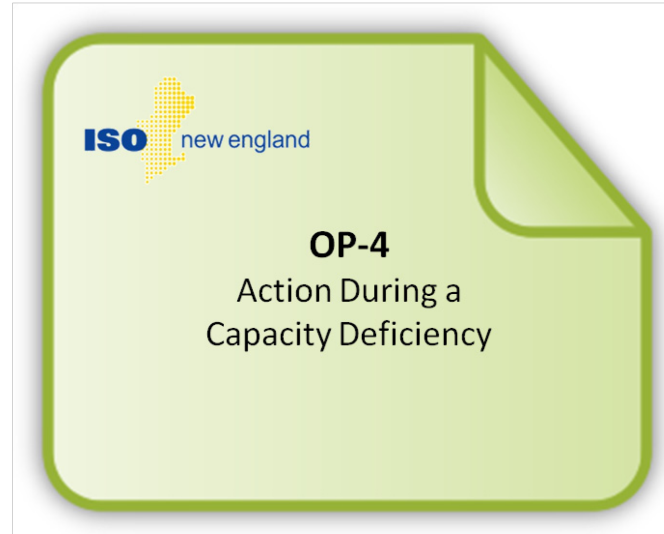
SHORT DISCUSSION ON OP-4

How OP-4 reflects the Operators strong desire to have reserve capability available

Capacity Deficiency (OP-4)

Purpose

- Establishes criteria and guides for actions during capacity deficiencies
  as directed by ISO and as implemented by ISO and Local Control Centers.

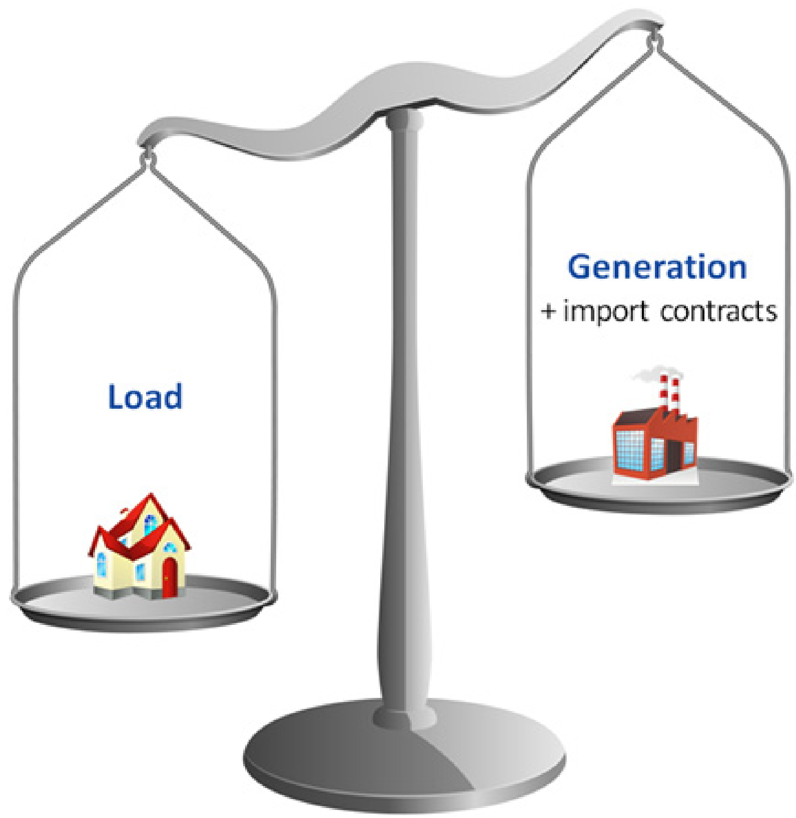


[Home > Rules & Procedures > Operating Procedures > ISO New England Operating Procedures]

Capacity Deficiency (OP-4)

Indicators

- New England running out of generating capacity
- Load plus reserve requirement greater than available resources



Capacity Deficiency (OP-4)

Potential Entry Conditions

OP-4 may be implemented any time one or more of the following events, or other similar events, occur or are expected to occur:

- Resources < [Load + Reserve]
- One or more contingency results in an immediate deficiency of available capacity resources required to meet the load plus Operating Reserve Requirements.
- Transmission facilities into a sub-area are loaded beyond established transfer capabilities.
- A sub-area is experiencing abnormal voltage and/or reactive conditions.
- Need to implement manual load shedding is imminent but load shedding may be avoided, or reduced in magnitude.
- Area experiences a capacity deficiency and has requested assistance from ISO, which will reduce actual Operating Reserve below the required levels.
- Any other serious threat to the integrity of the bulk power system

Capacity Deficiency (OP-4)

Actions Overview

- The Notices section of the ISO website is updated upon implementation of each action.
- While the actions of OP-4 are laid out in sequential order, ISO will implement each step as it best adds to system reliability.

OP-4 Action 1

ISO Responsibility

Notifications
ISO will inform all resources that a capacity shortage exists. Each generator and demand resource with a Capacity Supply Obligation will prepare to provide all associated operable capability.
ISO will notify via the Notices section of the ISO website that each "Settlement Only" generator with real-time obligations and Capacity Supply Obligation should be monitoring the status of the reserve pricing and are required to meet their obligation under the "Shortage Event" definitions in Market Rule 1.
Allow depletion of 30-minute reserve
Begin to allow the depletion of 30-minute reserve.
Power Caution
Implement a Power Caution. A Power Caution means that system reserves cannot be maintained using normal measures. State agencies and local organizations might have procedures that they follow when ISO declares a Power Caution.

OP-4 Action 2

ISO Responsibility

Dispatch Real-Time Demand Response as necessary
Dispatch Real-Time Demand Resources in the amount and location required. ISO will dispatch Real-Time Demand Response resources that are obligated to reduce load at their factory, businesses, etc., when dispatched.

OP-4 Action 6

- ISO responsible for demand resources and sharing reserves
- LCCs for voltage reduction

Action 6 may be implemented to the extent required to maintain **Ten-Minute Reserve**, in accordance with OP-8, and to enable ISO to better cope with possible continuing and deteriorating abnormal operating conditions.

5% Voltage Reduction > 10 minute
Implement a voltage reduction of five percent (5%) of normal operating voltage requiring more than 10 minutes to implement. A 5% voltage reduction that takes longer than 10 minutes to implement means voltage is dialed down on the distribution system. Voltage reductions have a big effect on large machinery, spinning motors, and other industrial loads in factories and businesses.

OP-4 Action 6 (cont.)

- ISO responsible for demand resources and sharing reserves
- LCCs for voltage reduction

Dispatch Real-Time Emergency Generation resources
Dispatch Real-Time Emergency Generation Resources in the amount and location required. At this time, System Operators also dispatch Real-Time Emergency Generation Resources. These are load reducing generators with air quality permits that are only allowed to generate when ISO has implemented a voltage reduction. If there is a power outage, ISO can't participate in the market but has two diesel generators that are used for back-up power. If program requirements are met, other businesses with diesel generators, such as grocery stores, can participate in the program.
Alert the New York Independent System Operator (NYISO) that <u>sharing of reserves within NPCC may be required.</u>

OP-4 Action 7

ISO Responsibility

NOTE: The following request will be made on a forecast basis when ISO anticipates it will be **unable to maintain Ten-Minute Reserves** or in real time based on the current operating day conditions.

Request generators not subject to a Capacity Supply Obligation (CSO) voluntarily provide energy for reliability purposes.
It is possible that a generator may have a CSO less than its actual physical capability. Generators are obligated to only offer in their CSO value as their maximum operating limit. In Action 7, ISO will ask generators to voluntarily supply additional energy. It is the discretion of each generator to make this capacity available. Action 7 is also accompanied by an ENS message, and along with Action 1, it notifies all generators to prepare to offer energy.

OP-4 Action 8

ISO and LCC Responsibility

Action 8 will be implemented to **maintain adequate ten-minute synchronized reserve** in the New England RCA/BAA. The amount of ten-minute synchronized reserve to be maintained will be determined based on actual system conditions at the time of the shortage or the need to aid another NPCC RCA/BAA under the NPCC Operating Reserve Policy.

5% Voltage Reduction < 10 minute
Implement a voltage reduction of five percent (5%) of normal operating voltage that is attainable within 10 minutes. At this point, ISO New England is starting to run out of options. In all, voltage reductions relieve approximately 1.5% of the total system load. This includes Actions 6 and 8.

OP-4 Action 9

LCC Responsibility

Actions 9, 10, and 11 will normally be implemented by ISO through the LCCs based upon advance projections made by ISO that it will be necessary to implement Actions 1 through 8, and that it will **not be possible to maintain adequate ten-minute synchronized reserve**. When Actions 9 and 10 are requested, the particular hours to be implemented will be specified by ISO. Actions 9, 10, and 11 should be implemented as early as possible to achieve maximum benefit.

- **Request all of the customer generation not contractually available to Market Participants**
- **Request voluntary load curtailments by large industrial and commercial customers.**

Questions

RESOURCES THAT CAN PROVIDE RESERVES

Unit Control Mode (UCM)

A Unit Control Mode (UCM) describes the current operational state of a generator/DARD.

UCM 1	UCM 2	UCM 3	UCM 4	UCM 5	UCM 6
Off-line and unavailable for dispatch	Off-line and available for dispatch	Generator on-line, not dispatchable	On-line and available for dispatch	Posture generator to maintain reliability or provide VAR support	Generator regulating

Available = Unit is capable of starting in accordance with bid-in start-up parameters.
Dispatchable = Unit can follow DDPs through its bid-in dispatchable range.

Units in UCM 1 and UCM 3 - not capable of providing reserves

Relevant Market Rule 1 Terminology

Per Section III.9.5.3 of Tariff

- CLAIM10 and CLAIM30 shall equal:
  - (a) the maximum output level reached, including output reached during a CLAIM10 or CLAIM30 audit, measured at the 10 minute or 30 minute point from the Resource's receipt of an initial electronic startup Dispatch Instruction during the current Forward Reserve Procurement Period or the preceding like-season Forward Reserve Procurement Period, subject to the conditions in Section III.9.5.3.1.2;
  - (b) multiplied by the Resource's then effective CLAIM10 or CLAIM30 performance factor established pursuant to Section III.9.5.3.3.

CLAIM10/CLAIM30 Auditing Changes - Overview

- On Sept 2, 2010, ISO failed to comply with NERC Disturbance Control Standard (DCS).
- An in-depth review of operations following the DCS Event raised questions about generator capabilities.
- Historical generator performances did not match the CLAIM values for a number of reasons.
- In order for ISO to model generator performance more accurately, the reserve auditing rules were changed and took effect June 1, 2013.

CLAIM10 Capability (similar rules for CLAIM30)

ISO calculates the reserve capability of an offline resource as the lower of the **CLAIM10** value or the **Offered CLAIM10**.

CLAIM10 Capability

Used for:

- Settlements
- Real time reserve calculations
- **Performance factor calculation**

Offered CLAIM10

- Provides a Market Participant the ability to offer (or redeclare) a TMNSR capability that is different than the CLAIM10 of the resource

CLAIM10

- Maximum amount of Ten-Minute Non-Spinning Reserve (TMNSR) that can be allocated to a resource based on historical performance

CLAIM10 Value

CLAIM10 Capability

Used for:

- Settlements
- Real time reserve calculations
- **Performance factor calculation**

— **Offered CLAIM10**

|

CLAIM10 = ***Maximum Output Level*** × ***Performance Factor***

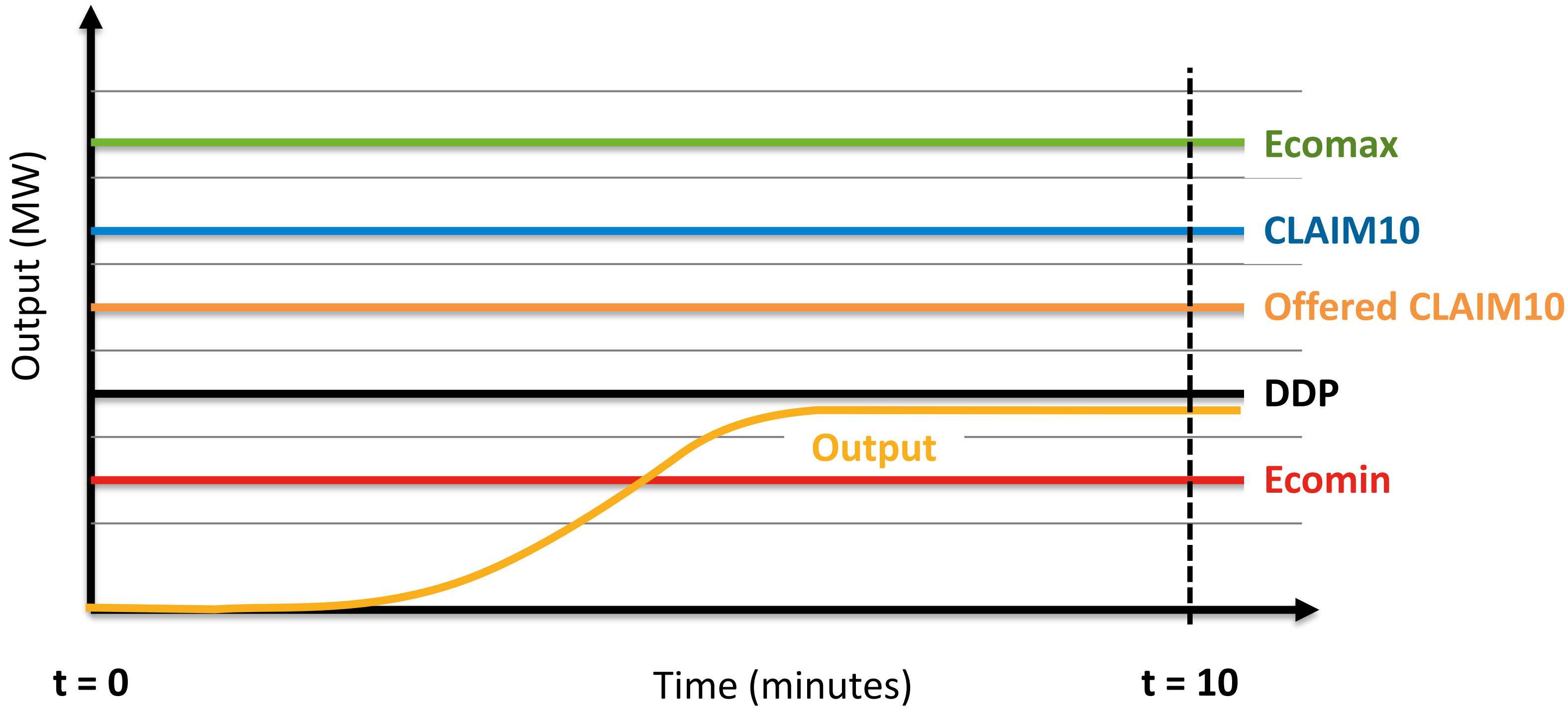
Maximum Output Level

CLAIM10 = ***Maximum Output Level*** × ***Performance Factor***

- The highest output a resource has reached at **ten minutes** in the current or previous like Forward Reserve Procurement Period.
- Resource must stay in service for **60 minutes** following dispatch (Unit Control Mode (UCM) 2 or higher)

Performance Factor and Target Value

- Each time a fast start resource is dispatched from an offline state its performance is evaluated based upon its output at ten minutes, in relation to its target value.



Relevant Market Rule 1 Terminology

Per ISO-NE Tariff section I.2.2 Definitions

- Fast Start Generator
  - Means a generating unit that the ISO may dispatch within the hour through electronic dispatch and that meets the following criteria: (i) minimum run time does not exceed one hour; (ii) minimum down time does not exceed one hour; (iii) time to start does not exceed 30 minutes; (iv) available for dispatch and manned or has automatic remote dispatch capability; (v) capable of receiving and acknowledging a start-up or shut-down dispatch instruction electronically; and (vi) has satisfied its minimum down time.

More information about CLAIM10/CLAIM30

- ISO New England did a WebEx specifically on the new CLAIM10/CLAIM30 process on May 7th, 2013
- Training material is posted on the ISO Website under
  - Home > Support > Training > Training Materials > CLAIM10 and CLAIM30 Auditing Changes
  - The text above will bring you to the following link:
    - http://www.iso-ne.com/support/training/courses/auditing_chng/index.html
- More details about the CLAIM10/CLAIM30 auditing process can be found in these materials

Reserve Market Design

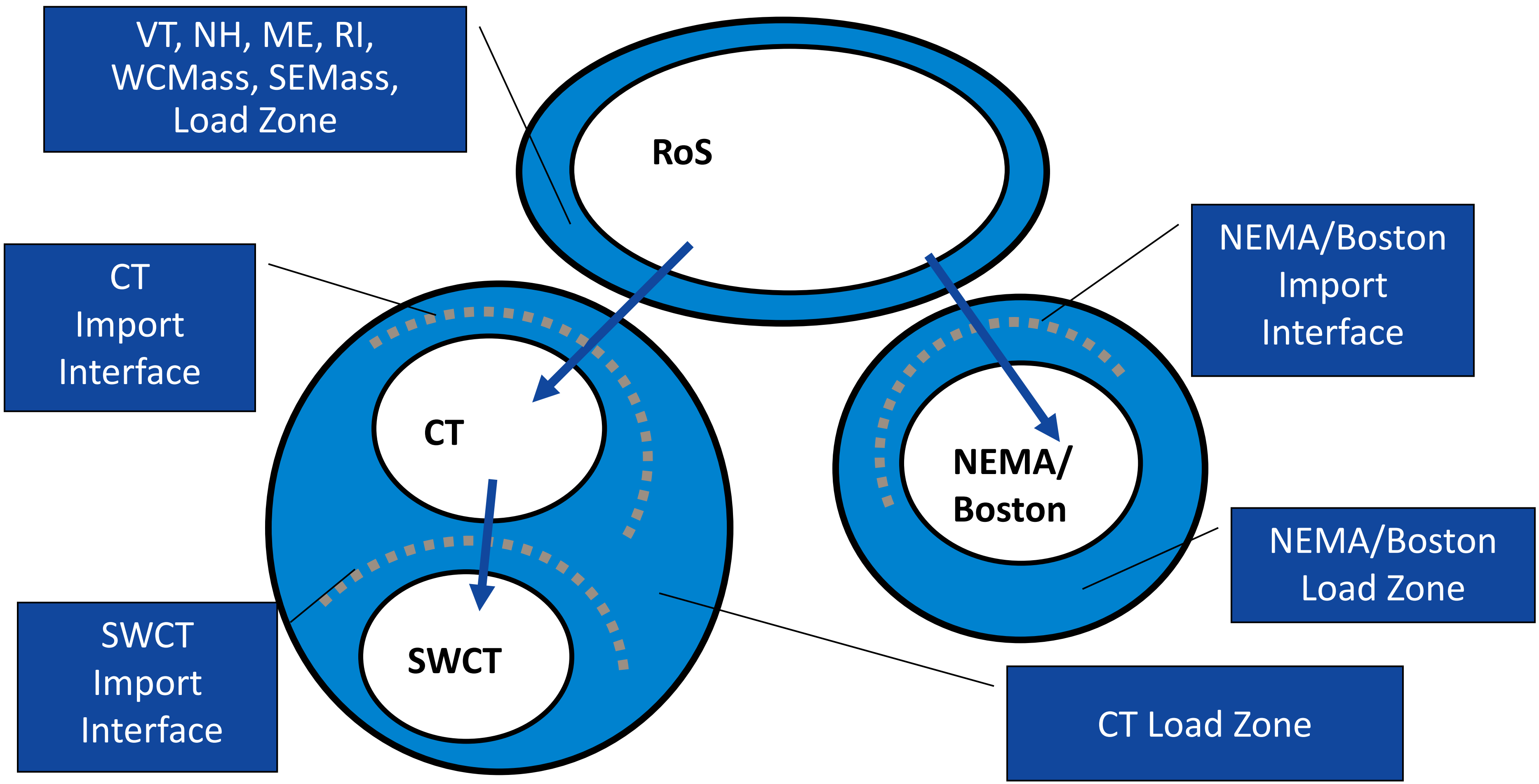
Forward Reserve Market (FRM)

- Market Mechanism to procure capacity in resources to provide the off-line reserves that are incorporated in the optimal dispatch of Real-Time Energy and Reserves
- FRM was designed to provide appropriate economic incentives to resources that provide these valuable Real-Time operating reserves
  - Location aspects to this design also tend to ensure procuring reserves to meet local and system-wide constraints optimally
- This is a “forward option” style market, that requires delivery of the product during the Real-Time Market
  - More discussion on this market will come towards the end of this presentation

SETTING REQUIREMENTS

For the System and Local Reserve Zones

Understanding the link between Reserve Zones and Load Zones



Operating Reserve

Locational Requirements

- Locational Requirements reflect the need to protect against a Double Contingency event in a Reserve Zone Area
- Currently Defined Reserve Zones:
  - NEMA/Boston Zone
  - CT Zone
  - SWCT Zone

Operating Reserve

Locational Requirements

- Typical Requirements
  - NEMA/Boston Zone : 1700 MW
  - CT Zone : 900 MW
  - SWCT Zone : 500 MW

- These requirements are very sensitive to load and generators within the Reserve Zone

RESERVE MARKET OVERVIEW

Reserve Market Design

Reserve Market Design

- ISO-NE Reserve Market
  - Two Components
    1. **Real-Time Reserve Market**
    2. Forward Reserve Market

JULY 12, 2013 | MARLBOROUGH, MA

Real-Time Reserve Market and Day-Ahead Energy Market

Ron Coutu

MANAGER,
BUSINESS ARCHITECTURE & TECHNOLOGY

Why have a Real-Time Reserve Market?

- Reserves are a product that is valued by the Operators
- This is evidenced by the strong desire to preserve the reserve capabilities as identified in OP4
  - Remember we will ask for voluntary load-reduction and implement voltage reductions to maintain our first-contingency reserves
- Markets should place a monetary value on this product
- What is the right price to pay?

Reserve Market Design

Real-Time Reserve Market

- Real-Time Energy and Reserves Co-optimization
  - The market clearing prices for Energy and reserves (TMSR, TMNSR, TMOR) are determined simultaneously
- Least cost method for meeting energy demand while maintaining system reliability
  - Dispatch point for each generator is optimal point for revenue from the Energy and Real-Time Reserve Markets
- Real-Time Reserve is monitored by the Control Room to ensure reserves throughout the operating day

Real-Time Reserve Market Pricing

- Each Real-Time dispatch execution dispatches and prices resources to simultaneously meet all active energy, reserve and transmission constraints
  - Suppliers do not submit offers for real-time reserves; the hourly Reserve Market Clearing Prices (RMCP) are determined using energy offers
    - TMSR RMCP, TMNSR RMCP, TMOR RMCP
- Real-Time Market Clearing prices for reserve are set by either:
  - Re-dispatch cost, which represents the additional cost, above the optimal dispatch, necessary to meet the reserve requirements, or
  - Reserve Constraint Penalty Factor is an administrative price designed to reflect the value of reserve scarcity when a reserve requirement cannot be satisfied

Real-Time Reserve Designation

- All units in New England that are capable of providing Operating Reserve will be evaluated for Real-Time Reserve
- Reserve quantities are designated by resource on the basis of reserve capability and the dispatch/re-dispatch cost of reserve
- Real-Time Reserves settlements:
  - Remember, there are no Real-Time Reserve Offers

In most hours, RMCPs are zero, later slides will explain why this is true. Non-zero RMCP values show in less than 10 % of the hours since inception of Ancillary Markets (2006)

Objective of the following sections…

- Provide a basic understanding of the Real-Time Energy and Reserve Market in New England, and answers to the following questions:
  - How are reserves modeled and designated?
  - What is the relationship between energy and reserve prices and the corresponding cleared quantities?
  - How do reserve penalty factors influence market clearing prices?

ENERGY RESERVE CO-OPTIMIZATION IN REAL-TIME MARKET

Overview of Energy Reserve Co-optimization

Why Co-optimization?

- Energy and reserve are naturally coupled
  - Energy and reserve may be provided from the same physical resource, and the trade-off has to be made when a resource can provide to both energy and reserve markets
- Clearing energy and reserve in a co-optimized solution
  - Reveals the coupling effect between energy and reserve prices;
  - Strengthen incentives for resources to follow dispatch instructions;
  - Maximizes the total social welfare

What is Energy-Reserve Co-optimization?

- Real-Time Power System Operations needs to:
  - meet Energy Demand (Energy Market)
  - meet Reserve Requirement (Reserve Markets)
- Real-Time Energy-Reserve Co-optimization jointly clears the Energy Market and Reserve Markets in a least cost fashion

Benefits of Co-optimization

The System Operator's View

- Provides the cheapest way of meeting energy demand while maintaining the system reliability
- Effectively determines the market clearing prices for both energy and reserve simultaneously
- Provides incentives for following dispatch
- Effectively identifies resources for system re-dispatch as well as proper compensation for the re-dispatched resources

Benefits of Co-optimization

The Market Participant's View

- Provides the optimal energy and reserve allocation that, based on its bid-in parameters, maximizes:
  - total as-bid profit of a generating resource
  - total as-bid benefit of a dispatchable load
- Following dispatch under co-optimization, is the best solution from participant's view too

How Did We Handle Meeting Reserve Constraints Without Co-optimization?

- In most cases, the committed set of resources will exceed the load plus reserve requirements of the system
  - Reserve will be met with a combination of off-line and on-line unloaded capacity
  - Reserve requirement is resolved by Unit Commitment
- When the amount of reserves is tight then re-dispatch of faster resources down while continuing to move slower units up must be done to exactly meet reserve & energy requirement
  - Without software co-optimization, this required an Operator to hold a resource down, out-of-merit, to preserve it’s reserve capabilities
  - This Operator action is not priced within the markets, paid through uplift

ENERGY RESERVE CO-OPTIMIZATION IN REAL-TIME MARKET

LMP Decomposition

$$LMP_i = \underbrace{LMP_E}_{\text{Energy Component}} \underbrace{- LF_i \cdot LMP_E}_{\text{Loss Component}} + \underbrace{\sum_{k=1}^{K} GSF_{k,i} \cdot SP_k}_{\text{Congestion Component}},$$

- The energy component is the same for all locations and equal to the shadow price of the system balance constraint (which may include System Reserve Constraints)
- The congestion components equal zero for all locations if there are no binding transmission or Local RESERVE constraints – all SP_k=0
- The loss component is the marginal cost of additional losses caused by supplying an increment of Load at the location

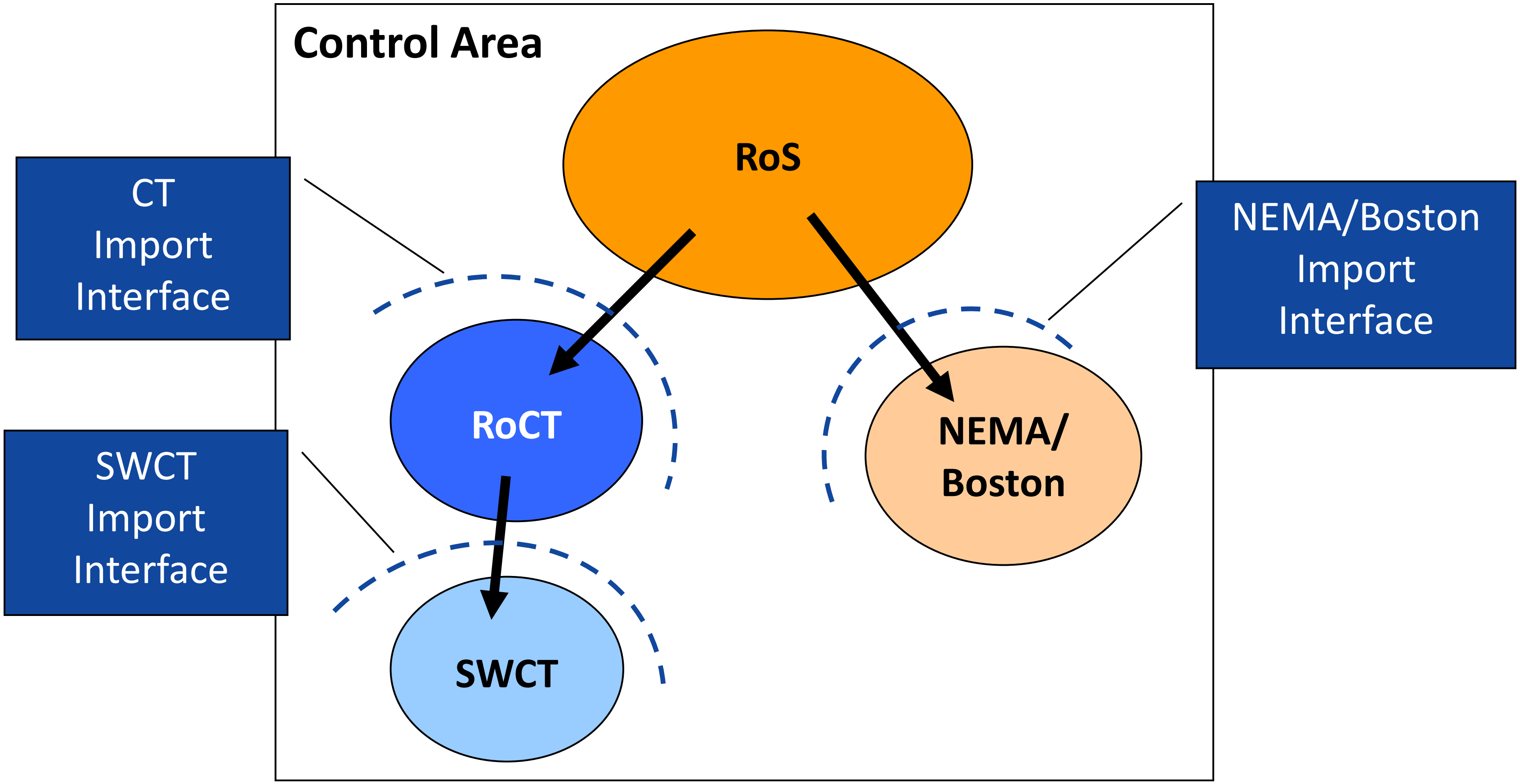
Features of Real-Time Market

- Bids for the RTM
  - Energy Offers and Demand Bids
  - External Transaction Purchases and Sales
  - There are no Real-Time availability bids for reserves
- Energy and Reserve Co-optimization
  - Locational Reserve Modeling
  - Reserve Shortage Pricing
  - Reserve Price Cascading

Current Reserve Products

- Ten-Minute Spinning Reserve (TMSR)
- Ten-Minute Non-Spinning Reserve (TMNSR)
- Thirty-Minute Operating Reserve (TMOR)

Reserve Zones and Pricing Locations



Note: **Three** Local Reserve Requirements (for three Interfaces), **Four** Pricing Locations (or four Reserve Zones), and Three Reserve Products (for each Reserve Zone)

RoS: Rest of System **RoCT: Rest of Connecticut**

Qualified Reserve Resources

- Online
  - Online dispatchable
  - Automatic Generation Control (AGC)
- Off-line
  - Qualified 10 minutes capable unit
  - Qualified 30 minutes capable unit
- Asset Related Demands (ARD)
  - Dispatchable ARDs
  - Pumps (pumped-storage unit)

ENERGY RESERVE CO-OPTIMIZATION IN REAL-TIME MARKET

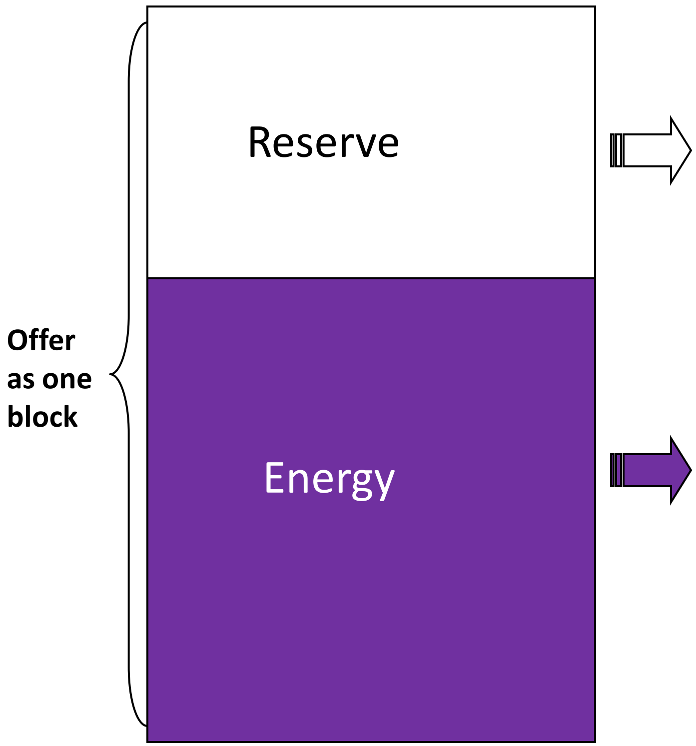
What does Co-optimization do for Resources?

Trade-off Between Energy and Reserve

- If not constrained by ramping capability, any potential MW of energy is a trade-off for a potential MW of reserve provided by the same unit
- Profit maximization will drive the unit's decision as to producing energy or providing reserve
- Energy-reserve co-optimization provides ISO Operations with the modeling capability to dispatch both energy and reserve optimally and simultaneously
- The optimal solution provides the best outcome to all dispatchable resources as well

Trade-off Between Energy and Reserve

Conceptual Illustration



Incremental Reserve Profit = RMCP - 0

Note: RMCP = Reserve Market Clearing Price

Which one is more profitable?

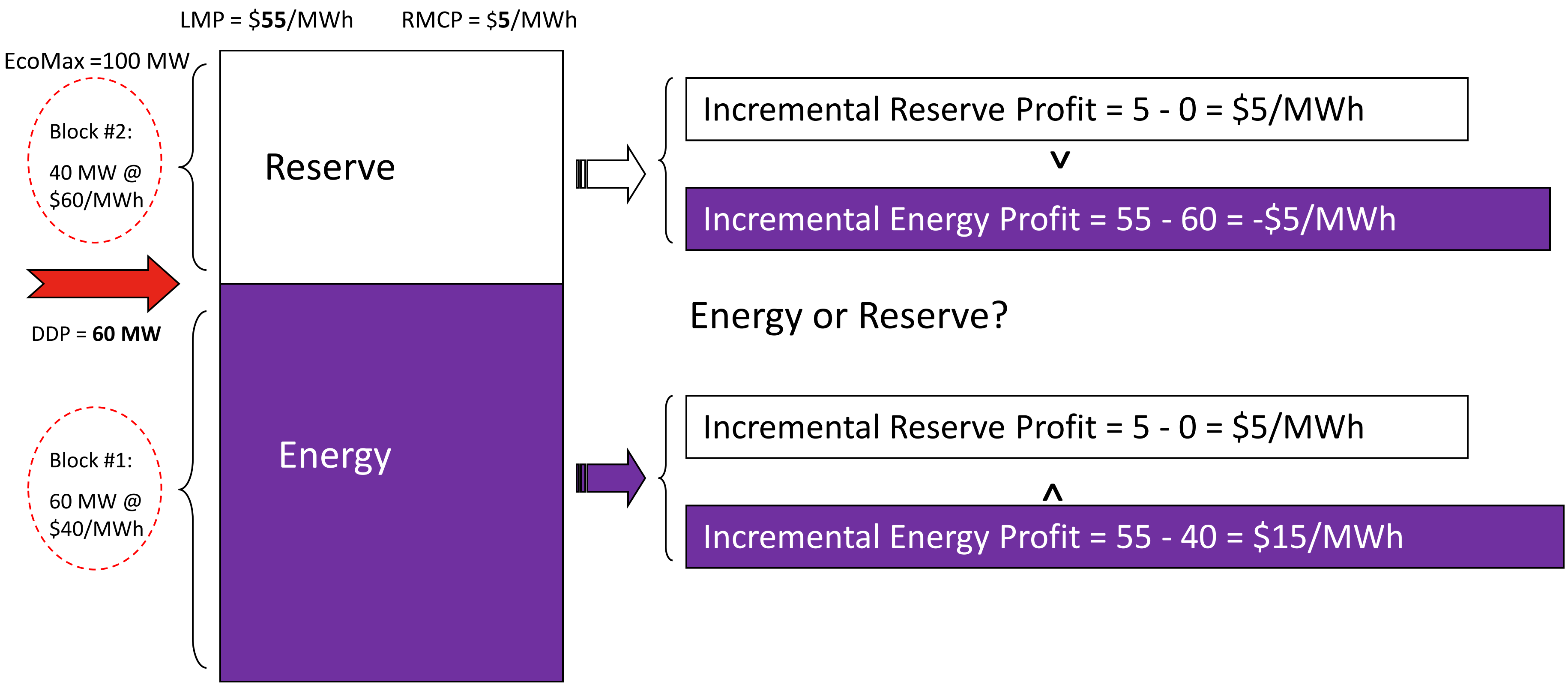
Incremental Energy Profit = LMP - Marginal Cost

Note: LMP = Locational Marginal Price (for energy)

Energy-reserve Co-optimization provides the optimal allocation of energy and reserve for each unit

Trade-off Between Energy and Reserve

Base Case Example

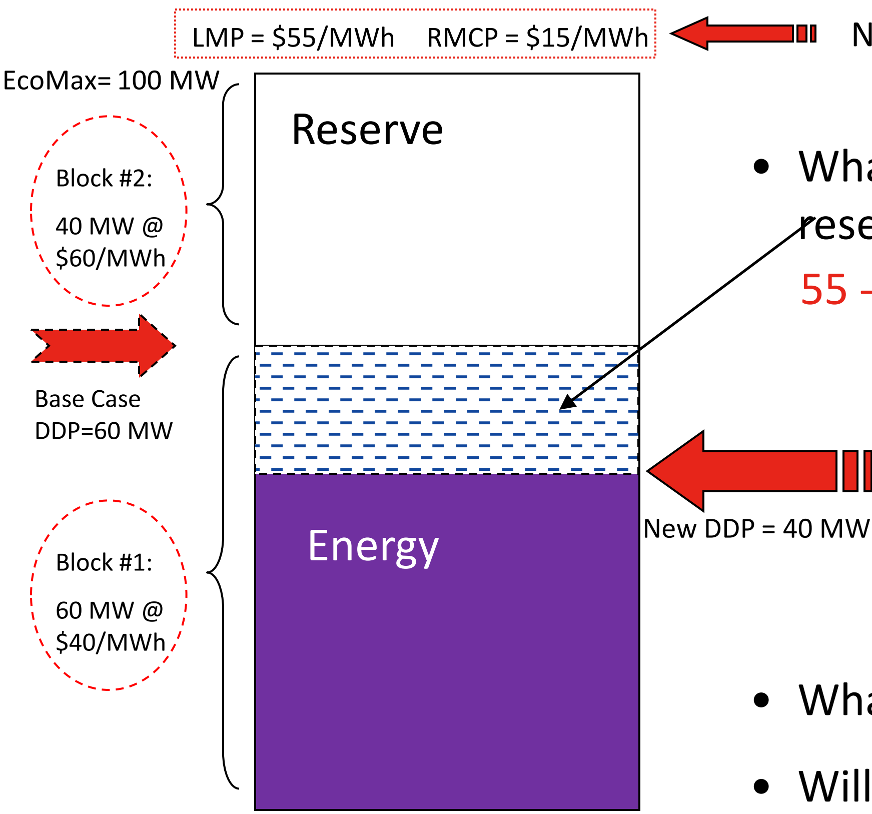


Unit maximizes its profit when operating at 60 MW Desired Dispatch Point (DDP):

- If DDP > 60 MW, providing reserve makes more profit than producing energy. Unit will choose to back down energy and provide more reserve.
- If DDP < 60 MW, producing energy makes more profit than providing reserve. Unit will choose to increase energy and reduce reserve.

Trade-off Between Energy and Reserve

Reserve Requirement Increased by 20 MW



- What is the unit’s lost opportunity cost to provide reserve instead of producing energy?
  55 - 40 = $15/MWh

Incremental Reserve Profit = 15 - 0 = $15/MWh
=
Incremental Energy Profit = 55 - 40 = $15/MWh

- What should be the right LMP and RMCP?
- Will the unit maximize its profit and follow DDP?

When the new prices send the right market signal, unit maximizes its profit when following the System Operator’s Desired Dispatch Point (DDP) - 40 MW

ENERGY RESERVE CO-OPTIMIZATION IN REAL-TIME MARKET

*Real-Time Reserve Modeling and Design*ation

ISO new england

Reserve Requirements

- Reserve requirements are based on System or Reserve Zone contingency recovery needs within 10 or 30 minutes
- At a Reserve Zone (NEMA/Boston, CT, and SWCT), the Real-Time Market design has only a 30-minute reserve requirement

Locational Reserve Requirement

- In Reserve Zones, such as NEMA/Boston, CT, and SWCT, there is no 10-minute reserve requirement
  - Anticipates that the local largest First Contingency recovery requirements can be met by operating at the (N-1) import Interface limit
- The Real-Time Market design has only a 30-minute reserve requirement to meet 100% of the largest Second Contingency recovery needs in the Reserve Zone subject to the (N-1) import Interface limit

Reserve Constraint Penalty Factor (RCPF)

- A RCPF is the cost of reserve from "virtual" reserve resources, that ISO software can "deploy" when there is a shortage of reserve from actual resources
- RCPFs are also a maximum cost that will be incurred to redispatch resources to continue to provide reserves (see examples below)
- RCPFs set a value for reserves when the requirements are not being met
- Penalty Factors are commonly used to prevent infeasible solutions of an optimization problem
  - The value of any Penalty Factor, including RCPF, does affect the market clearing and pricing

Reserve Constraint Penalty Factor (RCPF)

- Current RCPF values are in $/MWh:
  - $ 50MWh for system-wide TMSR constraint
    - Reflects an Operators desire to have a set portion of Total 10 provided by “spinning” resources
  - $850 MWh for system-wide total 10-min reserve constraint
    - Reflects the Operators requirement (and NERC requirement) to cover the loss of the system’s largest contingency within 10 minutes
  - $500 MWh for system-wide total operating reserve constraint
    - Reflects the Operators requirement to cover the loss of system’s largest and half of the system’s second largest contingency within 30 minutes
  - $250 Mwh for each Reserve Zone (TMOR) constraint
    - Reflects the need to cover the double contingency loss within a constrained area

Reserve Constraint Penalty Factor (RCPF) in Practice

- RCPF represents two values:
  - Penalty when reserve shortage cannot be met by the system
  - Cap on the re-dispatch cost of reserves that the system will allow before going short of reserves
- RCPF of $250 for a local reserve constraint means that if the local area cannot meet the reserve requirement, either because of lack of resources to provide reserves (from inside or through the interface from outside) or because re-dispatch of available resources would cost more than $250 then the “virtual” resource would be used, the reserve requirement would not be met and the price would be “capped” at $250

Where Does the Reserve Price Show in the Energy Price?

- If a Reserve Zone constraint is binding (through re-dispatch or RCPF) then it will be treated like a Transmission Congestion since it will create a difference in the objective function of delivery of the next increment of energy to different locations throughout the system
- If a system-wide constraint is binding (again through re-dispatch or RCPF) then it will show in the Energy Component since it impacts the objective function of delivery at every location throughout the system
- or, if the system is just "ramp constrained" the Reserve Price may not show in the Energy Price at all! (we have an example of this coming later)

LMP Decomposition

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- The energy component is the same for all locations and equal to the shadow price of the system balance constraint (which may include System Reserve Constraints)
- The congestion components equal zero for all locations if there are no binding transmission or Local RESERVE constraints – all SP_k=0
- The loss component is the marginal cost of additional losses caused by supplying an increment of Load at the location

ENERGY & RESERVE CO-OPTIMIZATION

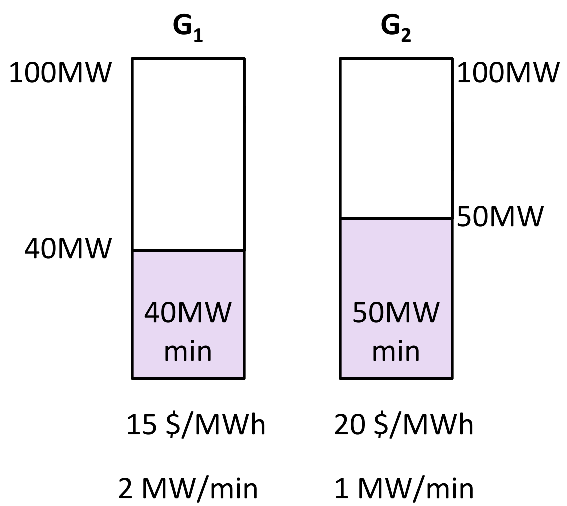
Some examples

Examples

- The following examples are very simple examples meant to explain and reinforce the concepts of co-optimization
- The examples cannot show all possible outcomes
- These examples are a good representation of normal outcomes of the market clearing

Energy-Reserve Co-optimization

- Two (2) Generators:
  - G1: Offer: 40-100 MW @ 15 $/MWh, ramp rate 2 MW/min
  - G2: Offer: 50-100 MW @ 20 $/MWh, ramp rate 1 MW/min
  - RCPF = 50 $/MWh (TMSR)



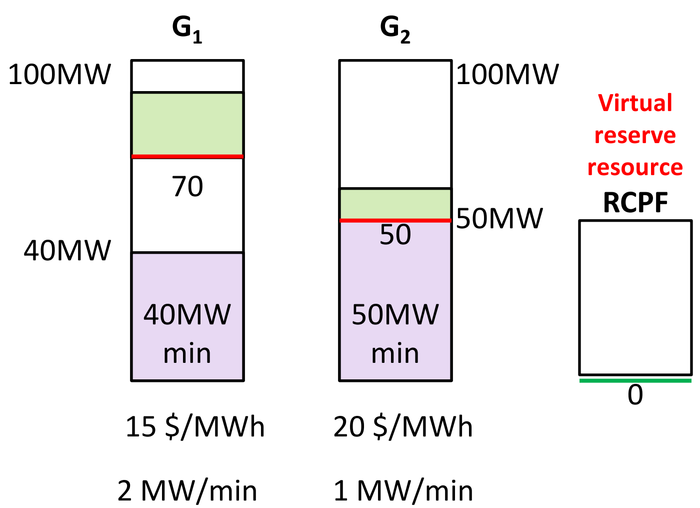
Find LMP and RMCP for these cases

	Load [MW]	TMSR Req. [MW]
A	120	25
B	145	25
C	145	35
D	175	35

Energy-Reserve Co-optimization

Case A (RMCP = 0)

- Two (2) Generators:
  - G1: Offer: 40-100 MW @ 15 $ /MWh, ramp rate 2 MW/min
  - G2: Offer: 50-100 MW @ 20 $ /MWh, ramp rate 1 MW/min
- Total load = 120 MW, Reserve (TMSR) requirement = 25 MW



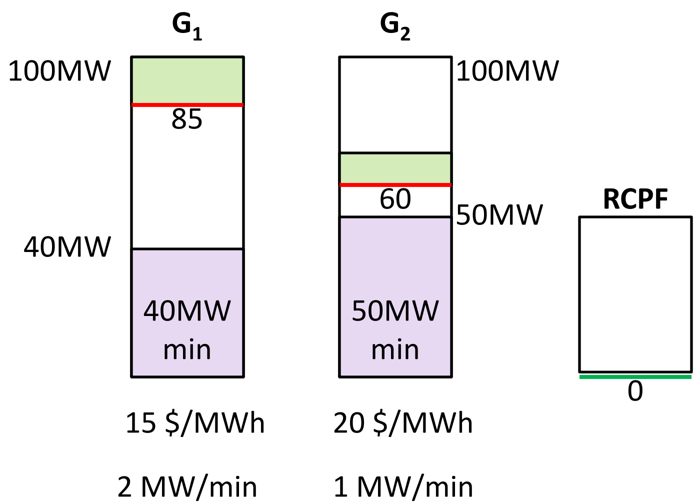
- Energy: G_1 = 70 MW; G_2 = 50 MW (70 + 50 = 120)
- Reserve: G_1 = 20 MW; G_2 = 10 MW (20 + 10 = 30)
- Price: Energy = 15 $/MWh; Reserve = 0 $/MWh

There is surplus of reserve (30 > 25)
Reserve market clearing price (RMCP) = 0 $/MW

Energy-Reserve Co-optimization

Case B (0 < RMCP < RCPF)

- Two (2) Generators:
  - G1: Offer: 40-100 MW @ 15 $ /MWh, ramp rate 2 MW/min
  - G2: Offer: 50-100 MW @ 20 $ /MWh, ramp rate 1 MW/min
- Total load = 145 MW, Reserve (TMSR) requirement = 25 MW



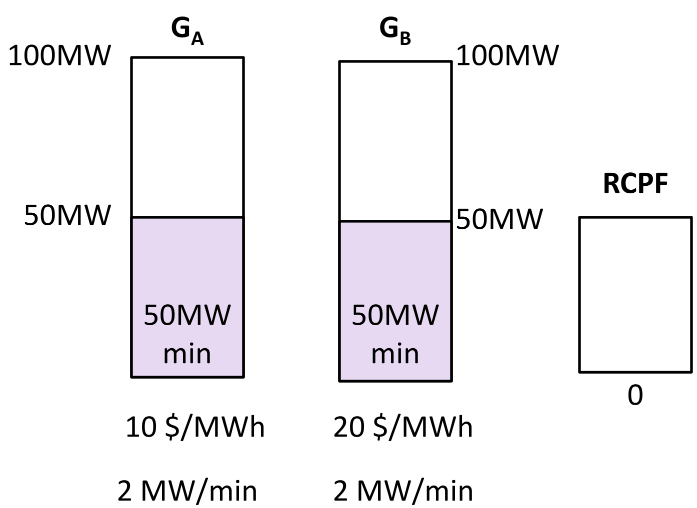
- Energy: G_1 = 85 MW; G_2 = 60 MW (85 + 60 = 145)
- Reserve: G_1 = 15 MW; G_2 = 10 MW (15 + 10 = 25)
- Price: Energy = 20 $/MWh; Reserve = 5 $/MWh

Cheaper generator (G1) had to be dispatched down, to provide reserve

Reserve clearing price = 5 $/MWh

Energy-Reserve Co-optimization – Exercise

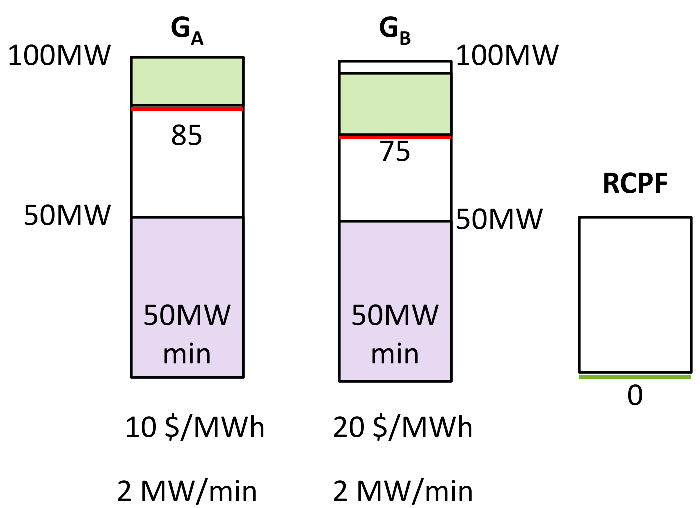
- Two (2) Generators:
  - G_A: Offer: **<u>50-100</u>** MW @ 10 $ /MWh, ramp rate 2 MW/min
  - G_B: Offer: 50-100 MW @ 20 $ /MWh, ramp rate **<u>2</u>** MW/min
- Total load = 160 MW, Reserve (TMSR) requirement = 35 MW
- Reserve penalty price (RCPF) = 50 $/MWh



- <u>Energy</u>: G_A = ____ MW; G_B = _____ MW
- <u>Reserve</u>: G_A = ____ MW; G_B = _____ MW
- LMP = _____ $/MWh
- RMCP = _____ $/MWh

Energy-Reserve Co-optimization – Solution

- Two (2) Generators:
  - G_A: Offer: 50-100 MW @ 10 $ /MWh, ramp rate 2 MW/min
  - G_B: Offer: 50-100 MW @ 20 $ /MWh, ramp rate 2 MW/min
- Total load = 160 MW, Reserve (TMSR) requirement = 35 MW
- Reserve penalty price (RCPF) = 50 $/MWh



- Energy: G_A = 85 MW; G_B = 75 MW
- Reserve: G_A = 15 MW; G_B = 20 MW
- LMP = 20 $/MWh
- RMCP = 10 $/MWh

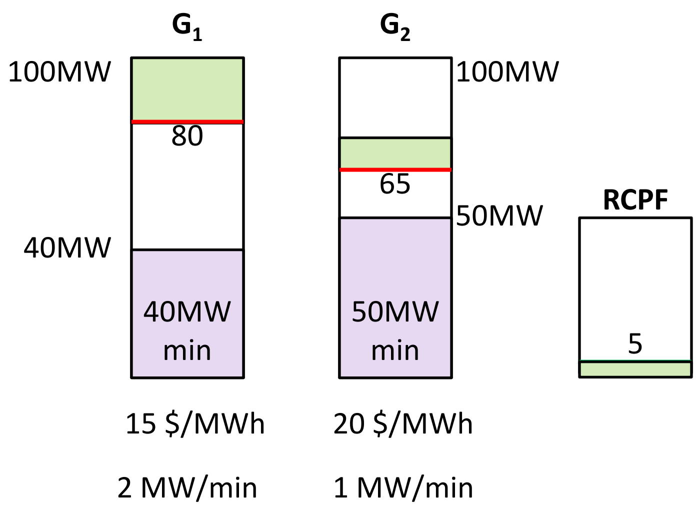
RCPF Triggered and Reserve Price Greater than Energy Price

- Can Reserve Price system-wide = RCPF and also > LMP?
  - The system must be ramp constrained, but not energy constrained
- That means that another MW of load can be met from the available resources without reducing your reserve, but resources cannot create more reserve

Energy-Reserve Co-optimization

Case C (LMP < RCMP = RCPF)

- Two (2) Generators:
  - G1: Offer: 40-100 MW @ 15 $ /MWh, ramp rate 2 MW/min
  - G2: Offer: 50-100 MW @ $20 $ /MWh, ramp rate 1 MW/min
- Total load = 145 MW, Reserve (TMSR) requirement = 35 MW



- Energy: G_1 = 80 MW; G_2 = 65 MW (80 + 65 = 145)
- Reserve: G_1 = 20 MW; G_2 = 10 MW (20 + 10 = 30)
- Price: Energy = 20 $ /MWh; Reserve = 50 $ /MWh

There is not enough reserve, but there is available energy

Reserve clearing price = 50 $/MWh (RCPF)
LMP < RMCP (20 < 50)

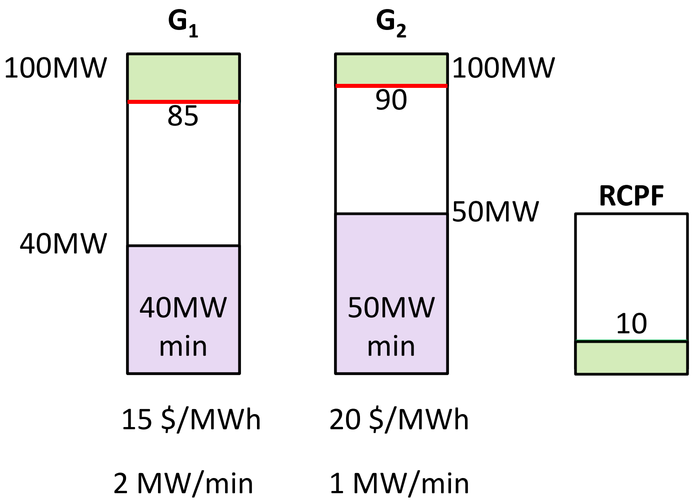
Reserve CP > Energy CP

- Under these conditions, every on-line resource is providing its maximum amount of reserves, BUT not its maximum amount of Energy
- Therefore, it is **RESERVES** that are limited but **ENERGY** is not, so the Penalty Factor, which is the price for violating the constraint is only included in Reserve CP

Energy-Reserve Co-optimization

Case D (LMP > RCMP = RCPF)

- Two (2) Generators:
  - G1: Offer: 40-100 MW @ 15 $ /MWh, ramp rate 2 MW/min
  - G2: Offer: 50-100 MW @ 20 $ /MWh, ramp rate 1 MW/min
- Total load = 175 MW, Reserve (TMSR) requirement = 35 MW



- Energy: G_1 = 85 MW; G_2 = 90 MW (85 + 90 = 175)
- Reserve: G_1 = 15 MW; G_2 = 10MW (15 + 10 = 25)
- Price: Energy = 65 $/MWh; Reserve = 50 $/MWh

Reserve clearing price = 50 $ /MWh (RCPF)
LMP = G_1 bid price + RCPF = 15 + 50 = 65
LMP > RMCP (65 > 50)

RCPF Triggered and Energy Price Greater than Reserve Price

- There is not enough reserve available, which triggers RCPF (next increment of reserve would be supplied from virtual reserve resource, with penalty price – RCPF)
- To provide next increment of energy, we would have to increase output of cheapest unit (15 $/MWh)
  - At the same time it would decrease reserve from that unit, which must be now supplied from virtual resource (with RCPF price –50 $/MWh)
  - It means that LMP also includes reserve price RCPF)

What Gets Paid (Designated) for Reserves?

- Reserve designation is based on the unloaded MW capable of providing energy within 10 or 30 minutes from on-line or off-line resources
- All MW that are capable are designated
  - Excluded based on the Unit Control Mode that cannot provide reserves (UCM 1 and UCM 3)
- Designations will exceed requirements in most hours
  - When designations > requirements, Reserve Clearing Price = $0
- When in re-dispatch, Designation = Requirements
- When in shortage (price set by RCPFs),
  Designations < Requirements

How does the designation process work?

- During the dispatch every resource that is capable of providing reserves (has some MW dispatchable above its DDP) gets an ex-ante “designation” for reserve
- During the ex-post pricing calculation those “designations” may be lowered if the resource did not follow it dispatch instructions
- Designations can also be lowered during the settlement process in order to account for metering differences between EMS systems and Revenue Quality Metering (if SCADA showed some reserve capability that was not actually available when RQM is evaluated)

Major takeaways to this point

- Real-Time Reserve Co-optimization
  - When Reserves constraints are binding (just being met or not able to be met) that;
    - impacts quantity dispatched for energy in Real-Time
    - Impacts prices for reserves and potentially for energy in Real-Time
- Operating Procedures
  - Try to preserve the ability to cover contingencies within the system at all times (OP4)
- Providers of Reserve
  - Any resource in a dispatchable or committable state that can provide additional capability to the system in the next 10 or 30 minutes
  - Designations Happen! (No action is required by the generator to get designated)

Questions

RESERVE ADEQUACY ANALYSIS (RAA)

How does Reserves and RAA impact each other?

Wait aren't you explaining these backwards?

- Doesn't RAA come before Real-Time?
- YES! But unless you understand what is going to happen in RT, how RAA treats the Reserve Requirements will not make as much sense
- In essence RAA is trying to assure that committed resources will be sufficient meet the reserve requirements during the real-time dispatch

How do Reserves Impact RAA and RAA Impact Reserves?

- The RAA process, which begins just after the DA Market finishes (is approved) attempts to ensure enough resources have been committed during every hour to meet the forecasted load plus forecasted Reserve Requirements for the remaining RT hours of the current day and the next day (the day for which the DA Market was just completed)
- Assuming the forecasted load and the forecasted Reserve Requirements are close to actual (actual load ≈ forecasted load), then Real-Time dispatch would be able to meet all Reserve Requirements

How do Reserves Impact RAA and RAA Impact Reserves? (cont.)

- So what is the impact on the Energy Market of the RAA?
- The following examples are illustrative and somewhat simple but extreme (not necessarily representative of a normal day)
- Simple example #1:
  - DA > Generation Committed = **18,000** (assume = cleared load) (Reserve Avail = **2500**)
  - RAA > Load Forecast = **20,000** (Reserve = **2500**)
  - RT > Load **= 20,000** (Reserves = **2500**)
- In this example RT needed 2000 MW more than DA committed, and the RAA successfully committed the resources needed to meet the RT capacity requirement

How do Reserves Impact RAA and RAA Impact Reserves? (Example #2)

- Simple example #2:
  - DA > Generation Committed = 18,000 (assume = cleared load) (Reserve Avail = 2500)
  - RAA > Load Forecast = 20,000 (Reserve = 2500)
  - RT > **Load = 18,000** (Plus Reserves = 2500)
- If the Load Forecast error is on the high side (this case over by 2000) what happens in RT?
- The extra amount of committed resources during RAA are still running (at least at minimum) the reserve available is much greater than requirement
- The Load Forecast error was this issue (not the DA)

How do Reserves Impact RAA and RAA Impact Reserves? (Example #3)

- Simple example #3:
  - DA > Generation Committed = 18,000 (assume = cleared load) (Reserve Avail = 2500)
  - RAA > Load Forecast = 20,000 (Reserve Req. = 2500)
  - RT > Load = **22,000** (Plus Reserves = 500) **SHORT of Requirement**
- If the Load Forecast error is on the low side (this case under by 2000) what happens in RT?
- The committed resources during RT do not meet the actual load and reserve requirements
  - Additional RAA commitments would have been done as soon as the ISO identifies that the load is diverging from the forecast
  - For this example assume this divergence was too abrupt to respond to with the RAA process
- The Load Forecast error was this issue (not the DA)

What do these examples show?

- RAA process is very important in committing sufficient additional resources, in addition to what was committed in the DA, to meet the load plus reserve requirement
- Load Forecast errors (usually caused by weather forecast errors) can introduce shortages of reserves in Real-Time
- Load Forecast errors can also lessen the likelihood of Real-Time Reserve constraints binding (when those errors cause commitment extra resources like example #2)
- DA Market, while it does create the initial commitment for the initial RAA process does not typically create issues in the Real-Time Market

Questions

DAY-AHEAD ENERGY MARKET

How do reserve requirements impact the Day-Ahead Energy Market?

Day-Ahead Energy Market – impact of reserves

- Do Reserve Requirements impact the DA Market?
  - Commitment in the DA meets the Load as bid, plus the expected Reserve Requirement
  - If the Reserve Requirement is "binding" then the commitment was impacted by the Requirement during one or more hours
    - The impact is that additional resources may have been committed more than was minimally needed to meet just the cleared load required
    - Any additional committed resource must run at least at Economic Minimum in the DA Market
- Why is there no Reserve Market in DA?
  - Commitment solves the reserve problem in DA
  - Reserve Shortage or redispatch unlikely to ever be needed in DA
  - Resources like Virtual Offers complicate how much reserves is being provided by resources

JULY 12, 2013 | MARLBOROUGH, MA

Forward Reserve Market

Ron Coutu

MANAGER,
BUSINESS ARCHITECTURE & TECHNOLOGY

Reserve Market Design

- ISO-NE Reserve Market
  - Two Components
    1. Real-Time Reserve Market
    2. **Forward Reserve Market**

What is a Forward Reserve Market?

- Contract for future physical delivery
- The delivery is accomplish in the Real-Time Market
- Auction is purely Financial (no check on physical assets is done at Auction)
- Forward Reserve Market Obligations can be traded bilaterally prior to the deliver period
- Central buyer (ISO) procuring on behalf of load
- Sellers must voluntarily enter into the auction (no default bids for those who do not choose to participate)

Why do we have it?

- Additional Capacity-Style market to ensure resources will be available to provide reserves under most cases
- Real-Time prices (spot) are very volatile and provide little revenue certainty
- A forward market sends a price signal for where local reserve resource types are needed (as was the case for CT in years prior to 2011)

Locational Forward Reserve Market Design

- Auction per season (Summer/Winter)
- Participant offers in auction (no assets)
- Auction clears the minimum cost of the offers to meet the system and local requirements
- Participants get FRM Obligation from auction at Clearing Price (one clearing price for each off-line product for each Reserve Zone)
- During delivery period Obligation met by:
  - Assigning Obligation (hourly) to assets that provide reserve (or energy)
  - Trade Obligation to another Participant

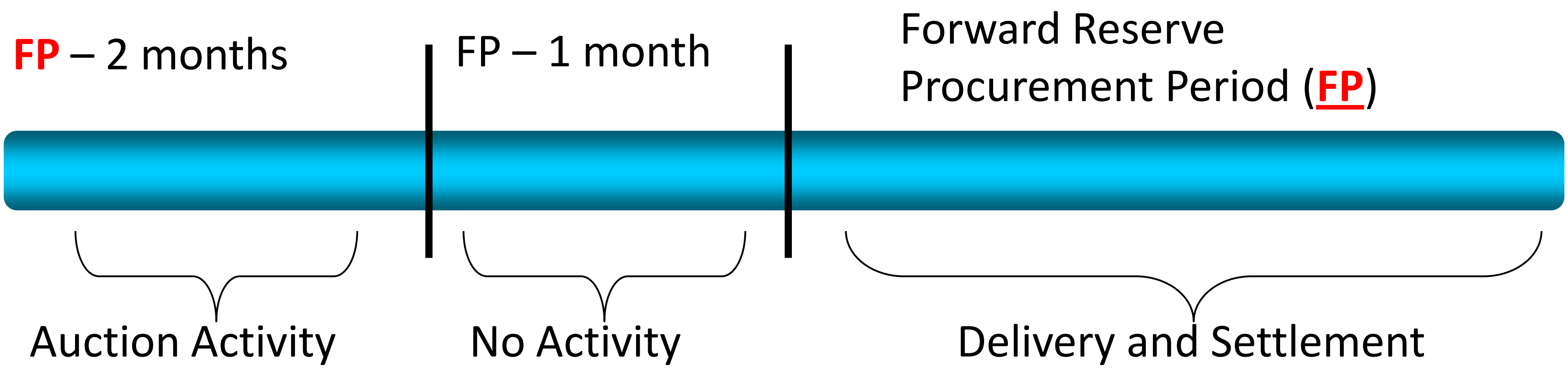
FORWARD RESERVE MARKET

Details

Forward Reserve Market – New England Design

- A Participant who takes on FRM obligation will be paid to assign resources to be available to meet Off-line (TMNSR, TMOR) Real-Time Reserve Requirements. This assignment is made in advance of the Operating Day "Forward" Reserve
  - In general, FRM capacity will be available for dispatch, but will not normally be in economic merit
    - Capacity is economically held in reserve, in the event of a contingency on the system
    - Note: FRM provides revenue to peaking resources that operate infrequently under normal economics

Auction Timeline Overview



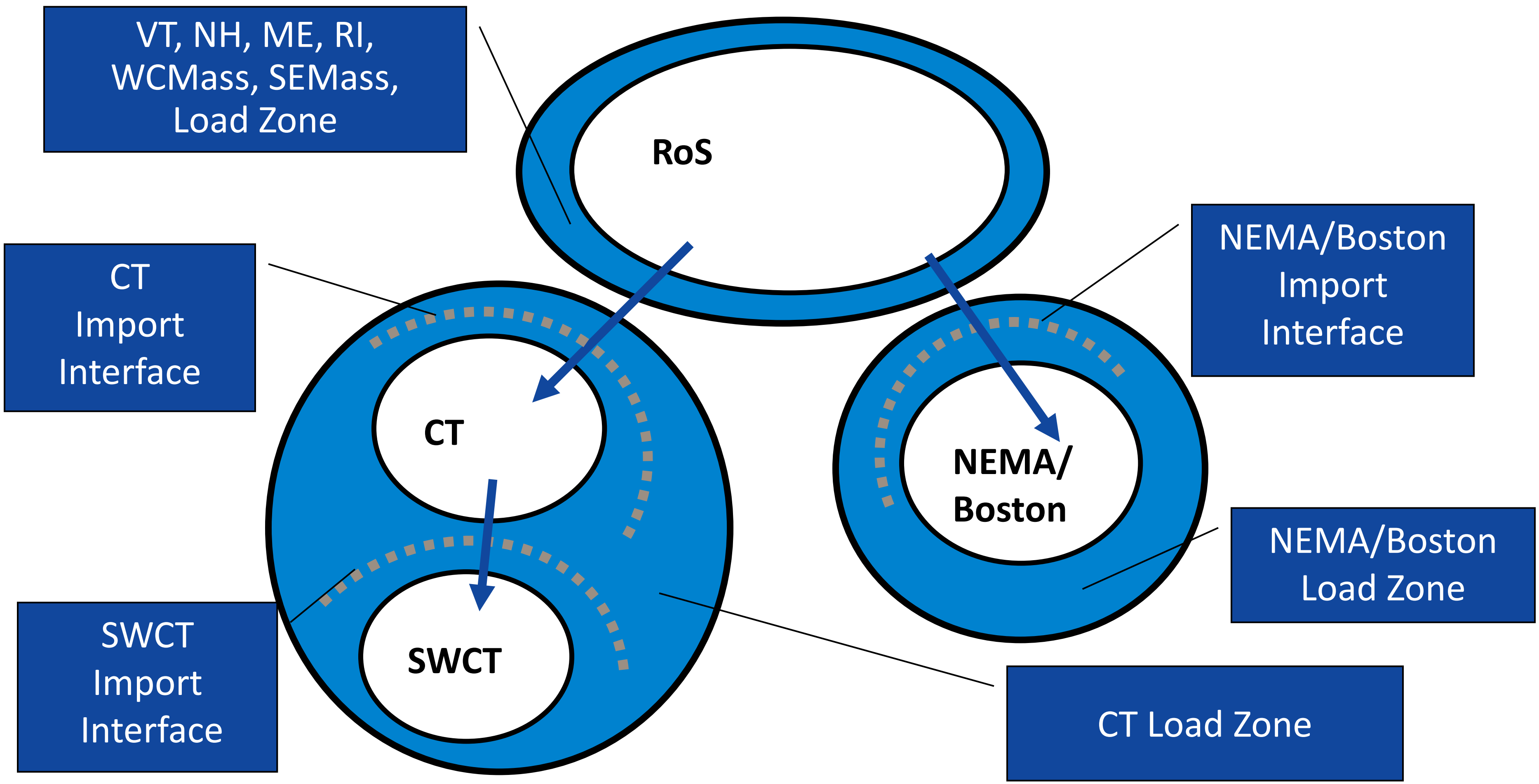
<u>Forward Reserve Procurement Periods</u>

- Summer Capability Period (June 1 - September 30)
- Winter Capability Period (October 1 - May 31)

<u>Delivery hours</u>

- On-Peak Hours (07:00 - 23:00)
- Weekdays, excluding NERC holidays

Reserve Zones and Load Zones



Forward Reserve Market

- Participants take on obligations in the FRM through Auctions that are held twice a year. The Auctions set the prices and procure the reserve capacity to meet system-wide TMNSR and TMOR requirements and local TMOR requirements
  - Summer 2011 Clearing Price for all products was $4.50/kW-month
  - Winter 2011/12 Clearing Price for all products was $4.35/kW-month
  - Summer 2012 Clearing Price for all products was $3.45/kW-month
  - Winter 2012/13 Clearing Price for all products was $3.301/kW-month
  - Summer 2013 Clearing Price for all products was $5.946/kW-month

Forward Reserve Market (cont.)

- Forward Capacity Auction Clearing Price is subtracted from the FRM Clearing price when settled
  - Sum 2011 = $4.50/kW-month -$3.60/kW-month = $0.90/kW-month
  - Win 2011/12 = $4.35/kW-month - $3.60/kW-month = $0.75/kW-month
  - Sum 2012 = $3.45/kW-month - $2.951/kW-month = $0.499/kW-month
  - Win 2012/13 = $3.301/kW-month - $2.951/kW-month = $0.35/kW-month
  - Sum 2013 = $5.946/kW-month - $2.951/kW-month = $2.955/kW-month

- Note: Rest of Pool FCA Clearing Price used for example above

Forward Reserve Market (cont.)

- Suppliers can offer to supply the FRM in Reserve Zones or in the Rest of System (RoS) in the Auction
- Participants whose bids clear in an Auction will have an obligation for the entire seasonal period
  - Obligations are for hours ending 8-23 weekdays, excluding NERC holidays
  - Winter season is October through May
  - Summer season is June through September
- Clearing Prices for TMNSR and TMOR in Zones and RoS may vary
  - Not in so in every case since Summer 2011; all prices same

Forward Reserve Market (cont.)

- A resource paid in the FRM will have its Real-Time Reserve payment adjusted to prevent double payment for same MW

Note: A unit does not have to be offered in the FRM to provide Real-Time Reserve

Forward Reserve Market (cont.)

- Suppliers manage their Forward Reserve capable resources daily, on a portfolio basis, to meet their FRM Auction obligations
- Obligations can be traded bilaterally between suppliers
- Real-time performance monitoring of FRM designated resources
  - A Participant that does not meet its FRM obligation in any hour will not be paid for any unmet obligation
  - A Participant that does not meet its FRM obligation in any hour will also be penalized for every MW of unmet obligation

FORWARD RESERVE MARKET

Market Mechanics

Reserve Market Design

Forward Reserve Market (FRM)

- Market Mechanism to procure capacity in resources to provide the off-line reserves that are incorporated in the optimal dispatch of Real-Time Energy and Reserves
- FRM was designed to provide appropriate economic incentives to resources that provide these valuable Real-Time operating reserves
  - Location aspects to this design also tend to ensure procuring reserves to meet local and system-wide constraints optimally
- This is a “forward option” style market, that requires delivery of the product during the Real-Time Market
  - The asset taking on this Forward Obligation gives up revenue from the RT Reserve Market which is very volatile, for fixed revenue

Relevant Tariff Terminology

Per ISO-NE Tariff Section I.2.2

- Forward Reserve − TMNSR and TMOR purchased by the ISO on a forward basis on behalf of Market Participants
- Forward Reserve Assigned Megawatts − Amount of Forward Reserve, in MWs, that a Market Participant assigns to eligible Forward Reserve Resources to meet its Forward Reserve Obligation
- Forward Reserve Auction − Periodic auction conducted by the ISO to procure Forward Reserve

*** Note: Section III.9 Forward Reserve Market

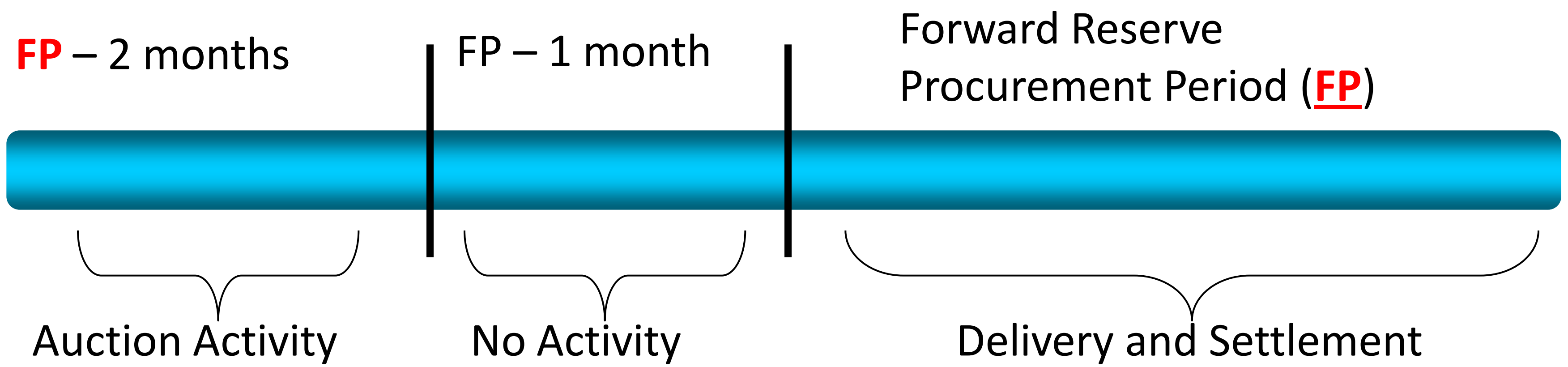
- Covers the detailed rules of the Forward Reserve Market

Relevant Tariff Terminology

Per ISO-NE Tariff Section I.2.2

- Forward Reserve Auction Offer − An offer to provide Forward Reserve to meet system and Reserve Zone requirements as submitted by a Market Participant
- Forward Reserve Clearing Price − Clearing price for TMNSR or TMOR, as applicable, for the system and each Reserve Zone resulting from the Forward Reserve Auction
- Forward Reserve Obligation − Market Participant’s amount, in MW, of Forward Reserve that cleared in the Forward Reserve Auction and adjusted, as applicable, to account for bilateral transactions that transfer Forward Reserve Obligations

Auction Timeline Overview



<u>Forward Reserve Procurement Periods</u>

- Summer Capability Period (June 1 - September 30)
- Winter Capability Period (October 1 - May 31)

<u>Delivery hours</u>

- On-Peak Hours (07:00 - 23:00)
- Weekdays, excluding NERC holidays

FRM Process Flow

1. Determination of Forward Reserve Requirements and Auction Parameters
2. Submittal of Forward Reserve Auction Offers
3. Forward Reserve Auction Clearing
4. Submission of Offer Data/Self Schedules for Units Assigned a Forward Reserve Obligation
5. Internal Bilateral Transactions between Participants
6. Assignment by Participants of Specific Resource to Meet Forward Reserve Obligations
7. Determination of Forward Reserve MW delivered to the RTM:
Determine Failure-to-Reserve Penalty and Determine Failure-to-Activate Penalty
8. Market Settlement/Billing

Determination of Forward Reserve

Requirements and Auction Parameters

1

- FRM system requirements are established consistent with ISO-NE Operating Procedure No. 8 (OP8) and operational practice
- FRM locational requirements are established per Market Rule 1, Section III.9.2.3 and are a function of historical operating requirements

Determination of Forward Reserve

Requirements and Auction Parameters (Summer 2013)

1

Reserve Zone	Reserve Category	Local 2nd Contingency MW	External Reserve Support MW	Reserve Requirement MW
Control Area	TMNSR	N/A	N/A	1349
Control Area	TMOR	N/A	N/A	723
SWCT	TMOR	718	1172	0
CT	TMOR	1211	464	747
NEMA/Boston	TMOR	1040	1224	0

Determination of Forward Reserve

Requirements and Auction Parameters (cont.)

1

- Forward Reserve Threshold Price
  - Threshold Price is a parameter used each day by Participants with LFRM obligations for supply offer determination
    - Resources must be offered at or above the Threshold price in the Energy Market in order for these resources to qualify as meeting the participant's LFRM obligations
  - Threshold Price is the product of the following variables:
    - Forward Reserve Heat Rate Index – set at Auction time and for the whole entire Forward Reserve procurement period
      - Summer 2013: 16010 Btu/kWh
    - Forward Reserve Fuel Index – set daily, and when multiplied by the Heat Rate Index, produces the Forward Reserve Threshold Price
    - Forward Reserve Threshold Price is posted on the ISO Website:
      http://www.iso-ne.com/markets/hst_rpts/hstRpts.do?category=Daily
    - Example: 7/7/2013 Forward Reserve Threshold Price = $93.02

Participant Forward Reserve Offers

- Forward Reserve Auction Offers are submitted on a portfolio basis by Participants
- Specific physical Resources are not offered into the auction
- Offer consists of MW, type, location, and price
- Offer price is capped at $14/kW-month
  - Offer cap amount is based on the estimated carrying cost of an aero-derivative combustion turbine
  - Offer cap reflects the sum of the components that a supplier would be expected to consider in developing its bid

ISO-NE Forward Reserve Auction Clearing

- ISO-NE clears the FRM auction based on offers and reserve requirements
- No more than the Locational Reserve Requirement must be purchased from Resources within an import-constrained location
- Auction obligations are met in real-time
  - No money changes hands when Auction results are published
  - Payment is contingent on meeting delivery performance obligations

Participant Submittal of Supply Offer

Data for Resources to be Assigned for Forward Reserve

4

- Supply Offers for the days during the Procurement Period
- MW of a resource assigned against a FRM obligation must be offered by the close of the re-offer period at a $/MWh rate that is greater than or equal to the Forward Reserve Threshold Price
- On-line resources assigned against an FRM obligation must be self-scheduled or have cleared the DAM
  - Resources committed by the ISO to provide Local Second Contingency Protection or VAR will not be credited with any Qualifying MW for the hour

Internal Bilateral Transactions

Between Participants

5

- Bilateral trading of obligations
  - Can trade previously acquired obligation (from Auction or other bilateral) to any other Participant
  - Buyer and Seller must confirm
  - Are communicated in similar Interface the same way that bilateral for Energy Market are submitted
  - Must be submitted prior to midnight of the day prior to the Operating Day
  - Buyer of Bilateral takes on assignment obligations

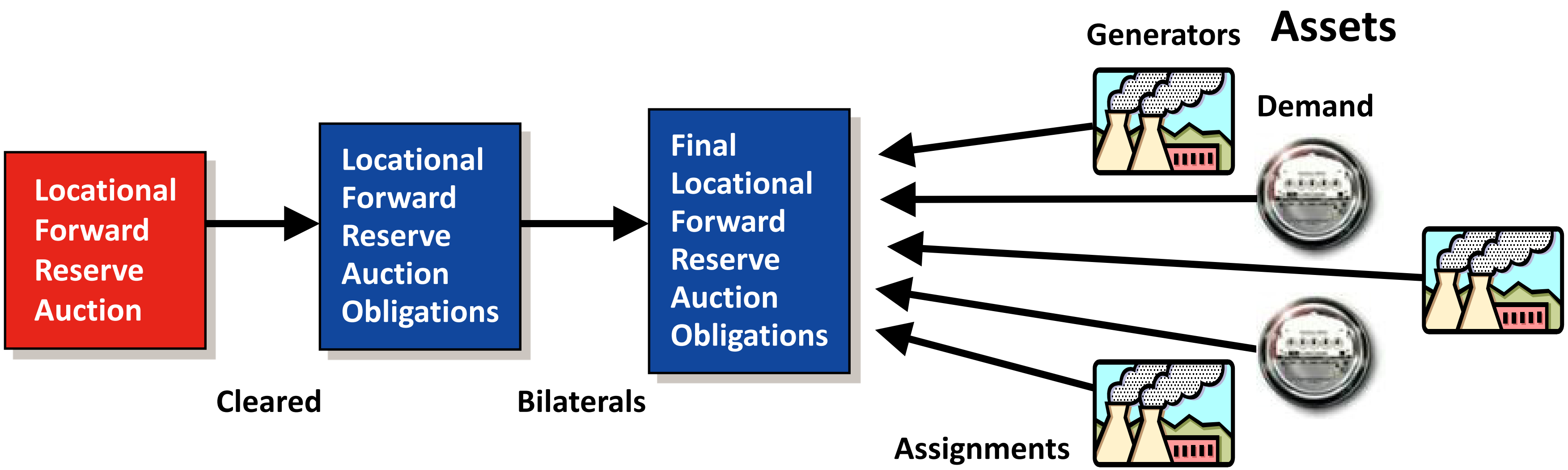
Assignment by Participants of *Specific Resources to Meet Forward Reserve Obligations*

6

- Assignment of Resources
  - Assignment must be done by Lead Participant for the Asset
  - Hourly Assignment of the resource
  - Over Assignment (> Obligation) is possible and allowed
  - Resource is assigned to meet product obligations (type and location)
  - All assignments must be made prior to close of re-offer period before the operating day
  - Assignments do not automatically “roll over”, assignments must be made specifically for each day
  - An assignment for a day may be performed in advance; assignments for all days in a Procurement Period can be made at once

Assignment by Participants of
Specific Resources to Meet Forward Reserve Obligations (cont.)

6



Assignment by Participants of
Specific Resources to Meet Forward Reserve Obligations (cont.)

- A resource that is being assigned against an FRM obligation must be able to receive and follow Dispatch Instructions
- Off-line resources must be available for dispatch in RT, and have a submitted and demonstrated "Claim10" or "Claim30" rating
  - Note: New Auditing provisions are in place for Claim10 and Claim30 (see Market Rule 1 Section III.9.5.3)
  - Basically the MR states that "A Resource's CLAIM10 or CLAIM30 performance factor shall be established based upon the 10 most recent ISO-issued initial electronic startup Dispatch Instructions…"
  - So, in essence, every event is an audit, the most recent events are weighted higher than the least recent for calculation purposes
  - Restoration process available for chronic operational problems

Assignment by Participants of
Specific Resources to Meet Forward Reserve Obligations (cont.)

- Remember:
  - MW of a resource assigned against a FRM obligation must have been offered by the close of the re-offer period at a $/MWh rate that is greater than or equal to the Forward Reserve Threshold Price
  - On-line resources assigned against an FRM obligation must be self-scheduled or cleared the DAM
  - Resources committed by the ISO to provide Local Second Contingency Protection or VAR will not be credited with any Qualifying MW for the hour

Determination of Forward Reserve

MW Delivery

- Forward Reserve Delivered MW
  - Assigned in advance of operating day
  - Offered at or above the FRM Threshold price
  - Resource is available, and can physically provide operating reserves
- Delivery evaluation and payment is hourly
  - Hourly payment rate determined from Auction rate, less Forward Capacity Auction (FCA) rate

Determination of Forward Reserve

Penalties

- Forward Reserve Market is a Forward Contract to Deliver Reserves
- Failure to "deliver" the contract is assessed penalties
- Two different types of penalties:
  - Failure to assign enough qualified resources to meet the contract obligation for the hour (Failure to Reserve)
  - Failure of assigned resources when activated from providing reserves to energy (Failure to Activate)

7

Determination of Forward Reserve

MW Delivered to the RTM (Penalties) – Failure to Reserve

- Failure to Reserve
  - A Participant that does not have enough Forward Reserve MW delivery in an hour to meet its obligation will have a Failure to Reserve in that hour.
- ***Failure to Reserve MW are assessed a penalty charge

1.5 x the FRM Hourly Rate

- Participant is also NOT PAID for any MW not reserved

**** Filed rule change, with an implementation date of 10/1/2013, if accepted would change the penalty to be:*

Maximum (1.5 x FRM Hourly Rate,
Real-Time Reserve Clearing Price – FRM Hourly Rate)

Determination of Forward Reserve

MW Delivered to the RTM (Penalties) – Failure to Activate

7

- Failure to Activate
  - Participant’s off-line Resource assigned for FRM fails to start when requested by the ISO; or
  - Participant’s off-line Resource assigned for FRM fails to reach Claim 10 or Claim 30 amounts in the required 10 or 30 minute interval; or
  - Participant’s on-line Resource assigned for FRM fails to follow dispatch instructions when Total system TMR requirement is binding or violated and Resource assigned as TMOR receives a dispatch instruction to provide energy

Determination of Forward Reserve

MW Delivered to the RTM (Penalties) – Failure to Activate (cont.)

- Failure to Activate MW are assessed a penalty charge

(FRM rate + Max[2.25 x FRM rate, RT LMP at generator node])

  - Participant is paid for delivered MW up to its Forward Reserve Obligation MW

Market Settlement and Billing

- Payments (and penalties, as applicable) are calculated for Participants with Forward Reserve Obligations
- Charges for Participants with Real-Time Load Obligations are calculated
- Settlement reports are issued, generally 4 business days after the operating day
  - Real-Time Reserve Market settlement is also included in these reports
- Once the settlement report is issued, the Reserve Market will be billed in the next service bill
  - Service bills are issued twice a week; on Mondays and Wednesdays (or next business day, if Monday or Wednesday is a holiday)

Summary of Forward Reserve Market

- Seasonal Auction (Summer, Winter)
- Auction Portfolio based (not asset based)
- Obligations from auction can be traded
- Obligations from auction met by assigned assets
- Assets that are assign FRM Obligation can be penalized
- FRM creates a Forward Contract for MWh that are then not paid the RT Reserve Market Clearing Price
  - Fixed revenue stream versus RT very volatile revenue stream (RMCP $ are zero in most hours)

Questions

JULY 12, 2013 | MARLBOROUGH, MA

Wrap-up: How Does this Design Work?

Forward, Day-Ahead, RAA, and Real-Time Working Together

Ron Coutu

MANAGER,
BUSINESS ARCHITECTURE & TECHNOLOGY

Reminder!

- Goal is to get the Operator what they want:
  - Meet the reserve requirements of the system
  - Convert lower quality reserve products (30 minute) to higher quality products (10 minute) when all requirements cannot be met
- Use Markets to procure these products efficiently
- Send appropriate price signals when these products are deficient and when they are plentiful
- Allow the Real-Time Energy Market to optimally meet the energy and reserve requirements of the system with minimal intervention by the Operators

How does this all work together?

Forward Reserves

- Well ahead of the day, procure enough MW to meet the portion of the system and local reserve requirements that can be met by off-line resources
- Allow flexibility to assign the MW obligations to different resources on a very granular basis to deal with resources being unavailable
- Require those assigned resources to offer in a fashion that would naturally allow them to provide reserves during commitment and dispatch of the Day-Ahead and Real-Time Markets

Day-Ahead Market

- Commit enough resources to meet the bid in load plus the expected reserve requirements of the system and local areas
- Reserve requirements will be binding (have an impact) on Day-Ahead commitments only in peak hours generally since other hours will have excess MWh available from units on-line to meet the load requirements
- Never need to “redispatch” to create reserve so no prices would ever show if reserve constraints were “priced” in DA

Reserve Adequacy Analysis

- Commit enough resources to meet the forecast load plus the expected reserve requirements of the system and local areas
- RAA is run first before the day (by 4pm), but then continually can be rerun after that if system conditions change (generators trip, load forecast error, etc.) enough to cause a potential capacity deficiency unless additional resources are committed
- RAA determines if the accessible resources during dispatch will be capable of meeting forecasted load plus forecasted reserve requirements

Real-Time Dispatch

- Where everything that was done in Forward, Day-Ahead and RAA processes comes together to provide what is needed by the Operator to meet the reliability criteria
- Under most normal operating conditions, during the Real-Time Market dispatch the reserve constraints are not binding on the solution
- The committed set of resources and the off-line reserve capable resources, will generally exceed the requirement

Facts about Reserve Markets

From the IMM Annual Report 2012

Table 2-19
Average Reserve Prices and Frequencies for Intervals with Nonzero Prices, 2011 to 2012[(a)]

Product	Year	Average Annual Price ($/MW/ 5-Min. Interval)	Frequency (% of Total 5-Min. Intervals)
10-minute spinning reserve	2011	$24.70	4.00%
	2012	$41.79	3.95%
	% change	***69.2%***	***−1.3%***
10-minute nonspinning reserve	2011	$110.92	0.10%
	2012	$118.58	0.82%
	% change	***6.9%***	***720.0%***
30-minute operating reserve	2011	$73.74	0.30%
	2012	$120.70	0.80%
	% change	***63.7%***	***166.7%***

(a) Prices are presented for the Rest-of-System reserve zone.

Facts about Reserve Markets

From the IMM Annual Report 2012

Table 2-21
Real-Time Reserve Payments, 2010 to 2012 ($)

Year	Systemwide TMSR	Systemwide TMNSR	Systemwide TMOR	SWCT TMOR	CT TMOR	NEMA/Boston TMOR	Total
2010	9,998,572	6,896,142	639,148	762,404	342,996	105,834	18,745,096
2011	5,931,579	2,373,491	220,488	535,377	354,332	56,249	9,471,516
2012	11,382,634	12,179,149	1,352,544	3,235,228	1,207,897	428,223	29,785,673

Facts about Reserve Markets

From the IMM Annual Report 2012

Table 3-11
Forward and Real-Time Reserve Payments and Penalties, 2010 to 2012

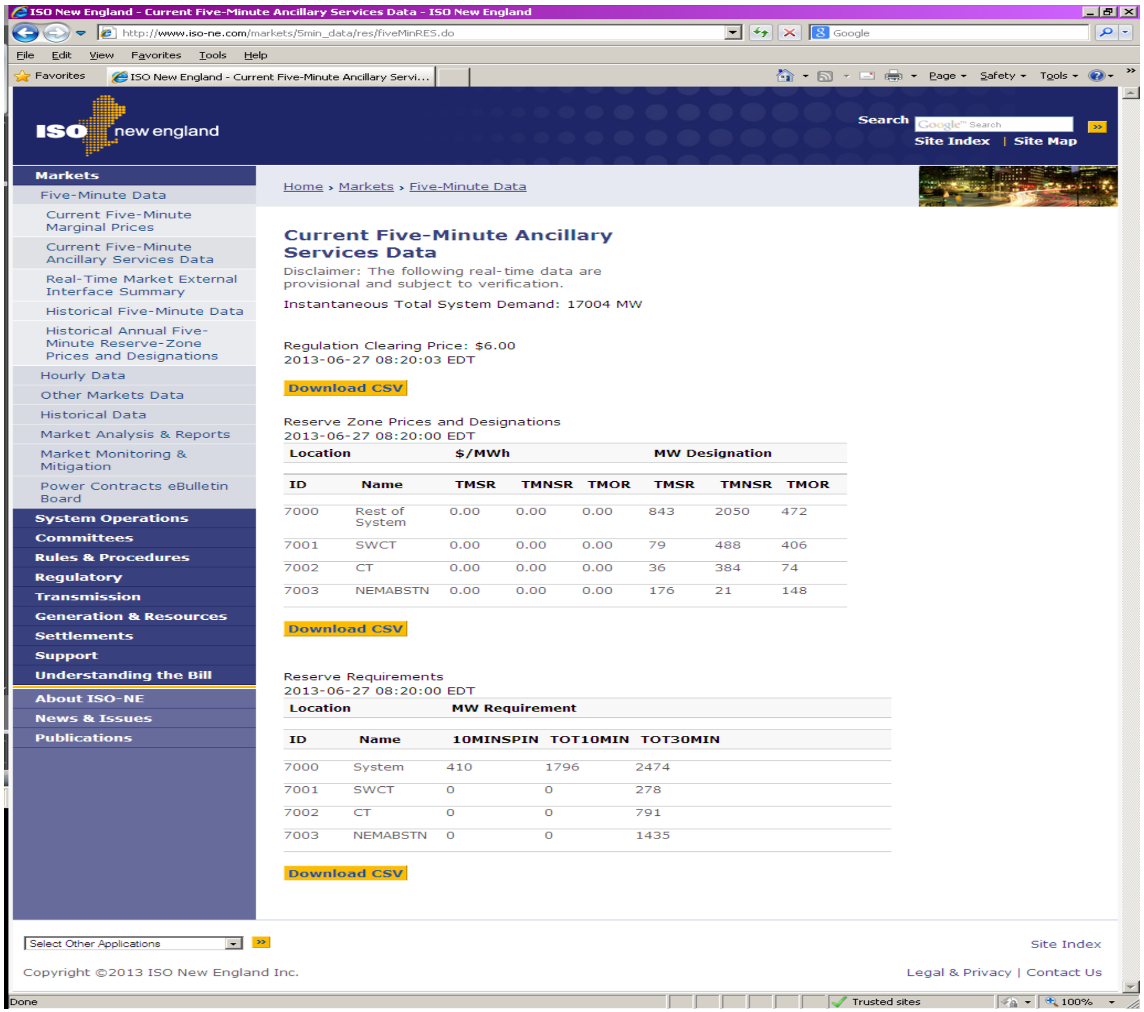
Year	Fail-To-Activate Penalties	Fail-To-Reserve Penalties	Forward Credit	Net Forward Credit
2010	–$87,510	–$5,057,742	$118,545,939	$113,400,687
2011	–$2,671	–$1,082,569	$18,950,856	$17,865,615
2012	$0	–$848,972	$10,138,757	$9,289,785

Questions

REVIEW OF SOME ELEMENTS

What have we learned?

Let’s have a little test looking at the data from our website.



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Current Five-Minute Ancillary Services Data

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Instantaneous Total System Demand: 17004 MW

Regulation Clearing Price: $6.00
2013-06-27 08:20:03 EDT

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Reserve Zone Prices and Designations
2013-06-27 08:20:00 EDT

Location		$/MWh			MW Designation		
ID	Name	TMSR	TMNSR	TMOR	TMSR	TMNSR	TMOR
7000	Rest of System	0.00	0.00	0.00	843	2050	472
7001	SWCT	0.00	0.00	0.00	79	488	406
7002	CT	0.00	0.00	0.00	36	384	74
7003	NEMABSTN	0.00	0.00	0.00	176	21	148

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Reserve Requirements
2013-06-27 08:20:00 EDT

Location		MW Requirement		
ID	Name	10MINSPIN	TOT10MIN	TOT30MIN
7000	System	410	1796	2474
7001	SWCT	0	0	278
7002	CT	0	0	791
7003	NEMABSTN	0	0	1435

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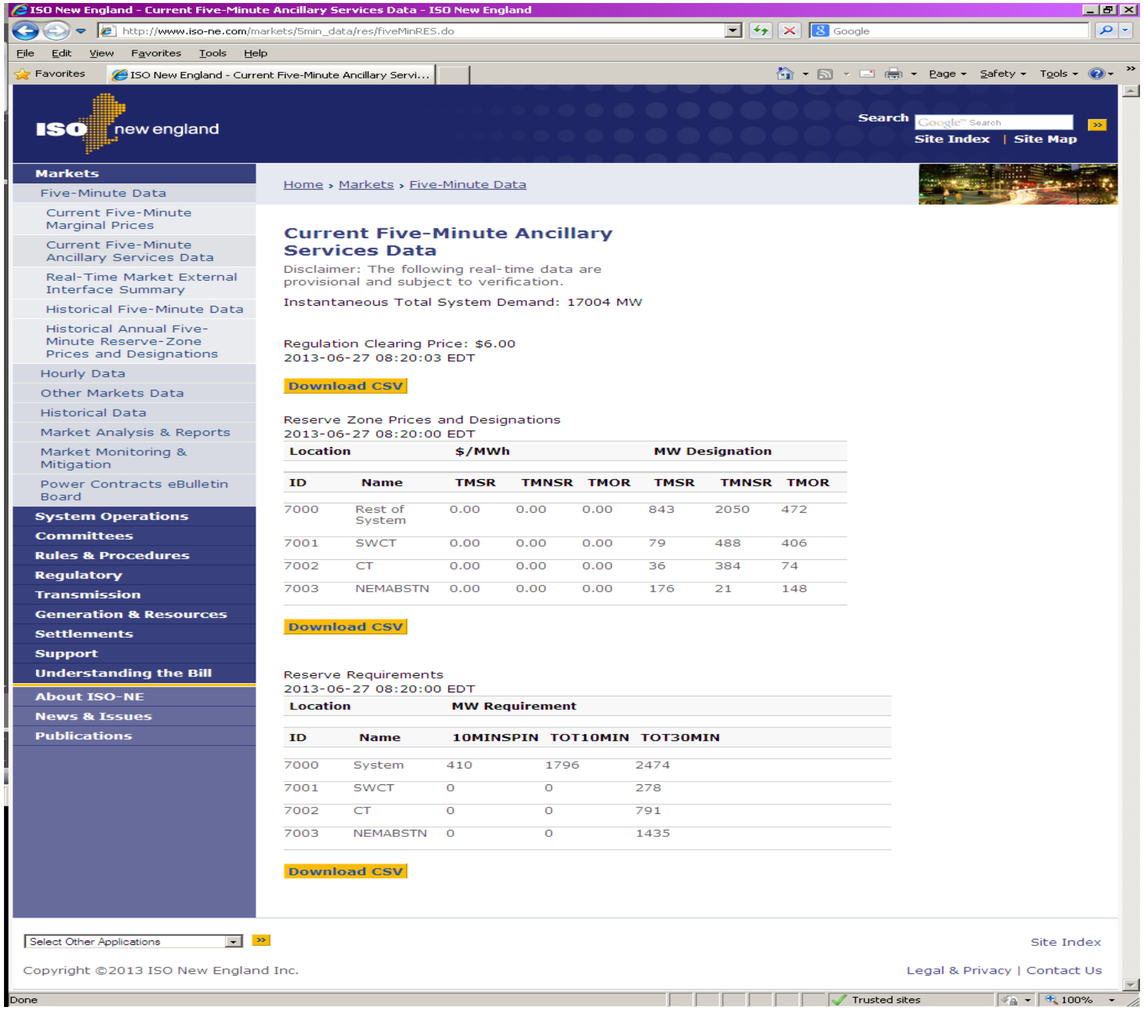
What is the TMSR Requirement this interval?



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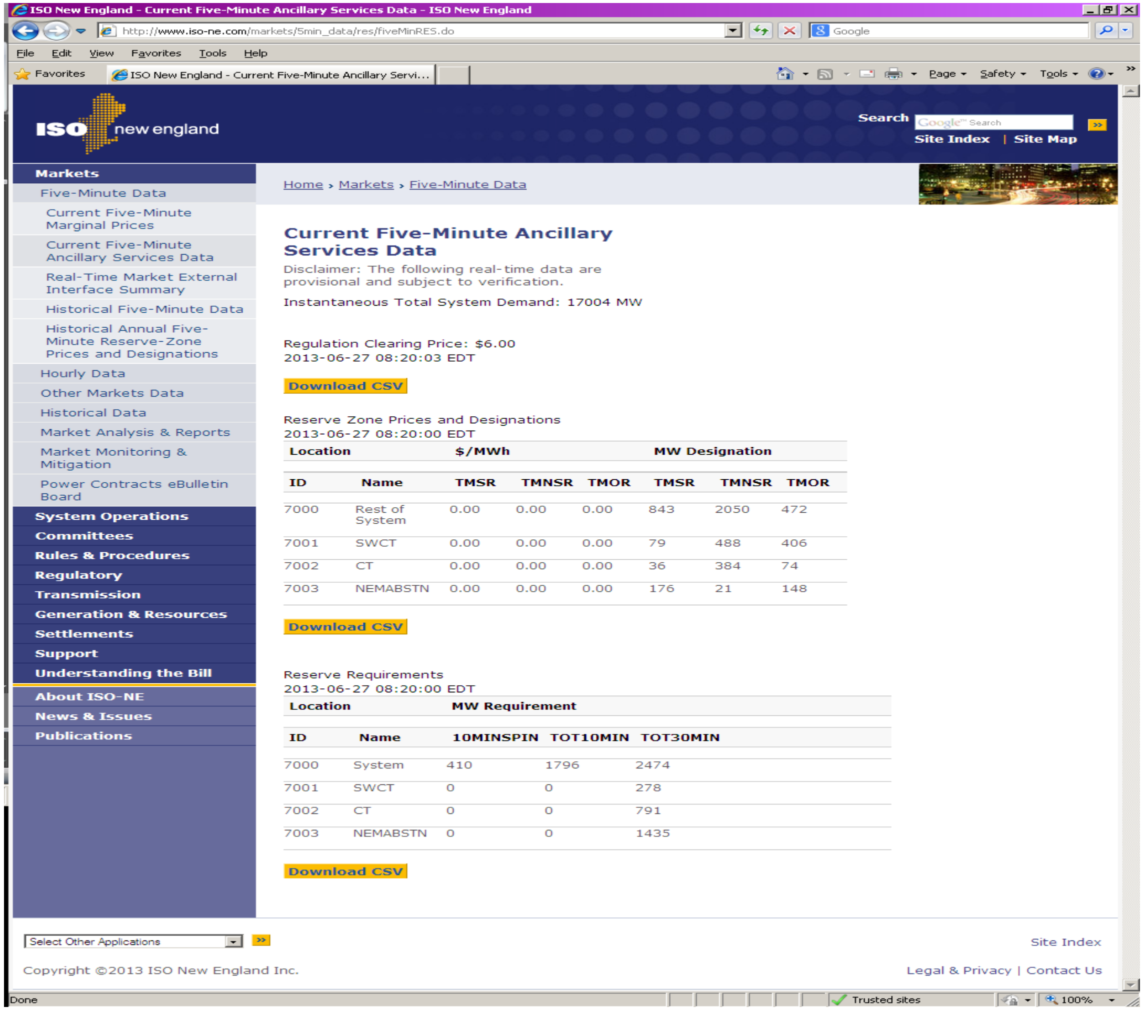
What is the TMSR available this interval?

(Hint: You may need a calculator)



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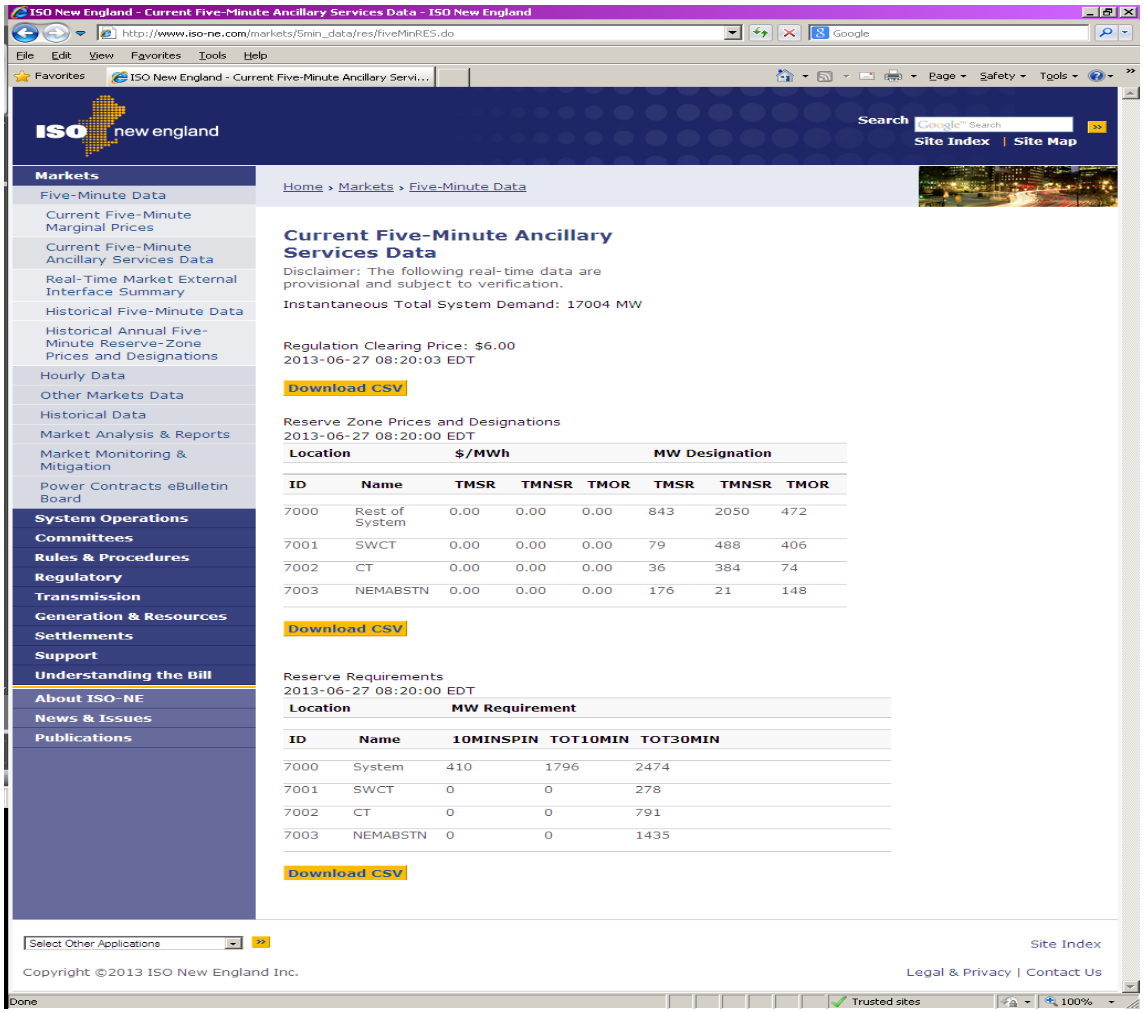
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7001	SWCT	0.00	0.00	0.00	79	488	406
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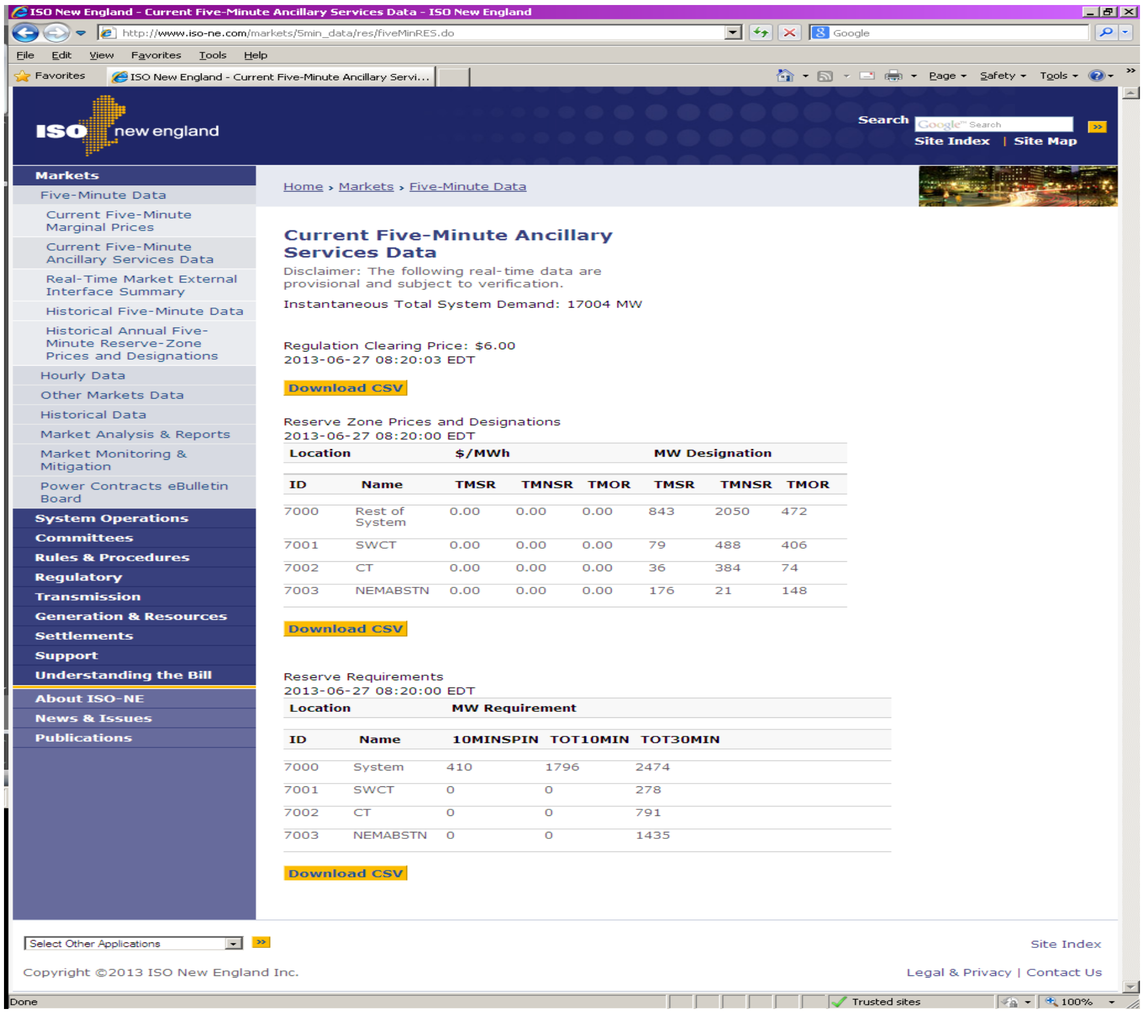
Why isn't there a TMNSR Requirement shown?



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7002	CT	0	0	791
7003	NEMABSTN	0	0	1435

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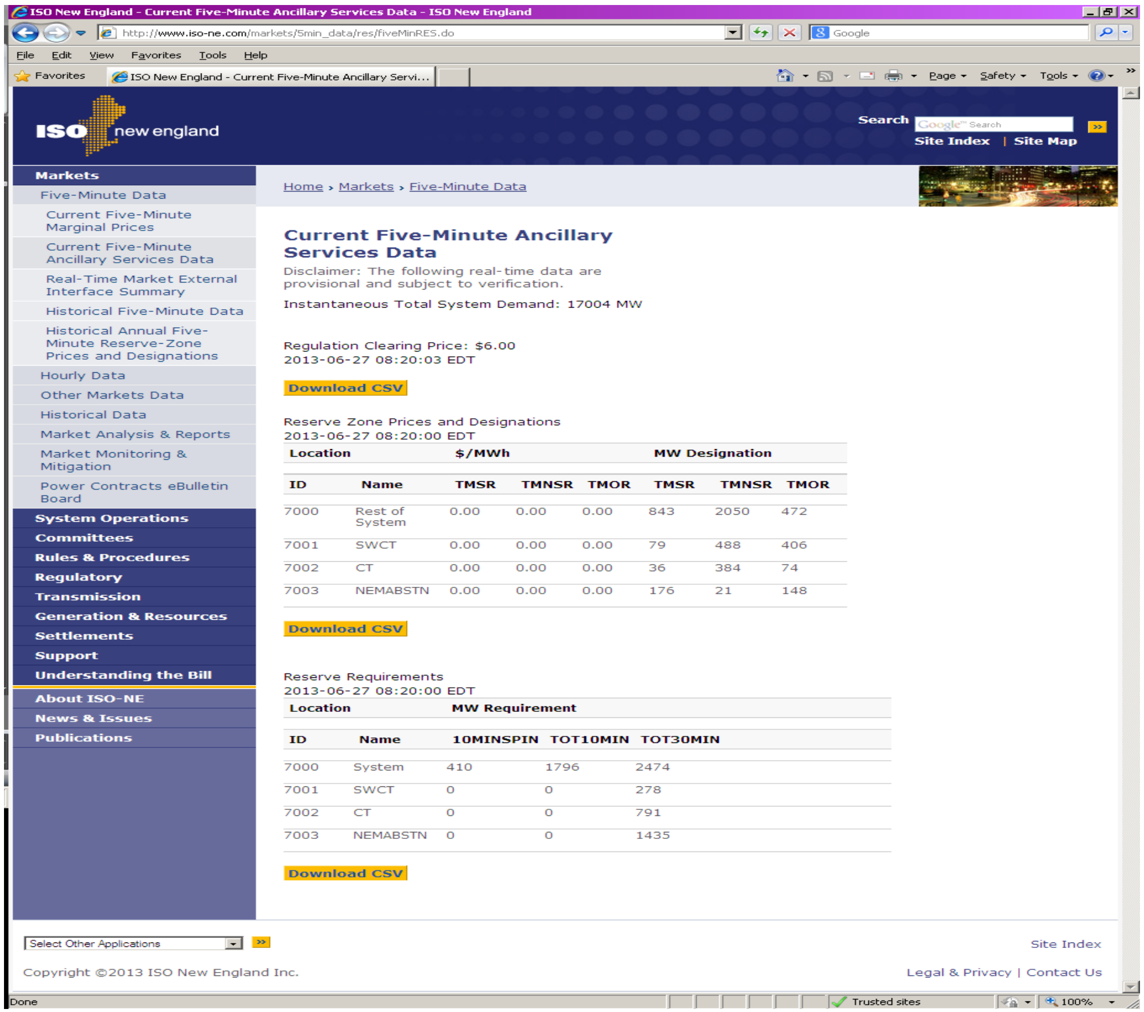
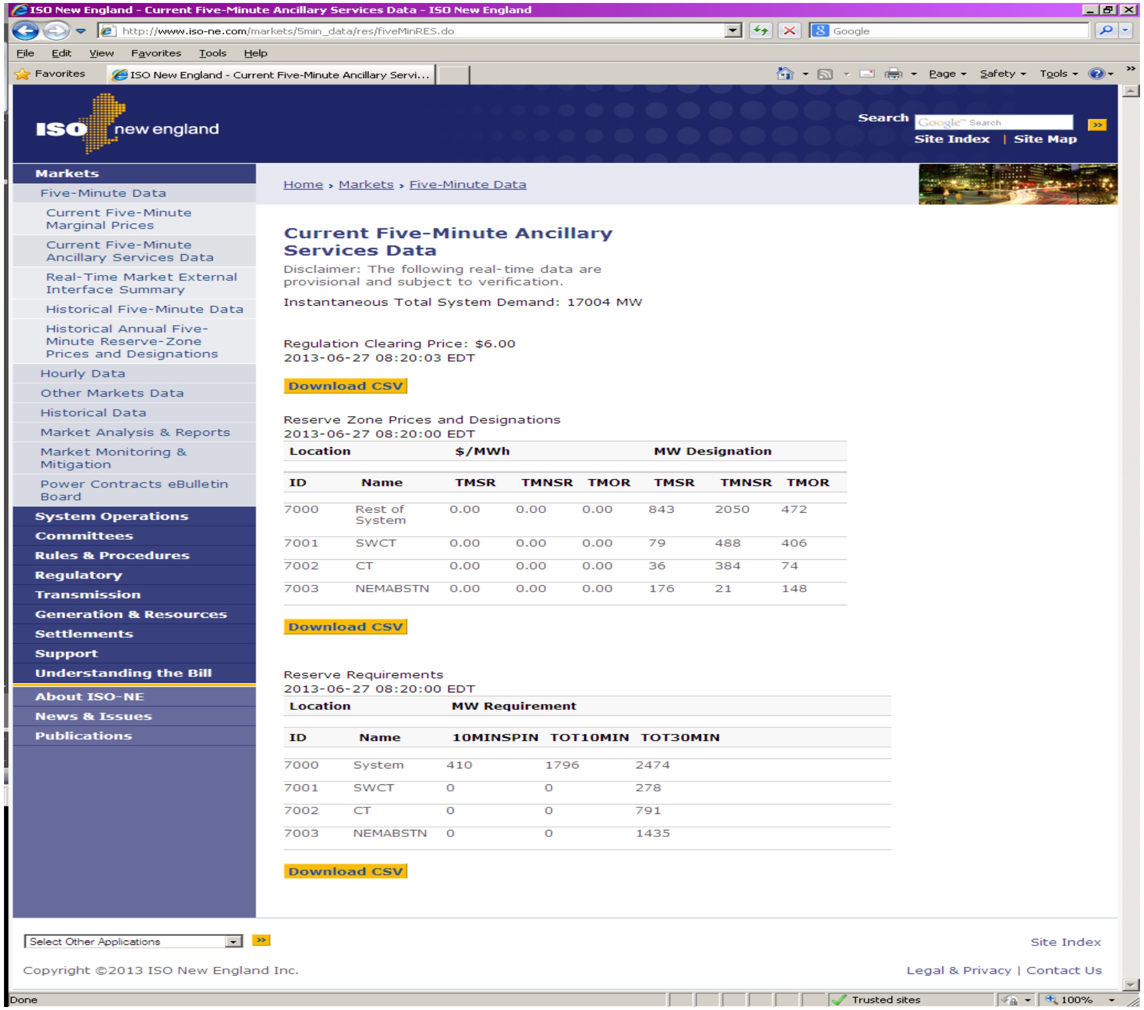
What is the Total 10 Minute Reserve available this interval?



What is the Total Operating Reserve Requirement this interval?



ISO New England - Current Five-Minute Ancillary Services Data - ISO New England

http://www.iso-ne.com/markets/5min_data/res/fiveMinRES.do

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Current Five-Minute Ancillary Services Data

Disclaimer: The following real-time data are provisional and subject to verification.

Instantaneous Total System Demand: 17004 MW

Regulation Clearing Price: $6.00
2013-06-27 08:20:03 EDT

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Reserve Zone Prices and Designations
2013-06-27 08:20:00 EDT

Location		$/MWh			MW Designation		
ID	Name	TMSR	TMNSR	TMOR	TMSR	TMNSR	TMOR
7000	Rest of System	0.00	0.00	0.00	843	2050	472
7001	SWCT	0.00	0.00	0.00	79	488	406
7002	CT	0.00	0.00	0.00	36	384	74
7003	NEMABSTN	0.00	0.00	0.00	176	21	148

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Reserve Requirements
2013-06-27 08:20:00 EDT

Location		MW Requirement		
ID	Name	10MINSPIN	TOT10MIN	TOT30MIN
7000	System	410	1796	2474
7001	SWCT	0	0	278
7002	CT	0	0	791
7003	NEMABSTN	0	0	1435

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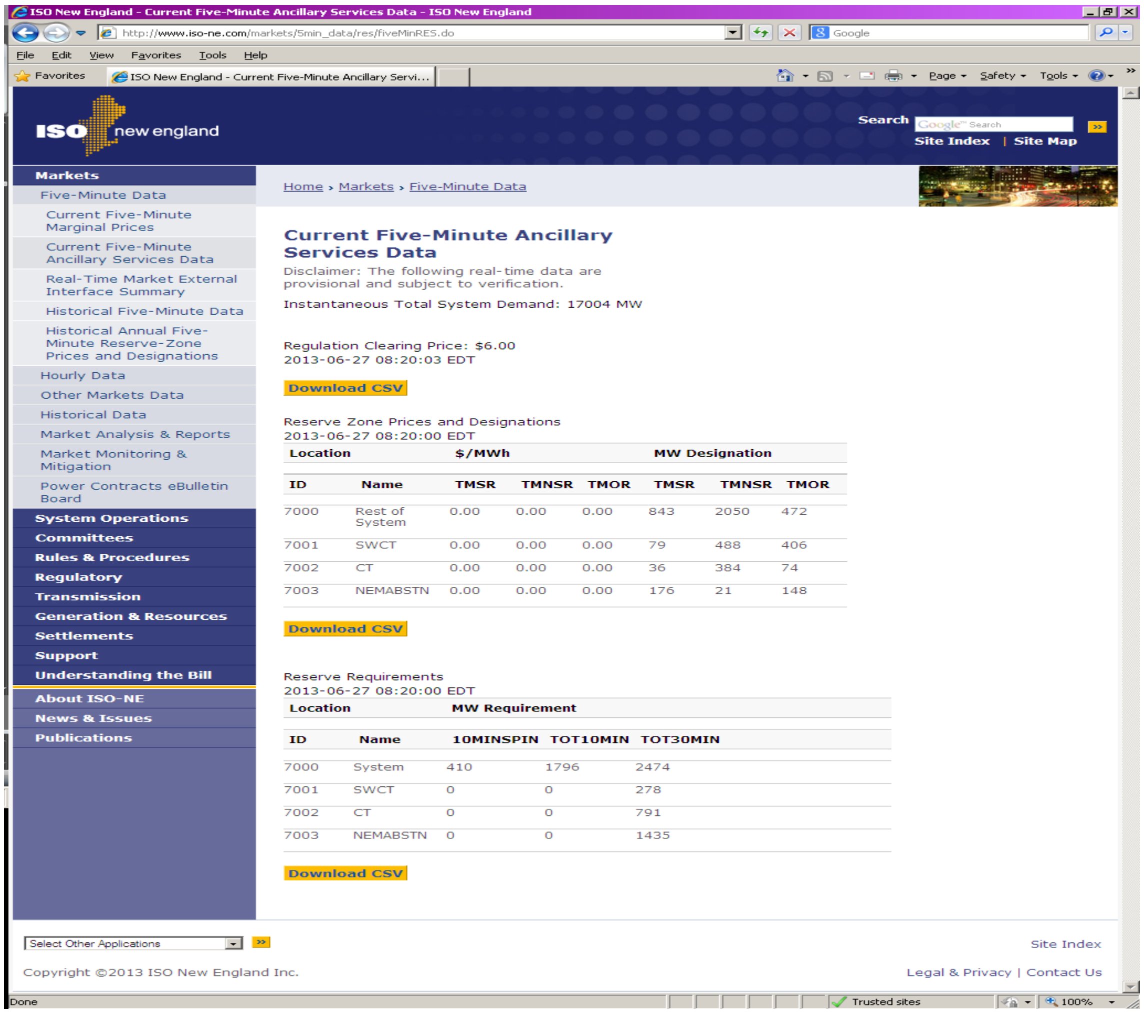
What is the Total Operating Reserve available this interval?



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Common Misconception: Dispelled

- TMSR Requirement = YES!
- TMSNR Requirement = NO!
- Total 10 Requirement = YES!
- TMOR Requirement = NO!
- Total Operating Reserve Requirement = YES!
- Why is this important?

Common Misconception: Dispelled

- Since there is a Total Operating Reserve Requirement, not an incremental 30 Minute Requirement, if Total 10 is short the software will procure additional 30 minute reserves to continue to try to meet the Total Operating Reserve Requirement

Reserve Requirements
2013-06-27 08:20:00 EDT

Location		MW Requirement		
ID	Name	10MINSPIN	TOT10MIN	TOT30MIN
7000	System	410	1796	2474
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Common Misconception: Dispelled

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- In the above example the additional 30 minute requirement used as part of the Total Operating Reserve Requirement is 2474 – 1796 (Total 10) = 678 MW
- In the above example, what if the Total 10 designated (available) in the system was only 1500 (short of the requirement) how much 30 minute reserves would the software attempt to procure?
  - 678 MW (from above)
  - 974 MW (2474 – 1500)

Let’s test your knowledge

- 1 MW of TMSR Reserve from a resource located in SWCT meets which of the requirements from previous slide?
  - System 10MinSpin
  - System Tot10Min
  - System Tot30Min
  - CT Tot30Min
  - SWCT Tot30Min
  - NEMA Tot30Min

Questions

JULY 12, 2013 | MARLBOROUGH, MA

Future Changes to Reserves

Changes that impact Reserve Markets or are impacted by Reserve Markets

Ron Coutu

MANAGER,
BUSINESS ARCHITECTURE & TECHNOLOGY

Reserve Market Changes

- Supplemental Reserve Requirement (Pending at the FERC)
  - Would extend the demand curve for the total operating reserves
  - Would create more times when reserve prices are non-zero
  - Supplemental Reserves would have a lower RCPF ($250) to reflect the Operator's desire to maintain the Supplemental Reserves but not as strong a desire as the Reserves needed to meet 1st and 50% of 2nd largest contingency
  - May help to resolve conditions where additional commitments are necessary to protect the system against normal system uncertainties

Reserve Market Change – (cont.)

- Operating the system to just meet energy and the minimum system operating reserve requirement may result in the need for emergency actions during peak hours
  - These actions would be required to address unexpected events such as load forecast errors, generator contingencies and reductions, and resource unavailability due to fuel limitations
  - To preclude excessive reliance on emergency actions to maintain system reliability, the ISO schedules additional resources above the load and reserve requirements in the RAA when necessary
- Scheduling additional resources above the load and reserve requirements maintains system reliability, but puts downward pressure on real-time energy and reserve prices
  - These additional scheduled resources are not included in the Day-Ahead Energy Market (as are the system TMSR, total system TMR and minimum system operating reserve requirements) or in real-time energy and reserve pricing

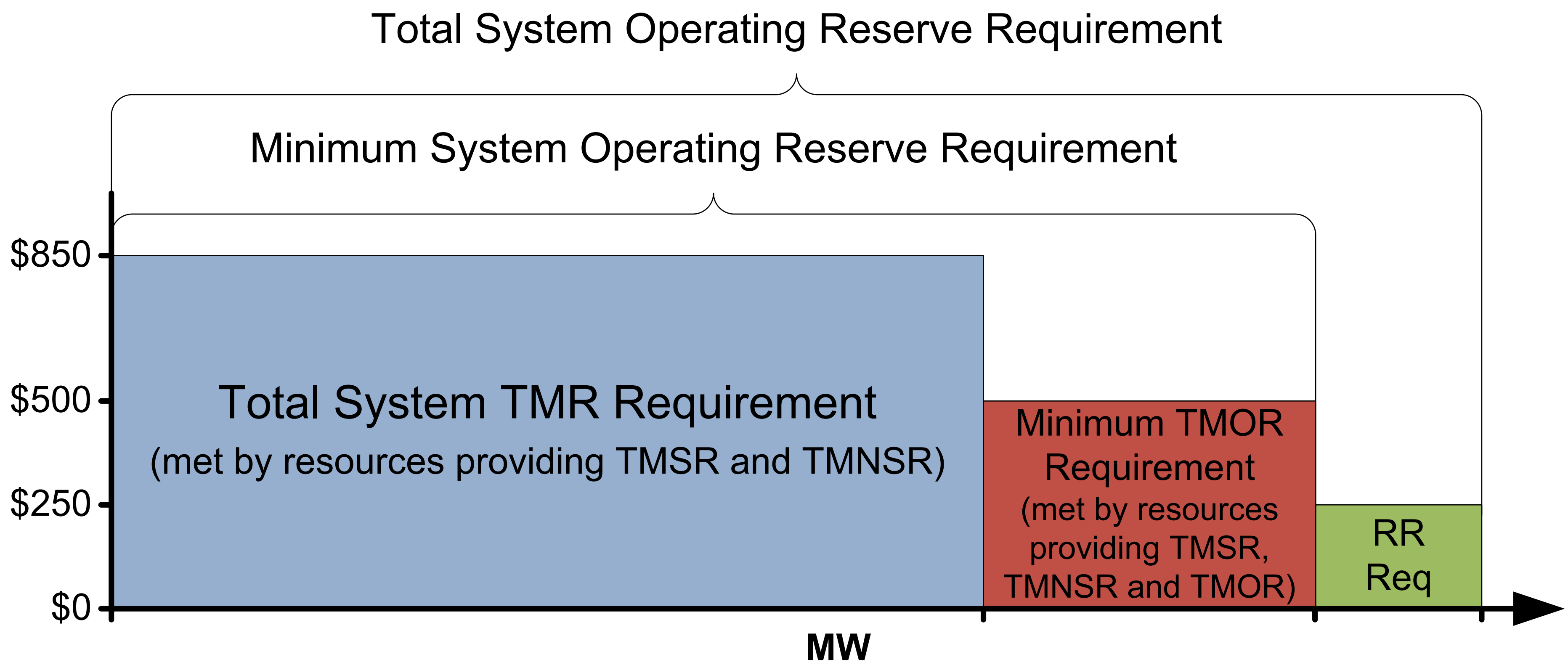
Reserve Market Changes – (cont.)

- An initial minimum replacement reserve requirement will be set at 160MW in the summer and 180MW in the winter (where summer and winter are defined based upon the change to Daylight Savings Time and Eastern Standard Time)
  - The ISO will continue to schedule additional resources as needed in order to maintain system reliability
- Replacement reserve requirement will be included in the Forward Reserve Market, Day-Ahead Energy Market and in the Real-Time Energy Market (including the RAA)

Reserve Market Changes – (cont.)

- An RCPF of $250/MWh was filed for the replacement reserve requirement (creating a tiered or stepped demand curve for the TMOR product)
  - Without the changes to the Market Rule, the RCPF for the replacement reserve requirement would be $500/MWh
- This RCPF was developed based upon two criteria:
  - RCPF must be high enough to ensure that system can be re-dispatched under most conditions
  - RCPF should be lower than the RCPF for the minimum system operating reserve requirement (of $500/MWh) because the ISO will not take emergency actions to maintain replacement reserve requirement
    - ISO will continue to take emergency actions to maintain the minimum system operating reserve requirement

Conceptual Representation of the Proposed System Reserve Requirements



Forward Reserve Market Changes

- Forward Reserve Market Changes (identified in previous slides)
  - Adjust the penalty for "Failure to Reserve"
    - Make the penalty more incentive compatible with the market conditions to ensure that Participant with FRM is not better off by not meeting the FRM Obligation
  - Adjust the determination of "Failure to Activate"
- Increased the amount of ten-minute reserves procured within the Forward Reserve Market (FRM) (ER13-465 Effective 3/1/2013)
  - Complements real-time operating changes to procure more ten-minute reserves to improve the ability to recover from a system contingency
- Enhanced auditing provisions for measurement of key resources parameters such as Claim 10 and Claim 30 to improve the information available to the ISO when scheduling and dispatching resources (ER13-323 Effective 6/1/2013)
- Failure-to-Activate Penalties are rarely assessed to resources meeting TMOR obligation because the FRM narrowly defines when Forward Reserve Resources are assessed for a Failure-to-Activate Penalty in the context of contingency dispatch

Using the Real-Time Reserve Clearing Price in the Failure-to-Reserve Penalty Rate corrects the incentives

- Modifying the Failure-to-Reserve Penalty Rate to include the Real-Time Reserve Clearing Price creates an incentive to follow dispatch instructions (changes in red)

- Maximum (1.5 x Forward Reserve Payment Rate,
  Real-Time Reserve Clearing Price -
  Forward Reserve Payment Rate)

- This will allow the Forward Reserve Market act more like a Forward Market "clearing" against the spot price (RT RMCP)
  - Resource failing to "deliver" its obligation must buy at a proxy for the spot price (if the spot price is not zero)

Shortage Event Trigger

- ISO has proposed that a Shortage Event could be triggered on different conditions
  - Currently 30 minutes of not meeting Total 10 Minute Reserve Requirement
  - Future is the above condition or 30 minutes of not meeting Total Operating Reserve Requirement (with the $500/MWh RCPF) and activating Price Responsive Demand (OP4 – Step 2)
- Proposed Future Shortage Events (under FCM PI) could be triggered on:
  - Any five minute shortage of Total Operating Reserve, any five minute shortage of Total 10 Minute Reserve or any five minute shortage of Reserve Zone Reserve requirements (certain Reserve Zones only)

Questions

Customer Support

- Ask ISO
  - Self-service interface for submitting inquires
  - Accessible through the SMD Applications Homepage
  - Requires a valid digital certificate with the role of Ask ISO/External User
  - Contact your Security Administrator for assistance
- Phone: 413-540-4220
  - Monday through Friday, 7:30 A.M. to 5:30 P.M. Eastern Time
  - Recorded/monitored conversations
- Email: custserv@iso-ne.com

Evaluations