# Dynamic Reserves

Reposted with revisions in Green Font on Slide 16

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# Agenda

- Background
- 2023 Project Kickoff
- DAM Scheduling Examples
- Next Steps

# Background

| Title/Topic | Link |
| --- | --- |
| 2021 RECA Study (Updated 2/2022) | https://www.nyiso.com/documents/20142/26734185/RECA(Dynamic%20Reserves)%20Study%20Report.pdf/27990919-e81b-76a4-12e1-57b9458b553d |
| March 3, 2022 MIWG Project Kickoff | https://www.nyiso.com/documents/20142/28897222/Dynamic%20Reserves%20Kickoff%20MIWG%2003032022_Final.pdf/b2b5cd26-4740-ab35-015c-5e93bf3ca23e |
| May 11, 2022 MIWG | https://www.nyiso.com/documents/20142/30555355/Dynamic%20Reserves%20MIWG%2020220511.pdf/35e8b44a-6a54-c8e0-ee30-b9e0709738af |
| June 16, 2022 MIWG | https://www.nyiso.com/documents/20142/31532822/6%20Dynamic%20Reserves.pdf/ca9ad944-c911-1874-2710-9ba04521d789 |
| August 9. 2022 MIWG | https://www.nyiso.com/documents/20142/32687686/20220809%20Dynamic%20Reserves%20MIWG.pdf/c63d67ab-4498-efc9-7ad6-954c0d07af04 |
| October 4, 2022 MIWG (Presented by FTI Consulting) | https://www.nyiso.com/documents/20142/33562316/20220928%20Dynamic%20Reserves%20Examples%20MIWG%20draft%20revised%20v2%20(002).pdf/75b413e2-30b8-2cda-6100-1620deebd5de |
| October 19. 2022 MIWG | https://www.nyiso.com/documents/20142/33857891/05_20221019%20Dynamic%20Reserves%20MIWG.pdf/1e4d90d6-10d8-2da8-b10f-96afa50e9ce0 |
| November 8, 2022 MIWG | https://www.nyiso.com/documents/20142/34285499/3%20Dynamic%20Reserves%20MIWG%20v2.pdf/d49af783-0496-0b4f-0a16-d9908a6435da |
| December 5, 2022 MIWG: Market Design Concept Proposed | https://www.nyiso.com/documents/20142/34833356/8%20Dynamic%20Reserves%20-%20MDCP%20Presentation%20v2.pdf/56da2b89-7fcc-3357-ca77-d255fb33ee2f |

# Market Design Concept Proposal

## Components of NYISO's Market Design Concept Proposal included:

- Formulation for Loss of Generation
- Formulation for Loss of Transmission
- Formulation for Loss of Generation and Loss of Transmission
- Correlated contingencies that might impact reserve requirements
- Use of forecast load in mathematical formulation
- Interaction of dynamic modeling with intermittent resource contingencies
- Securing of reserves in export constrained areas (e.g., Long Island)
- Interplay between Thunderstorm Alerts (TSAs) and dynamic reserves
- Process for posting of dynamic reserve requirements
- Interaction of dynamic reserves with operating reserve demand curves
- Interaction of dynamic reserves with transmission demand curves
- Interplay between dynamic reserves scheduling and additional reserve requirements
- Reserve cost allocation
- LBMP formation (pricing and scheduling of resources under Dynamic Reserves)
- Impacts on scarcity pricing logic
- Interplay with current/future efforts: More Granular Operating Reserves, Long Island Constraint Pricing, Reserves for Congestion Management

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# Implementation Considerations: Project Phases

- **Phase 1:**
  - Formulation for Loss of Generation (based only on the largest single-source generator or single contingency proxy Import)
    - The formulation for Loss of Generation could exceed today's limit of 1310 MW, based on the economic evaluation of Generator offers. Total 30-min reserves procured can exceed 2620 MW
  - Formulation for Loss of Transmission
  - Formulation for Simultaneous Loss of Generation and Transmission
  - Dynamic 30-Minute NYCA ORDC
  - Enhancements to Long Island reserve scheduling
  - Updates to the posting of reserve requirements
- **Phase 2:**
  - Formulation for Correlated Loss of Multiple Generators
  - Formulation for Intermittent Resource Contingency
  - Phase 2 could also include additional changes that have been further vetted and included in the 2023 Market Design Complete effort, such as Transmission Demand Curves, Thunderstorm Alerts, and Scarcity Pricing

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# 2023 Project Description

- **Deliverable: Q3 2023 – Market Design Complete**
- **Project Description:**
  - Building upon the 2022 Market Design Concept Proposed (MDCP), the 2023 effort will develop potential changes to the NYISO's market software and market rules to facilitate more efficient scheduling of operating reserves based on system conditions.
    - The market design involves dynamically accounting for the single largest source contingency or transmission capability into a region when determining reserve requirements.

# Upcoming Stakeholder Discussions

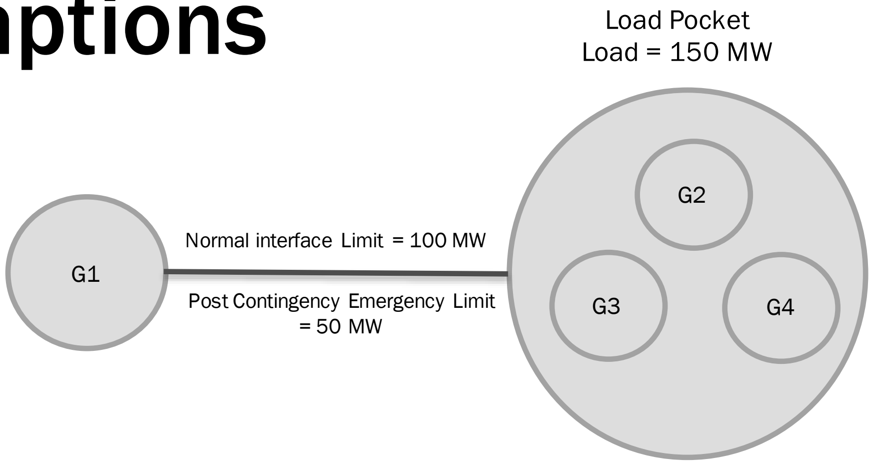
- **The following components will be addressed this year to achieve a Market Design Complete**
  - Setting of the reserve requirements
    - Determination of interface topology and interface limits
    - Definition of multipliers used in the calculation of different reserve product requirements
    - Use of [Forecast Load – Bid Load] component in NYCA 30-Minute requirement
  - Posting of reserve requirements
  - Impacts to NYISO processes:
    - Identify potential changes across NYISO processes necessary to accommodate Dynamic Reserves (e.g., settlements, mitigation)
  - Pricing concepts (e.g., LBMP formation, cost allocation)
    - Prepare examples to support understanding on pricing and LBMP formation
    - Identify potential changes to existing processes for reserve pricing, LBMP formation, and cost allocation
  - Continue prototype development to inform Market Design concepts

# Day-Ahead Market (DAM) Examples

# DAM Examples: Introduction

- **A key benefit of Dynamic Reserves is the functionality to determine the least-cost generation and reserves mix to meet load, based on current system conditions.**
  - The Dynamic Reserves formulation allows the software to determine the appropriate trade-offs in a constrained area utilizing transmission headroom
  - NYISO developed a set of simplified scheduling examples which demonstrate these tradeoffs in the DAM
    - In October 2022, NYISO presented examples of Dynamic Reserve pricing and scheduling in the RTM. Since reserve offers are \$0/MWh in the RT, the software does not need to consider the reserve bids when calculating the reserve requirement

# DAM Examples: Assumptions




- The examples are based on a simple pipe and bubble model, with three generators (G2, G3, G4) within a load pocket and one generator (G1) outside
  - Internal Load = 150 MW
  - Normal Interface limit = 100 MW
  - Post Contingency Emergency Limit = 50 MW
- In this example, we are calculating the reserve requirement for the load pocket.

| | UOL | Energy bid ($/MW) | Reserve bid ($/MW) |
|---|---|---|---|
| G1 | 100 | 20 | N/A |
| G2 | 50 | 100 | 3 |
| G3 | 50 | 20 | 5 |
| G4 | 25 | 22 | 3 |

# Optimal Solution

- The least-cost solution results in the following reserve requirement for the load pocket:

| | UOL | Energy bid ($/MW) | Reserve bid ($/MW) | Energy Schedule (MW) | Reserve Schedule (MW) |
|---|---|---|---|---|---|
| G1 | 100 | 20 | N/A | 75 | - |
| G2 | 50 | 100 | 3 | 0 | 25 |
| G3 | 50 | 20 | 5 | 50 | 0 |
| G4 | 25 | 22 | 3 | 25 | 0 |

- Headroom = Limit – Flow = Limit – (Load – Generation in the Load pocket) = 100 – (150 – 75) = 25 MW
- Reserve requirement (RR) = Max(RR for Loss of Transmission, RR for Loss of Generation) = 25 MW
  - RR for Loss of Transmission = Flow - Post Contingency Emergency Limit = (150-75) - 50 = 25 MW
  - RR for Loss of Generation = G3 Energy – Headroom = 50 – 25 = 25 MW
- Production cost = Energy Cost + Reserve cost = $20*75 + $20*50 + $22*25 + $3*25= $3125

- The next few slides walk through why this combination of energy and reserves is the least-cost solution

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# Alternative: Shifting from 75 MW to 74 MW on G1

- **The least-cost solution resulted in 75 MW of energy outside of the load pocket on G1. What would have been the market outcome with 74 MW of energy on G1?**
  - G1: 74 MW of energy @ $20/MWh
  - G2: 1 MW of energy @ $100/MWh, 25 MW of reserves @ $3/MWh
    - G2 would need to provide energy since G3 and G4 are at UOL
  - G3: 50 MW of energy @ $20/MWh
  - G4: 25 MW of energy @ $22/MWh

| | Least Cost Solution | | -1 MW Energy Outside Reserve Area | |
|---|---|---|---|---|
| | Energy | Reserves | Energy | Reserves |
| G1 | 75 | 0 | 74 | 0 |
| G2 | 0 | 25 | 1 | 24 |
| G3 | 50 | 0 | 50 | 0 |
| G4 | 25 | 0 | 25 | 0 |

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# Alternative: Shifting from 75 MW to 74 MW on G1 (continued)

- **The least-cost solution resulted in 75 MW of energy outside of the load pocket on G1. What would have been the market outcome with 74 MW of energy on G1?**
  - Headroom = Limit – Flow = 100 – 74 = 26 MW
  - Reserve requirement = 24 MW
    - RR for Loss of Transmission = Flow - Post Contingency Emergency Limit = 74 - 50=24 MW
      - Reserve requirement will decrease as interface flow decreases
    - RR for Loss of Generation = G3 Energy – Headroom = 50 – 26 = 24 MW
      - Reserve requirement will decrease as headroom increases
  - Production cost = Energy Cost + Reserve cost = $20*74 + $1*100 + $20*50 + $22*25 + $3*24= $3202
  - Shifting 1 MW of energy from G1 to G2:
    - Reduces RR for the Loss of Generation due to increased headroom
    - Reduces RR for the Loss of Transmission due to decreased flow
    - Increases production cost by $77 (difference between energy offers of G1 and G2, less the savings from -1 MW of reserves)
    - The reserve requirement goes down, but the cost of energy increases, so it is more efficient to have another MW outside of the reserve area and a higher reserve requirement

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# Alternative: Shifting from 75 MW to 76 MW on G1

- **The least-cost solution resulted in 75 MW of energy outside of the load pocket on G1. What would have been the market outcome with 76 MW of energy on G1?**
  - G1: 76 MW of energy @ $20/MWh
  - G2: 26 MW of reserves @ $3/MWh
  - G3: 50 MW of energy @ $20/MWh
  - G4: 24 MW of energy @ $22/MWh
    - G4 would be backed down since it more expensive than G3

| | Least Cost Solution | | -1 MW Energy Outside Reserve Area | | +1 MW Energy Outside Reserve Area | |
|---|---|---|---|---|---|---|
| | Energy | Reserves | Energy | Reserves | Energy | Reserves |
| G1 | 75 | 0 | 74 | 0 | 76 | 0 |
| G2 | 0 | 25 | 1 | 24 | 0 | 26 |
| G3 | 50 | 0 | 50 | 0 | 50 | 0 |
| G4 | 25 | 0 | 25 | 0 | 24 | 0 |

# Alternative: Shifting from 75 MW to 76 MW on G1

- **The least-cost solution resulted in 75 MW of energy outside of the load pocket on G1. What would have been the market outcome with 76 MW of energy on G1?**
  - Headroom = Limit – Flow = 100 – 76 = 24 MW
  - Reserve requirement = 26 MW
    - RR for Loss of Transmission = Flow - Post Contingency Emergency Limit = 76 – 50 = 26 MW
      - Reserve requirement will increase as interface flow increases
    - RR for Loss of Generation = G3 Energy – Headroom = 50 – 24 = 26 MW
      - Reserve requirement will increase as headroom decreases
  - Production cost = Energy Cost + Reserve cost = $20*76 + $20*50 + $22*24 + $3*26= $3126
  - Shifting 1 MW of energy from G4 to G1:
    - Increases RR for the Loss of Generation due to decreased headroom
    - Increases RR for the Loss of Transmission due to increased flows on the interface
    - Increases production cost by $1 (cost of an extra MW of reserve, less the savings in energy)
    - The savings of $2/MWH for energy leads to an increased reserve requirement at a cost of $3/MWh

# Dynamic Reserves: Trade-offs

- **These examples illustrate how the following trade-offs can be made by the optimization to generate a least-cost solution:**
  - Increasing MW outside of the reserve area will:
    - Increase flow and decrease headroom
    - Increase in RR for both Loss of Transmission and Loss of Generation
  - Increasing MW inside of the reserve area will:
    - Decrease flow and increase headroom
    - Decrease in RR for both Loss of Transmission and Loss of Generation
  - These tradeoffs must account for energy offers, reserves offers, transmission limits, load
    - In our simplified example, the software was able to shift generation to G1 until the net savings from the shift was outweighed by the net cost of the extra reserves

# Impact of a Change in Energy Offer

- **Say that the energy offer of G3 is increased to $25. Now there is larger difference between the energy offers of G1 (external) and G3 (internal) – the software can shift more MWs to the external generator. The optimal solution would be:**
  - G1: 100 MW of energy @ $20/MWh
  - G2: 50 MW of reserves @ $3/MWh
  - G3: 25 MW of energy @ $25/MWh (no longer at its UOL)
  - G4: 25 MW of energy @ $22/MWh
  - Headroom = Limit – Flow = 100 - 100 = 0 MW
  - Reserve requirement = 50 MW
    - Reserve requirement for Loss of Transmission = – (N-1 Limit – Flow) = – (50 – 100) = 50 MW
    - Reserve requirement for Loss of Generation = G3 Energy – Headroom = 25 – 0 = 25 MW
  - Under these conditions, it is more efficient to schedule 100 MW (+25 MW from original example) to meet the same amount of load (150 MW) due to the offer of G3
    - This also results in a larger reserve requirement due to the flows on the transmission interface

# Questions?

# Appendix I: Mathematical Formulation

# Securing Reserve Area for the Loss of Generation

- **The first concept is that reserves should cover for the largest source contingency in a Reserve Area, less available headroom**
  - Available headroom would reflect the ability to import reserves into the existing reserve region
  - Currently, largest source contingency in a Reserve Area is determined by the largest single generation schedule
- **In addition to the largest single-source contingency, NYISO is proposing additional constraints to be considered when evaluating the largest source contingency:**
  - Correlated loss of multiple generators: Multiple resources that share a single point of failure (transmission tower, gas regulator valve)
  - Intermittent resource contingencies: Resources in close geographic proximity that may be susceptible to a common weather pattern, which poses a risk of simultaneous loss or reduction of energy output
- **An example of the generic formulation for Loss of Generation (applied to a 30-Minute Reserve product) is:**

$$Res_{RA_{a_i}}^{30Total} \geq Mult_{\mathrm{RA}_a}^{30Total} * \{\max_{\mathrm{k}\in\mathrm{Gen}_{RA_a}} \{gen_{k_i} + res_{k_i}^{30Total}\}\} - RA_{a_{Headroom}}$$

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# Securing Reserve Area for the Loss of Transmission

- **The second concept is that reserves should account for the loss of transmission (energy imports) into an existing reserve area**
  - This evaluation calculates the difference between the post-contingency interface limits and the current flow, following the loss of the largest line on the interface
  - Loss of Transmission is not considered when evaluating NYCA reserve requirements because external proxies are evaluated as generators
- **An example of the generic formulation for Loss of Transmission (applied to a 30-Minute Reserve product in a locality) is:**

$$30minute_{PostCon_{Import_{RA_{a_i}}}} = Limit_{N-2Emer_{RA_{a_i}}} - RA_{Flow_{a_i}}$$

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# Tying Loss of Generation and Loss of Transmission Together

- The equations for the generation and transmission constraints would be co-optimized along with energy, reserves, and transmission
- The reserve requirements would be determined by the most restrictive equation for each reserve product in each reserve area
  - Would be dynamically determined in DAM and RTM

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# Equations: Securing a Reserve Area for the Loss of Generation

# Calculating Actual Energy Flows in a Reserve Area

$$RA_{a_{Flow_i}} = (RA_{a_{Load_i}} + RA_{a_{Losses_i}} - RA_{a_{Gen_i}})$$

- $\mathrm{RA_a}$ is the applicable reserve area
- $\mathrm{RA_{a_{Flow_i}}}$ is the actual energy flow into or out of reserve area *a* for time step *i*
  - $RA_{a_{Flow_i}}$ is positive into reserve area *a*
  - $RA_{a_{Flow_i}}$ is negative out of reserve area *a*
  - Note: For the NYCA reserve area (Load Zones A-K), $RA_{a_{Flow_i}}$ value is equal to 0 MW because external proxies are evaluated as generators
- $\mathrm{RA_{a_{Load_i}}}$ is the forecasted load in reserve area *a* for time step *i* (Day-Ahead or Real-Time, as applicable)
- $RA_{a_{Losses_i}}$ is the calculated losses in reserve area a for time step *i* (Day-Ahead or Real-Time, as applicable)
- $\mathrm{RA_{a_{Gen_i}}}$ is the sum of all energy schedules on resources inside reserve area *a* for time step *i*

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# Calculating the Available Transmission Headroom in a Reserve Area for Generation

$$RA_{a_{Headroom}} = RA_{a_{EmerLimit_i}} - RA_{a_{Flow_i}}$$

- $\mathrm{RA}_{Headroom}$ is the capability to secure reserves external to reserve area *a* for time step *i*
- $\mathrm{RA}_{\mathrm{a}_{\mathrm{EmerLimit_i}}}$ is the pre-contingency emergency limit for the reserve area *a* for time step *i*
  - Note: For the NYCA reserve area (Load Zones A-K), the $\mathrm{RA}_{\mathrm{EmerLimit}}$ and $\mathrm{RA}_{\mathrm{NormLimit}}$ value is equal to 0 MW because external proxies are evaluated as generators

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# Multipliers Determine Product Quality Ratios

$$Res_{RA_{a_i}}^{10Spin} \geq Mult_{\mathrm{RA}_a}^{10Spin} * \{\max_{\mathrm{k \in Gen}_{RA_a}} \{gen_{k_i} + res_{k_i}^{10SPin}\}\} - RA_{a_{Headroom}}$$

$$Res_{RA_{a_i}}^{10Total} \geq Mult_{\mathrm{RA}_a}^{10Total} * \{\max_{\mathrm{k \in Gen}_{RA_a}} \{gen_{k_i} + res_{k_i}^{10Total}\}\} - RA_{a_{Headroom}}$$

$$Res_{RA_{a_i}}^{30Total} \geq Mult_{\mathrm{RA}_a}^{30Total} * \{\max_{\mathrm{k \in Gen}_{RA_a}} \{gen_{k_i} + res_{k_i}^{30Total}\}\} - RA_{a_{Headroom}}$$

- $\mathrm{Res}_{\mathrm{RA}_{a_i}}^{\mathrm{10Spin}}$ is the 10 − minute spinning reserve requirement in reserve area $a$ for time step $i$
- $\mathrm{Res}_{\mathrm{RA}_{a_i}}^{\mathrm{10Total}}$ is the 10 − minute total reserve requirement in reserve area $a$ for time step $i$
- $\mathrm{Res}_{\mathrm{RA}_{a_i}}^{\mathrm{30Total}}$ is the 30 − minute total reserve requirement in reserve area $a$ for time step $i$

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# Securing a Reserve Area for the Loss of Transmission

# Contingency Headroom on Interface

$$10minute_{PostCon_{Import_{RA_{a_i}}}} = Limit_{N-1Emer_{RA_{a_i}}} - RA_{Flow_{a_i}}$$

$$30minute_{PostCon_{Import_{RA_{a_i}}}} = Limit_{N-2Emer_{RA_{a_i}}} - RA_{Flow_{a_i}}$$

- $\mathrm{10minute_{PostCon_{Import_{RA_{a\,i}}}}}$ is the applicable post-contingency transfer limit of reserve area *a* for time step *i* that the flow should be under within 10 minutes
- $\mathrm{30minute_{PostCon_{Import_{RA_{a\,i}}}}}$ is the applicable post-contingency transfer limit of reserve area *a* for time step *i* that the flow should be under within 30 minutes
- $\mathrm{Limit}_{N-1\mathrm{Emer}_{\mathrm{RA}_{\mathrm{a_i}}}}$ is the emergency transfer limit of reserve area *a* for time step *i*, with the largest in-service element taken out of service
- $\mathrm{Limit_{N-2Emer_{RA_{a_i}}}}$ is the emergency transfer limit of reserve area *a* for time step *i*, with the two largest in-service element taken out of service

# Contingency Headroom on Interface

- The difference between the applicable transfer limit and the flow is the available import capability
  - When negative, this number represents a deficiency that needs to be held as reserves within the reserve area due to the lack of transmission headroom to import reserves.
- All limits will be calculated via an offline study by NYISO Operations

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# Securing the RA for Loss of Transmission

$$Res_{RA_{a_i}}^{10Spin} \geq -Mult_{\mathrm{RA}_a}^{10Spin} * (10minute_{PostCon_{Import_{RA_{a_i}}}})$$

$$Res_{RA_{a_i}}^{10Total} \geq -(10minute_{PostCon_{Import_{RA_{a_i}}}})$$

$$Res_{RA_{a_i}}^{30Total} \geq -\left(30minute_{PostCon_{Import_{RA_{a_i}}}}\right)$$

**The multiplier is only used for Spin as it represents a quality flag (percentage) of the 10T requirement which should be held as spinning. Any number from 0 to 1 is valid.**

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# Tying the Loss of Generation and Loss of Transmission Together

# Securing for one source contingency and N-1 transmission contingency

- $Res_{RA_{a_i}}^{30Total} \geq \{\max_{k \in \mathrm{Gen}_{RA_a}} \{\mathrm{gen}_{k_i} + res_{k_i}^{30Total}\}\} - (Limit_{N-1Emer_{RA_{a_i}}} - RA_{Flow_{a_i}})$

# Simultaneous Constraints 30-Minute Total Reserves

- **Secure multiple of largest generator to emergency transfer capability:**

$$Res_{RA_{a_i}}^{30Total} \geq Mult_{\mathrm{RA}_a}^{30Total} * \{\max_{\mathrm{k}\in\mathrm{Gen}_{RA_a}} \{gen_{k_i} + res_{k_i}^{30Total}\}\} - RA_{a_{Headroom}}$$

$$RA_{a_{Headroom}} = RA_{a_{EmerLimit_i}} - RA_{a_{Flow_i}}$$

- **Secure transmission for N-2 to emergency transfer capability:**

$$Res_{RA_{a_i}}^{30Total} \geq -(Limit_{N-2Emer_{RA_{a_i}}} - RA_{Flow_{a_i}})$$

- **Secure for loss of two elements within 30 minutes:**

$$Res_{RA_{a_i}}^{30Total} \geq \{\max_{\mathrm{k}\in\mathrm{Gen}_{RA_a}} \{\mathrm{gen}_{k_i} + res_{k_i}^{30Total}\}\} - (Limit_{N-1Emer_{RA_{a_i}}} - RA_{Flow_{a_i}})$$

The more restrictive of the equations will determine the applicable requirement for the reserve area.

# Simultaneous Constraints 30-Minute Total Reserves

- **Secure multiple of largest generator to emergency transfer capability:**

$$Res_{RA_{a_i}}^{30Total} \geq Mult_{\mathrm{RA}_a}^{30Total} * \{\max_{\mathrm{k} \in \mathrm{Gen}_{RA_a}} \{gen_{k_i} + res_{k_i}^{30Total}\}\} - RA_{a_{Headroom}} + ORDC + RA_{scarcity_i}$$

$$RA_{a_{Headroom}} = RA_{a_{EmerLimit_i}} - RA_{a_{Flow_i}}$$

- **Secure transmission for N-2 to emergency transfer capability:**

$$Res_{RA_{a_i}}^{30Total} \geq -\left(Limit_{N-2Emer_{RA_{a_i}}} - RA_{Flow_{a_i}}\right) + ORDC + RA_{scarcity_i}$$

- **Secure for loss of two elements within 30 minutes:**

$$Res_{RA_{a_i}}^{30Total} \geq \{\max_{\mathrm{k} \in \mathrm{Gen}_{RA_a}} \{\mathrm{gen}_{k_i} + res_{k_i}^{30Total}\}\} - (Limit_{N-1Emer_{RA_{a_i}}} - RA_{Flow_{a_i}}) + ORDC + RA_{scarcity_i}$$

- **Scarcity Minimum Reserve Constraint Penalty Cost**

$$Res_{RA_{a_i}}^{30Total} \geq RA_{scarcity_i} + \$500\_Penalty\_Cost\_Curve$$

The more restrictive of the equations will determine the applicable requirement for the reserve area.

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