Dynamic Reserves

Matthew Musto

Market Solutions Engineering

Ashley Ferrer

Energy Market Design

Kanchan Upadhyay

Ting Dai

Market Solutions Engineering

ICAPWG/MIWG

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Agenda

- Background
- Review Nodal Reserve Market Design
- Examples
- Energy and Reserve Pricing Under a Nodal Design
- Next Steps

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Background

Previous Presentations

Title/Topic	Link
March 7, 2023 MIWG	https://www.nyiso.com/documents/20142/36639552/Dynamic%20Reserves%20-%2020230307%20MIWG_final.pdf/a29ccf5d-4c26-5cbf-0103-5bece7edb276
March 31, 2023 MIWG	https://www.nyiso.com/documents/20142/36828420/MIWG%20March%2031%20Dynamic%20Reserves%20Postings%20and%20LMP.pdf/81c35384-2438-1e03-e021-6e7ecc18f9d7
September 5, 2023 MIWG	https://www.nyiso.com/documents/20142/39768278/2%2020230905%20MIWG%20-%20Dynamic%20Reserves.pdf/d58e28ab-de87-7a86-4296-a8c21f7c764f

Current Progress

- At the 9/5/2023 MIWG, the NYISO discussed several challenges to implementing the methodology introduced during the MDCP phase and proposed an alternative method for determining dynamic reserve requirements, a “Generator Shift Factor Approach.” That presentation outlined the challenges identified and a qualitative description of the proposed approach.
- Today’s presentation will provide numerical examples to demonstrate this approach and a discussion of how a Nodal Reserve Design will impact energy scheduling, reserve scheduling, LBMP formation, and reserve price formation.

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Foundation for Market Design Concepts

- **Energy scheduling constraints are formulated as follows:**
  - $\sum Shift\ Factors\ *\ (Gen\ and\ Load\ Schedules) \leq Line\ Limit$
    - ‘Line Limit’ is based on the normal limit for base case constraints and LTE or MTE limits for post-contingency constraints.
    - The associated shift factors for Generation and Load come from the Network Security Analysis (NSA) power flow tool.
- **This formulation would be extended for Operating Reserves subject to successful integration into NYISO BMS software**
  - NYISO has identified approximately 20 lines that make up key interfaces across NYCA and factor into reserve area definitions, for which NYISO would monitor for post-contingency limits
  - New reserve constraints need to be modeled similarly to the transmission constraint and validated within the market software: $\sum Shift\ Factors\ (Gen, Load, and\ Reserves) \leq Line\ Limit$
  - Reserve shift factors are negative in the above equation so that only resources which would provide relief for the constraint would be evaluated
  - The ‘Line Limit’ and reserve product would be based on the projected overload and timing requirements to restore the flows on the facility, after the contingency
  - The shift factors used to calculate the reserve constraints are based on the appropriate constraints operating requirements

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*No changes to this slide from the 9/5 materials

Generator Shift Factor Approach: Defining Locational Reserve Constraints

- **The locational reserve requirements (except for NYCA) would need to reflect the post-contingency system conditions as defined by reliability criteria:**
  - Loss of Transmission: The constraint would be evaluated for each monitored transmission element or interface[1] (*e.g.*, Central-East)
    - 10-Minute Total Reserves: Transmission elements must be below applicable limits[2] within 15 minutes following a single transmission contingency
      - [Post-Contingency Energy Flow – 10-Minute Reserves] <= Applicable Limits
    - 30-Minute Total Reserves: Transmission elements must be below Normal Transfer Criteria within 30 minutes following two transmission contingencies
      - [Post-Contingency Energy Flow – 30-Minute Reserves] <= Normal Transfer Criteria

1: The only interface that would be evaluated would be Central-East. All other transmission elements would be monitored individually.

2: An applicable limit for different constraints based on reliability criteria or system topology. For example, 1) reserve constraints for voltage conditions across the East interface would be based on Central East – Voltage Collapse maximum transfer capability and 2) reserve constraints for thermal conditions in NYC may be based on actual flows over LTE limits and 3) reserve constraints for thermal conditions in Long Island may be based on post contingency flows for the next contingency over LTE limits.

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Generator Shift Factor Approach: Defining Locational Reserve Constraints (Cont.)

- **The locational reserve requirements (except for NYCA) would need to reflect the post-contingency system conditions as defined by reliability criteria:**
  - Loss of Generation: The constraint would be evaluated for each monitored transmission element or interface against the loss of each generator
    - 10-Minute Total Reserves: Transmission elements must be below applicable limits within 15 minutes following the loss of a generator
      - [Post- Generator Contingency Energy Flow – 10-Minute Reserves*] <= Applicable Limits
    - 30-Minute Total Reserves: Transmission elements must be below Normal Transfer Criteria within 30 minutes following the loss of two generators
      - [Post- Generator Contingency Energy Flow – 30-Minute Reserves*] <= Normal Transfer Criteria
  - Loss of Generation and Transmission: This constraint would be evaluated for each monitored transmission against the loss of a generation and transmission element
    - 30-Minute Total Reserves: [Post-Contingency Energy Flow – 30-Minute Reserves*] <= Normal Transfer Criteria
    - N-1 Transmission flow and loss of largest effective unit (Gen_MW * N-1_SF) for 30T requirement

* Not counting Reserves on the lost unit

Generator Shift Factor Approach: Defining NYCA Reserve Constraints

- **Transmission flows and limits are only used in determining the reserve distribution within the NYCA**
  - NPCC and NYSRC rules require the NYISO to procure reserves in NYCA to cover the largest capability loss; therefore, the determination of the reserve requirement for NYCA does not consider transmission from external control areas
- **Nodal transmission security will determine distribution of the requirement**
  - All Reserve providers will have a shift factor of "unity" towards NYCA requirement
- **The proposed reserve constraints for NYCA would be:**
  - 10-Minute Spin: Equal to one-half of the NYCA 10-Minute Total requirement
  - 10-Minute Total: Equal to the output of most severe contingency (*i.e.*, largest generator schedule)
  - 30-Minute Total: Equal to the output of the Largest Generator + Second Largest Generator + max(0,(Forecast – Bid))
    - Basing the requirement on the combined output of the largest and second largest generators meets the NYSRC requirement for 30-Minute reserves. The NYSRC requirements state that: 1) NYISO must have enough 30-Minute Reserves equal to one-half of the 10-Minute Reserve requirement (i.e., one-half of the capability of the largest generator; and 2) NYISO must restore 10-Minute reserves within 30 minutes of a contingency[1]
    - NYISO's use of a multiplier of 2*largest generator is an approximation of this requirement. Calculating the reserve requirement based on the capability of the largest and second largest contingency would allow NYISO to have enough reserves to restore flows and 10-Minute reserves within 30 minutes

1: https://www.nysrc.org/wp-content/uploads/2023/07/RRC-Manual-V46-final.pdf

Stakeholder Feedback from 9/5/23

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Current Reserve Criteria (10S and 10T)

	NYCA	East	SENY	NYC	LI
10-Minute Spinning Reserves (Static Value Reliability Rule Dynamic Reserves Calculation)	1/2*A = 655 MW 10-minute spinning reserve is equal to at least one-half of the 10-minute total reserve. [NYSRC Reliability Rules, Section E] DR: ½ Largest Schedule (The Largest Schedule is formulated as the capability of the largest generator, as the combined energy, regulation, 10-Minute Spin, 10-Minute Total, 30-Minute Total schedules)	1/4*A = 330 MW* 10-minute spinning reserve is based on the NERC requirement to plan to meet energy reserve requirements, including the deliverability/capability for any single Contingency and the NPCC requirement that reserves be distributed to ensure that they can be used without exceeding individual element ratings or transfer limitations. [NERC TOP-002-2.1b; NPCC Reliability Directory No. 5, Section 5.6] DR: ½ 10T Requirement	0	0	0
10-Minute Total Reserves (Static Value Reliability Rule Dynamic Reserves Calculation)	A = 1310 MW 10-minute total reserve is equal to the operating capability loss caused by the most severe contingency under normal transfer conditions. [NYSRC Reliability Rules, Section E] DR: Largest Schedule	1200 MW 10-minute total reserve is based on Reliability Rules that require immediate measures (activation of EAST 10-minute reserves) be applied to bring loadings on an internal NY transfer interface to within limits in 15 minutes. [NYSRC Reliability Rules, Section D] (Energy and Reserves) * Shift Factor <= Single contingency limit	0 (Energy and Reserves) * Shift Factor <= Single contingency limit All SENY Interface lines to LTE for N-1 topology or loss of largest generator in SENY	500 MW 10-minute total reserve is based on Reliability Rules that require a calculated percentage of the NYCA 10-minute total reserve requirement be procured within NYC. [NYSRC Reliability Rules, Section G] During Thunderstorm Alerts, will be reduced to zero. (Energy and Reserves) * Shift Factor <= Single contingency limit	1/10*East = 120* [NERC TOP-002-2.1b; NPCC Reliability Directory No. 5, Section 5.6] (Energy and Reserves) * Shift Factor <= Single contingency limit

https://www.nyiso.com/documents/20142/3694424/Locational-Reserves-Requirements.pdf

https://www.nysrc.org/wp-content/uploads/2023/07/RRC-Manual-V46-final.pdf

Current Reserve Criteria (30 Total)

	NYCA	East	SENY	NYC	LI
30-Minute Total Reserves	2*A = 2620 MW 30-minute total reserve is equal to two times the 10-minute reserve necessary to replace the operating capability loss caused by the most severe contingency under normal transfer conditions. [NYSRC Reliability Rules, Section E] DR: Largest Schedule + 2nd Largest Schedule	1200 MW Hold 30-Minute total reserve to bring loadings on an internal NY transfer interface to within limits in 30 minutes. [NERC TOP-002-2.1b; NPCC Reliability Directory No. 5, Section 5.6] (Energy and Reserves) * Shift Factor <= Two contingency limit	1300-1800 30-minute total reserve is, depending on the hour, based on Reliability Rules that require the ability to restore a transmission circuit loading to Emergency or Normal Transfer Operating Criteria within 30 minutes of the contingency. (Energy and Reserves) * Shift Factor <= Two contingency limit	1000 MW 30-minute total reserve is based on Reliability Rules that require the ability to bring transmission line loadings to Normal Operating Criteria within 30 minutes following a contingency. [NYSRC Reliability Rules, Section C] During Thunderstorm Alerts, will be reduced to zero. (Energy and Reserves) * Shift Factor <= Two contingency limit	270-540 MW [NYSRC Reliability Rules, Section D] (Energy and Reserves) * Shift Factor <= Two contingency limit

Dynamically Modelling Reserve Criteria

	NYCA	East	SENY	NYC	LI
10-Minute Spinning Reserves	DR: ½ Largest Schedule	DR: ½ 10T Requirement	N/A	N/A	N/A
10-Minute Total Reserves	DR: Largest Schedule	(Energy and Reserves) * Shift Factor <= Single contingency limit Central East – VC N-1 Limit	(Energy and Reserves) * Shift Factor <= Single contingency limit All SENY Interface lines to LTE for N-1 topology or loss of largest generator in SENY	(Energy and Reserves) * Shift Factor <= Single contingency limit	(Energy and Reserves) * Shift Factor <= Single contingency limit
30-Minute Total Reserves	DR: Largest Schedule + 2nd Largest Schedule	(Energy and Reserves) * Shift Factor <= Two contingency limit Central East – VC N-2 Limit	(Energy and Reserves) * Shift Factor <= Two contingency limit All SENY Interface lines to LTE for N-2 topology or loss of largest two generators in SENY. All SENY interface lines to LTE for N-1 topology and loss of one generator	(Energy and Reserves) * Shift Factor <= Two contingency limit	(Energy and Reserves) * Shift Factor <= Two contingency limit

Generator Shift Factor Approach: Examples

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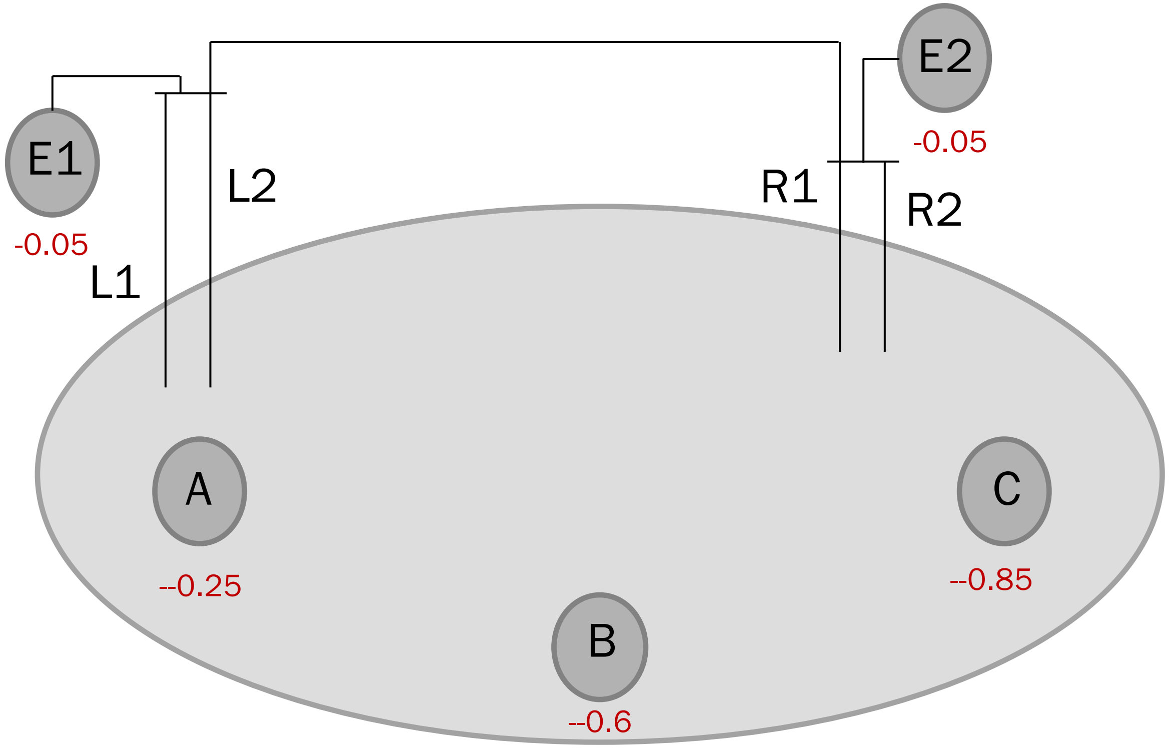
System Overview

- The next set of slides will walk through an example outlining the Generator Shift Factor Approach
- These examples are based on a simplified system representing a reserve area in NYC and assume the following:
  - All Line have ratings of 799/956/1,250 for Normal, LTE, MTE
  - Generators A, B, and C can provide energy and reserves with the shift factors on R1 provided in red



Using Shift Factors To Set Reserve Requirements for Loss of Transmission

- **The binding constraint that we will evaluate is R1 flow for loss of R2, with flow of R1 at 1250**
- **Assuming a unity shift factor of "1" would calculate the reserve requirement based on the amount of MW to get the line below LTE: 1250-956 = 294 MW**
  - This assumes that 1 MW of energy from any generator in the load pocket would provide 1 MW of relief to the constraint
- **Realistically, the average shift factor for deployable resources is around -0.6. Therefore, with an average shift factor of -0.6, the amount of reserves that would need to be scheduled in the load pocket would be (1250-956)/0.6 = 490 MW**
  - This assumes that 1 MW of energy from any generator in the load pocket would provide 0.6 MW of relief to the constraint
- **The Generator Shift Factor Approach would calculate the reserve requirement based on the specific shift factor of that generator to the constraint.**
  - If Generator A has a -0.25 shift factor on R1 due to the transmission topology. The amount of reserves that would need to be scheduled on Generator A would be (1250-956)/0.25 = 1,176 MW
  - Therefore, 1 MW of energy from Generator A would reduce 0.25 MW of flow of R1

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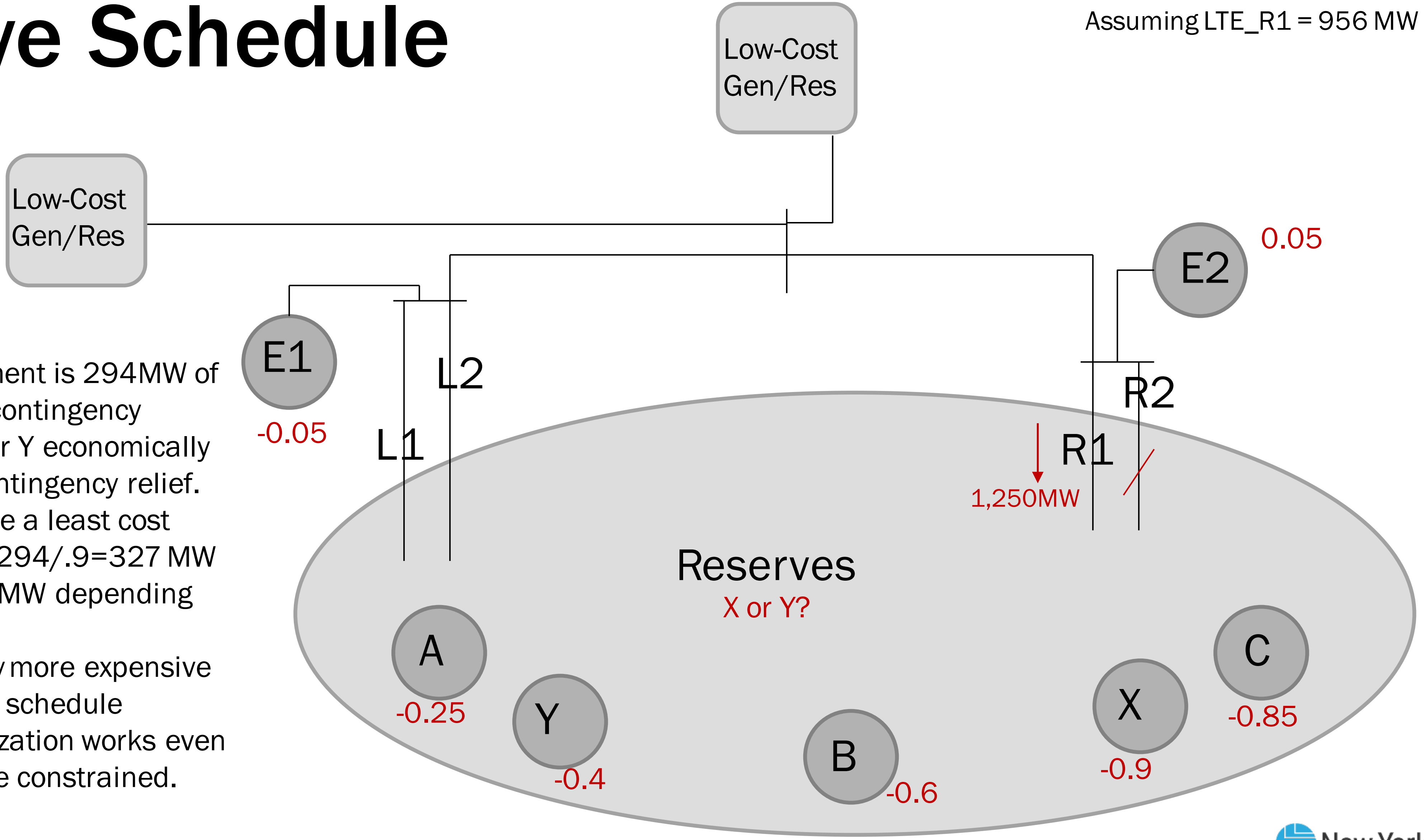
$$\sum(X_{10T} * 0.9 + Y_{10T} * 0.4) \geq 294\ MW\ relief\ on\ R1$$

Assuming LTE_R1 = 956 MW

Reserve Schedule



- Reserve Requirement is 294MW of relief on R1 post contingency
- Let's schedule X or Y economically to provide post contingency relief.
- The value would be a least cost solution between 294/.9=327 MW and 294/.4=735 MW depending on their offers.
- Even if X is slightly more expensive than Y, X will get a schedule
- This Linear optimization works even if L1 or L2 also are constrained.

How Shift Factors Demonstrate Tradeoffs

- **Under Dynamic Reserves, the energy dispatch can reduce the need to buy reserves, considering generation shift factors and the shadow price of the constraint**
- **Assume Generator C's energy output is increased by 1 MW**
  - Generator C has a -0.85 shift factor on R1, so a 1 MW increase in output leads to a 0.85 MW decrease in flow on R1
  - Therefore, 0.85 MW decrease in flow on R1 decreases the reserve requirement by 1.41 MW (0.85 MW/0.6)
- **If the shadow price of reserves is $10, the total savings of 1.41 MW of reserves in the load pocket is $14.41 ($10*1.41 MW)**
  - The 1 MW produced on Generator C needs to now not be produced somewhere else, as determined by the optimization and compared with the $14.41 savings

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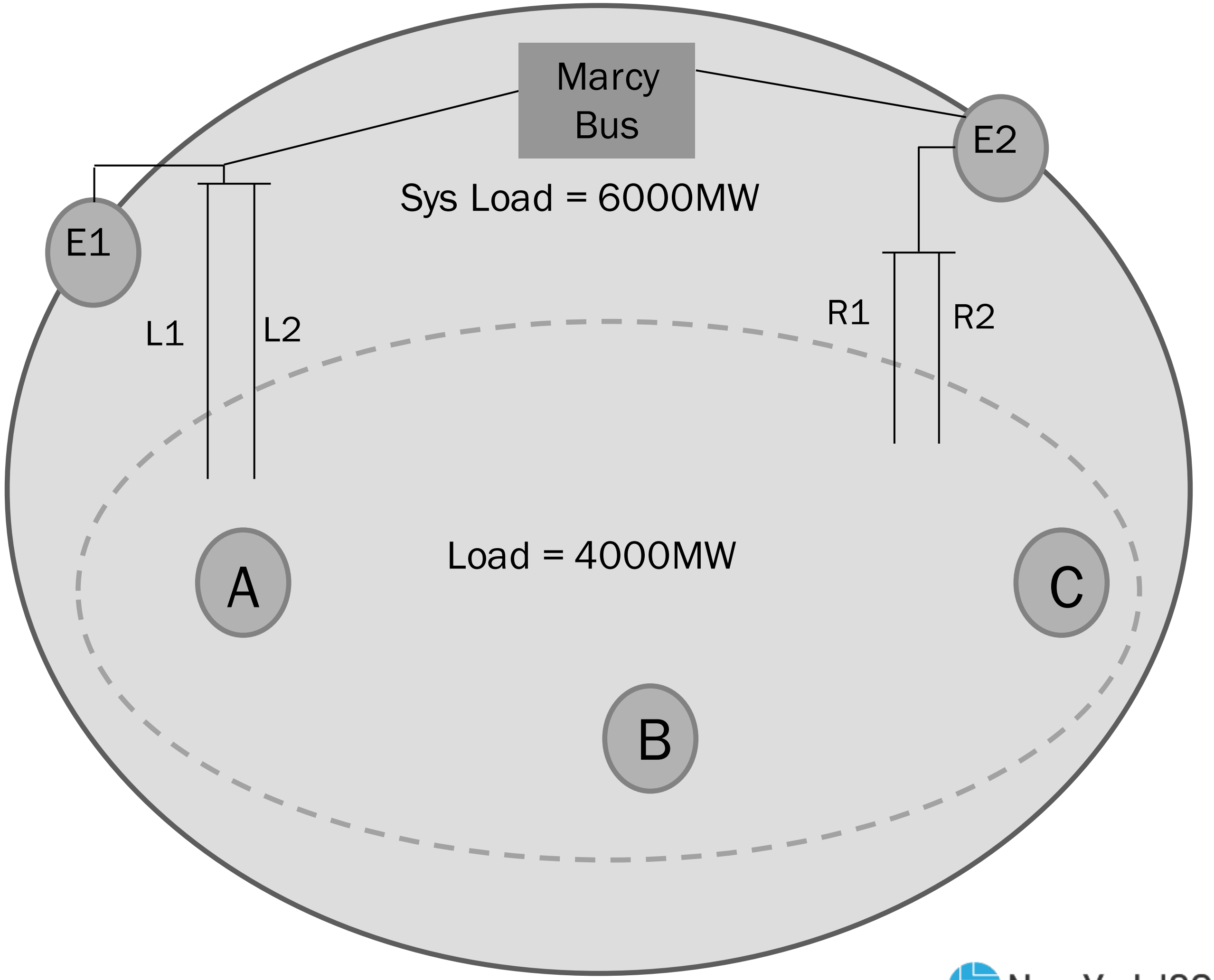
Generator Shift Factor Approach: Proof of Concept Model

Development of a 5-Bus Model

- **NYISO developed a Security Constrained Economic Dispatch (SCED) 5-Bus Model to test the feasibility of the Generator Shift Factor Approach to solve for 10-Minute Reserves (N-1 transmission or generation contingency)**
  - This model is similar to a transmission interface into an existing reserve area (such as NYC, SENY, East, and Long Island)
- **The setup and results of this model are discussed on the following slides**
  - The model co-optimizes energy and reserves using nodal reserve constraints
- **The model supports the concept of using the Generator Shift Factor Approach to solve for reserves dynamically**
  - Demonstrates the pricing and scheduling calculations

Model Setup: System Topology

- The model solves for a system load of 6000 MW with a downstream load of 4000 MW
- The model consists of:
  - 4 transmission lines (2 transmission interfaces with 2 lines each)
  - 3 generators downstream of the transmission interfaces, 2 generators upstream



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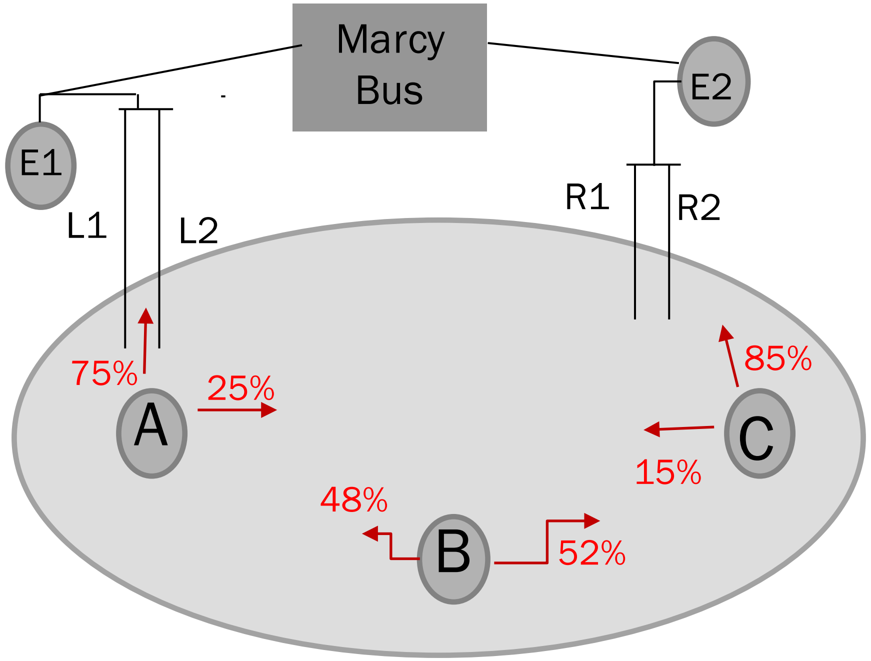
Model Setup: Pre-Contingency Generator Shift Factors

- **The model utilizes the following pre-contingency generator shift factor assumptions:**
  - Downstream generators have high negative shift factors on the transmission lines (i.e., one 1 MW of energy from an internal generator provides a higher amount of relief compared to an external generator)
  - Upstream generators have low negative shift factors or positive shift factors on interface lines
  - Pre-contingency generator shift factors are used to evaluate whether energy schedules violate limits in the base case, and whether energy plus reserve schedules violate limits in the Loss of Generation contingency cases
  - The percent of output from each generator that would flow across each line is shown in red

Pre-contingency Generator Shift Factors

	L1	L2	R1	R2	Sum
A	-0.375	-0.375	-0.125	-0.125	-1
B	-0.24	-0.24	-0.26	-0.26	-1
C	-0.075	-0.075	-0.425	-0.425	-1
E1	0.025	0.025	-0.025	-0.025	0
E2	-0.025	-0.025	0.025	0.025	0



Model Setup: Post-Contingency Generator Shift Factors

- **The model utilizes the following generator shift factor assumptions:**
  - Post-contingency generator shift factors are used for post-contingency flow analysis and Loss of Transmission reserve constraints
    - The table can be read as follows: Generator A has a shift factor of -0.65 on L2 following the Loss of L1 . For example, if L1 was lost, 1 MW of energy on Generator A would provide .65 MW of relief (reduce flows by .65 MW) on L2
  - The table on this slide shows the post-contingency shift factors for Generator A. The post-contingency shift factors for Generators B, C, E1 and E2 are in the Appendix

Generator A Post-Contingency Shift Factors

Loss of L1				
L1	L2	R1	R2	Sum
N/A	-0.65	-0.175	-0.175	-1
Loss of L2				
L1	L2	R1	R2	Sum
-0.65	N/A	-0.175	-0.175	-1
Loss of R1				
L1	L2	R1	R2	Sum
-0.4	-0.4	N/A	-0.2	-1
Loss of R2				
L1	L2	R1	R2	Sum
-0.4	-0.4	-0.2	N/A	-1

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Model Setup: Load Shift Factors

- Load shift factors are also an input into the Dynamic Reserves solution. The load shift factors represent the impact a MW of load has on the reserve constraint. The model utilizes the following load shift factor assumptions:
  - Upstream load: This load is modeled to be located at the Marcy Bus and therefore have a shift factor of 0 on the interface lines.
  - Downstream load: An equal distribution across each line, with a pre-contingency load shift factor .25 for each line, and a post-contingency load shift factor .33 for each line.

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Model Setup: Reserve Constraints

- **Reserve constraints are introduced into the model to represent each potential N-1 contingency only**
- **These constraints require that there be enough reserves to restore flows to the LTE rating within 10 minutes following a generation or transmission contingency**
- **In this model, there are 24 different reserve constraints which are evaluated**
  - For example, the 12 Loss of Transmission constraints includes Loss of L1 on R2, Loss of L1 on R1, and Loss of L1 on L2, etc.
  - For example, the 12 Loss of Generation constraints includes Loss of Generator A on L1, Loss of Generator A on L2, Loss of Generator A on R1, Loss of Generator A on R2 etc.

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Development of Examples

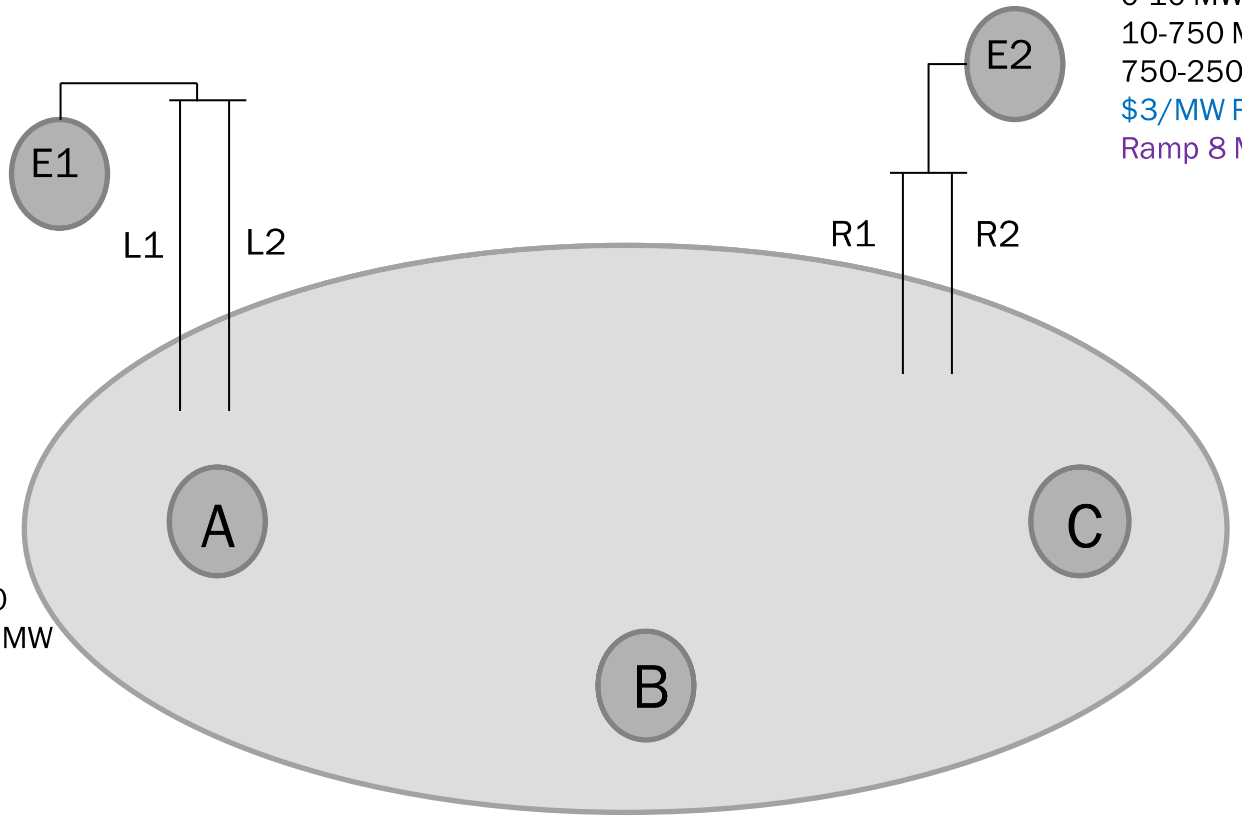
- **NYISO developed 2 examples to demonstrate how a Nodal Reserves Design would solve for reserves**
  - Example 1: Expensive Reserves
    - This example illustrates a scenario in which using the energy redispatch to limit post-contingency flows to LTE is less expensive than procuring reserves.
  - Example 2: Higher Availability of Inexpensive Reserves
    - This example illustrates a scenario in which using the energy redispatch to limit post-contingency flows to LTE is more expensive than procuring reserves.
- **The energy offer curves do not change between the examples. The only generator parameters that change are the reserve offer prices.**
- **In these examples, post-contingency flows for energy scheduling are allowed up to MTE**

Example 1

Example 1 Inputs: Generator Offers and Ramp Rates

0-10 MW @ $5
10-800 MW @ $8
800-2500 @ $9/MW
$2/MW Reserves
Ramp 7 MW/min

0-10 MW @ $10
10-750 MW @ $15
750-2500 @ $21/MW
$3/MW Reserves
Ramp 8 MW/min



0-10 MW @ $10
10-600 MW @ $20
600-1000 @ $22/MW
$8/MW Reserves
Ramp 10 MW/min

0-10 MW @ $20
10-200 MW @ $24
200-300 @ $25/MW
$3/MW Reserves
Ramp 10 MW/min

0-5 MW @ $15
5-500 MW @ $20
500-700 @ $23/MW
$9/MW Reserves
Ramp 10 MW/min

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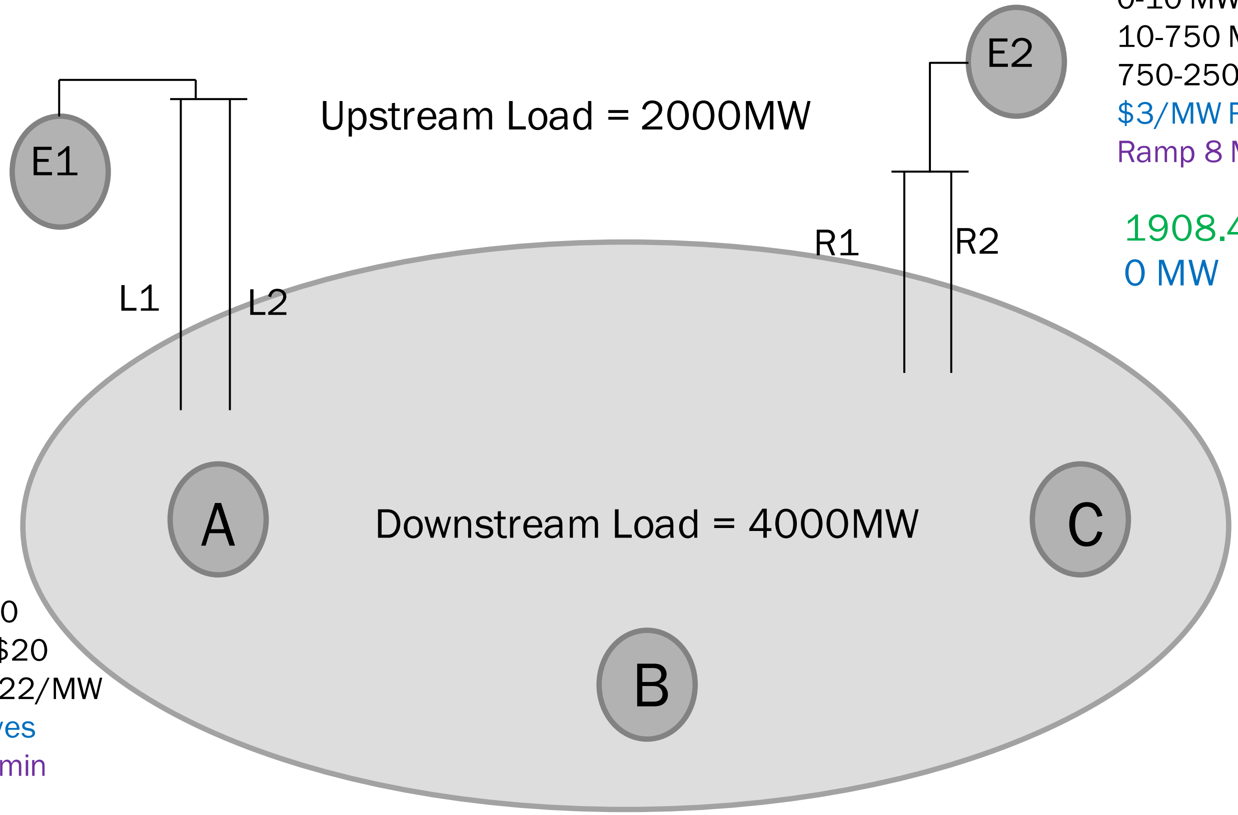
Example 1 Results: Generator Scheduling

0-10 MW @ $5
10-800 MW @ $8
800-2500 @ $9/MW
$2/MW Reserves
Ramp 7 MW/min

2500 MW
0 MW

0-10 MW @ $10
10-750 MW @ $15
750-2500 @ $21/MW
$3/MW Reserves
Ramp 8 MW/min

1908.4 MW
0 MW



0-10 MW@$20
10-200 MW @ $24
200-300 @ $25/MW
$3/MW Reserves
Ramp 10 MW/min

10 MW
0 MW

0-10 MW @ $10
10-600 MW@ $20
600-1000 @ $22/MW
$8/MW Reserves
Ramp 10 MW/min

931.4 MW
0 MW

0-5 MW @ $15
5-500 MW @ $20
500-700 @ $23/MW
$9/MW Reserves
Ramp 10 MW/min

650.2 MW
0 MW

Green values represent Energy Schedules
Blue values represent Reserve Schedules

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Example 1 Results: Solve for Reserve Constraints

- **In Example 1, the reserve procurement is 0 MW**
- **The energy dispatch would avoid flows on transmission lines in excess of the LTE rating by scheduling energy on Generators A, B, and C to reduce post contingency flows at a lower cost than scheduling reserves**
- **The table on the right shows the base case flows and worst-case post-contingency (transmission and generation) flows for each line**
  - The worse-case post-contingency flows are based on the flows from a specific N-1 transmission or generation reserve constraint
  - The yellow highlighted value represents that there was at least one case where flows were scheduled at or above LTE. No contingencies resulted in post-contingency flows over LTE
- **Since the post-contingency flows are at or below LTE, there is no need to hold 10-Minute Reserves in order to reduce post-contingency flows to LTE**
  - Recall that the constraint that is being evaluated is: $\sum Shift\ Factors\ (Gen, Load, and\ Reserves) \leq Line\ Limit$. In this example, the reserves are not needed to keep flows at or below line limits following a contingency.

	L1	L2	R1	R2
Line Ratings (Normal/LTE/MTE)	741/858/ 1083	741/858/ 1083	799/956/ 1249.5	799/979/ 1260.5
Base Flow	508.7	508.7	695.5	695.5
N-1 Transmission Contingency Flow	779.2	779.2	956 Loss of L1	956 Loss of L1
N-1 Generation Contingency Flow	858 Loss of Gen A	858 Loss of Gen A	864.5	864.5

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Example 1 Results: Reserve Constraint Shadow Prices

- **There are two binding reserve constraints with non-zero Shadow Prices:**
  - For the Loss of L1 on R1: $5.18/MW
  - For the Loss of Generator A on L1: $1.46/MW
  - The Nodal Reserve approach could result in non-zero shadow prices for multiple reserve constraints
  - These reserve constraint Shadow Prices will be reflected in the Nodal Generator LBMP as a factor of each generator’s shift factor on the particular constraint
    - This reflects the value of that generator’s energy in relieving the reserve constraint.
    - This is the same way that transmission constraint shadow prices are reflected in the Nodal Generator LBMP
  - These shadow prices would be also be used to calculate the nodal reserve price that would be used to settle reserve schedules
  - For the Loss of Generation constraints, a generator will not receive the reserve shadow price if the binding constraint is caused by the loss of that generator
    - In this example, Generator A does not receive the shadow price for the Loss of Generator A on L1 since it is the Generator A outage contingency causing that shadow price

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Example 1 Results: Generator Energy Pricing

- The Nodal Generator LBMPs would be calculated based on the System Lambda (the marginal cost of meeting load at the Marcy Bus), and the sum of the reserve constraints, with (Generator Shift Factor on each constraint) * (Shadow Price of constraint)
  - Gen A will not get the reserve shadow price for the Loss of Gen constraint as the Loss of Gen A is the binding constraint but will receive the shadow price for the Loss of Transmission constraint
- The nodal generator LBMP makes sense with respect to their energy offers

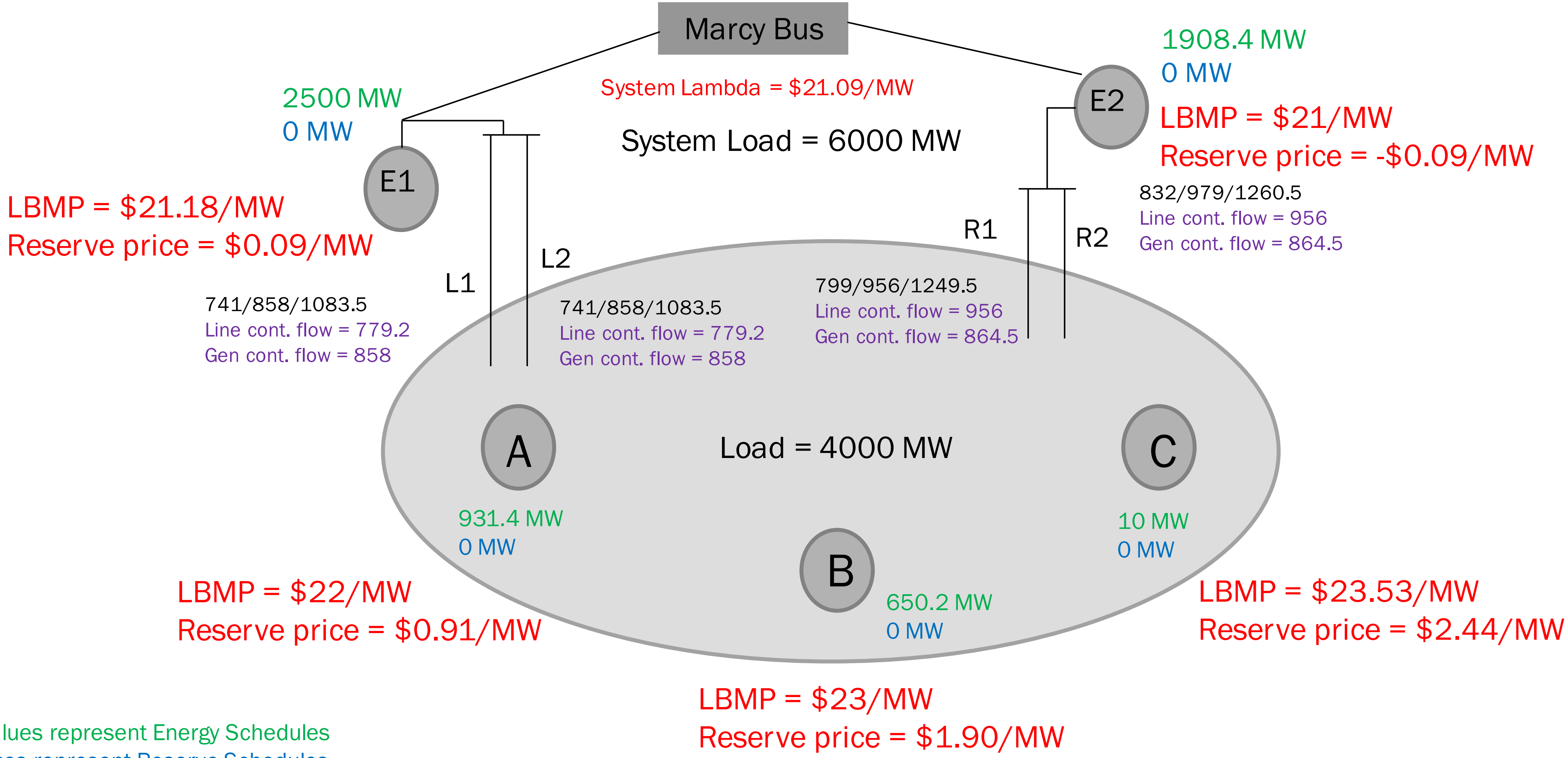
	System Lambda	Shadow Price Loss of L1 on R1	Shift Factor on R1 for Loss of L1	Shadow Price Loss of Generator A on L1	Pre-Contingency Shift Factor on L1	LBMP Formation	LBMP
Generator A	21.09	5.18	-0.175	1.46	N/A	$LBMP_A = 21.09 + 0.175 * 5.18$	$ 22.00
Generator B	21.09	5.18	-0.3	1.46	-0.24	$LBMP_B = 21.09 + 0.3 * 5.18 + .24 * 1.46$	$ 23.00
Generator C	21.09	5.18	-0.45	1.46	-0.075	$LBMP_C = 21.09 + 0.45 * 5.18 + 0.075 * 1.46$	$ 23.53
Generator E1	21.09	5.18	-0.025	1.46	0.025	$LBMP_{E1} = 21.09 + .025 * 5.18 - 0.025 * 1.46$	$ 21.18
Generator E2	21.09	5.18	0.025	1.46	-0.025	$LBMP_{E2} = 21.09 - .025 * 5.18 + 0.025 * 1.46$	$ 21.00

Example 1 Results: Generator Reserve Pricing

- The reserve procurement in this example was 0 MW.
- The energy dispatch would avoid flows on transmission lines in excess of the LTE rating by scheduling energy on Generators A, B, and C to reduce post contingency flows at a lower cost than scheduling reserves
- Calculating the nodal generator reserve price illustrates that the price are below the reserve offers for each generator

	Shadow Price Loss of L1 on R1	Shift Factor on R1 for Loss of L1	Shadow Price Loss of Generator A on L1	Pre-Contingency Shift Factor on L1	Reserve Price Formation	Reserve Price
Generator A	5.18	-0.175	1.46	N/A	$0.175 * 5.18$	$ 0.91
Generator B	5.18	-0.3	1.46	-0.24	$0.3 * 5.18 + .24 * 1.46$	$ 1.90
Generator C	5.18	-0.45	1.46	-0.075	$0.45 * 5.18 + 0.075 * 1.46$	$ 2.44
Generator E1	5.18	-0.025	1.46	0.025	$.025 * 5.18 - 0.025 * 1.46$	$ 0.09
Generator E2	5.18	0.025	1.46	-0.025	$-.025 * 5.18 + 0.025 * 1.46$	-$ 0.09

Example 1: Results



Green values represent Energy Schedules
Blue values represent Reserve Schedules

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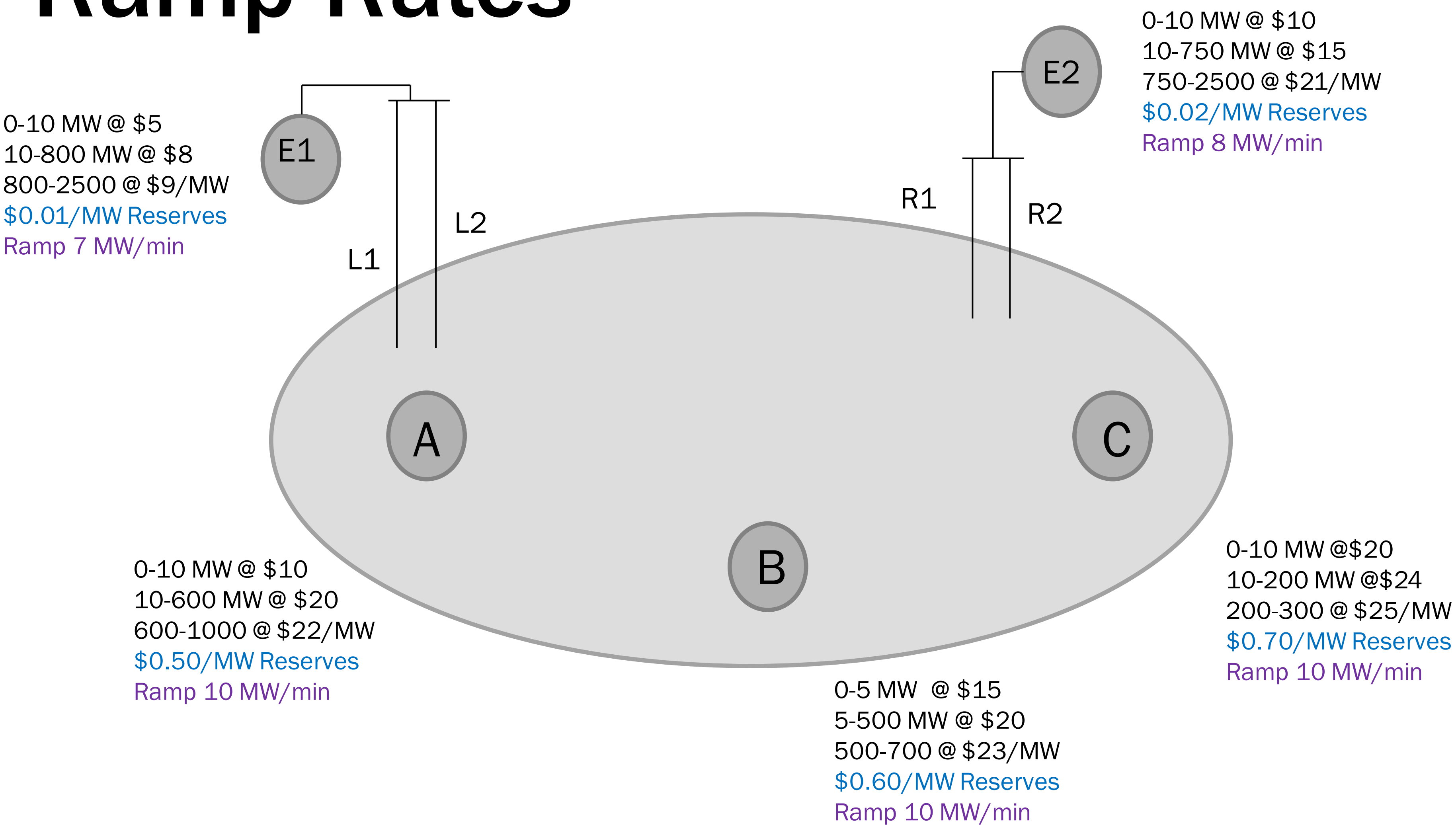
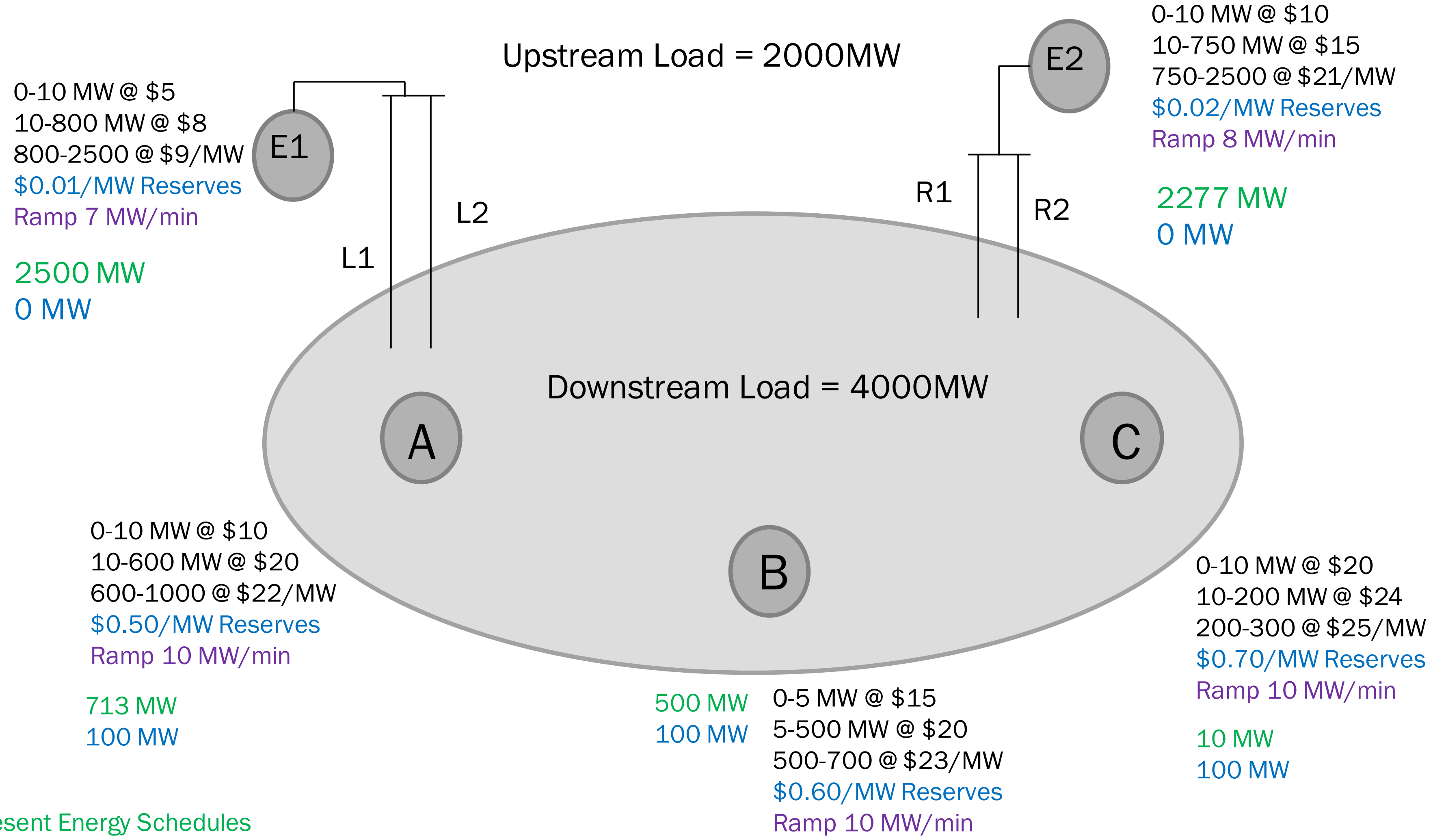
Example 2

Example 2 Inputs: Generator Offers and Ramp Rates



Example 2 Results: Generator Scheduling



Green values represent Energy Schedules
Blue values represent Reserve Schedules

Example 2 Results: Solve for Reserve Constraints

- In Example 2, the reserve procurement is 300 MW
- The table on the right shows the base case flows and worst-case post-contingency (transmission and generation) flows for each line
  - The worse-case post-contingency flows are based on the flows from a specific N-1 transmission or generation reserve constraint
  - The yellow highlighted value represents that there was at least one case where flows were scheduled at or above LTE. No contingencies resulted in post-contingency flows over LTE
- Reserves are held to reduce post-contingency flows to LTE
  - Recall that the constraint that is being evaluated is: $\sum Shift\ Factors\ (Gen, Load, and\ Reserves) \leq Line\ Limit$. In this example, the reserves are needed to keep flows at or below line limits following a contingency

	L1	L2	R1	R2
Line Ratings (Normal/LTE/MTE)	741/858/ 1083	741/858/ 1083	799/956 /1249.5	799/979/ 1260.5
Base Flow	617	617	771	771
N-1 Transmission Contingency Flow	902 Loss of R1	902 Loss of R1	1049 Loss of L2	1049 Loss of L2
N-1 Generation Contingency Flow	885 Loss of Gen A	885 Loss of Gen A	901	901

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Example 2 Results: Reserve Constraint Shadow Prices

- **There is one binding reserve constraint with a non-zero Shadow Price:**
  - For the Loss of L2 on R1: $5/MW
  - These reserve constraint Shadow Prices will be reflected in the Nodal Generator LBMP as a factor of each generator's shift factor on the particular constraint
    - This reflects the value of that generator's energy in relieving the reserve constraint.
    - This is the same way that transmission constraint shadow prices are reflected in the Nodal Generator LBMP
  - These shadow prices would be also be used to calculate the nodal reserve price that would be used to settle reserve schedules

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Example 2 Results: Demonstrating Adequacy of Reserve Procurement

- **In this example, the binding constraint was the Loss of L2 on R1**
  - This was the most limiting constraint
- **This example also showed post-contingency flows on L1, L2, and R2 exceeding LTE**
  - The amount of reserves procured to solve the binding constraint will also ensure that flows on L1, L2, and R2 can be brought below LTE following a contingency
- **Calculating the available relief by each generator based on their reserve schedule and shift factor can be used to illustrate adequate reserve capacity procurement for contingency event**

Transmission Contingency Flow - Binding Flow on R1 for Loss of L2			
	Reserve Schedule (MW)	Shift Factor on R1 for Loss of L2	Available Relief (MW) [Reserve Schedule*Shift Factor]
Generator A	100	-0.175	17.5
Generator B	100	-0.3	30
Generator C	100	-0.45	45
Post-Contingency Flow			1049 MW
Total Available Relief			93 MW
Line Flow Post Reserve Activation [Post-Contingency Flow – Total Available Relief]			956 MW
LTE			956 MW

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Example 2 Results: Demonstrating Adequacy of Reserve Procurement (continued)

Transmission Contingency Flow - Binding Flow on R2 for Loss of L2			
	Reserve Schedule	Shift Factor R2 for Loss of L2	Available Relief [Reserve Schedule*Shift Factor]
Generator A	100	-0.175	17.5
Generator B	100	-0.3	30
Generator C	100	-0.45	45
Post-Contingency Flow			1049
Total Available Relief			93
Line Flow Post-Reserve Activation [Post-Contingency Flow – Total Available Relief]			956
LTE			979

Transmission Contingency Flow - Binding Flow on L1 and L2 for Loss of R1			
	Reserve Schedule	Shift Factor on L1 and L2 for Loss of R1	Available Relief [Reserve Schedule*Shift Factor]
Generator A	100	-0.4	40
Generator B	100	-0.3	30
Generator C	100	-0.125	12.5
Post-Contingency Flow			902
Total Available Relief			83
Line Flow Post-Reserve Activation [Post-Contingency Flow – Total Available Relief]			820
LTE			858

Generation Contingency Flow - Binding Flow on L1 and L2 for Loss of Generator A			
	Reserve Schedule	Pre-Contingency Shift Factor on L1 and L2	Available Relief [Reserve Schedule*Shift Factor]
Generator A	0	N/A	0
Generator B	100	--0.24	24
Generator C	100	--0.075	7.5
Post-Contingency Flow			885
Total Available Relief			32
Line Flow Post-Reserve Activation [Post-Contingency Flow – Total Available Relief]			853
LTE			858

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Example 2 Results: Generator Energy Pricing

- The Nodal Generator LBMPs would be calculated based on the System Lambda, and the sum of the reserve constraints, with (Generator Shift Factor on each constraint) * (Shadow Price of constraint)
- The nodal generator LBMP makes sense with respect to their energy offers

	System Lambda	Shadow Price Loss of L2 on R1	Shift Factor on R1 for Loss of L2	LBMP Formation	LBMP
Generator A	21.13	5	-0.175	$LBMP_A = 21.13 + 0.175 * 5$	$ 22.00
Generator B	21.13	5	-0.3	$LBMP_B = 21.13 + 0.3 * 5$	$ 22.63
Generator C	21.13	5	-0.45	$LBMP_C = 21.13 + 0.45 * 5$	$ 23.38
Generator E1	21.13	5	-0.025	$LBMP_{E1} = 21.13 + .025 * 5$	$ 21.25
Generator E2	21.13	5	0.025	$LBMP_{E2} = 21.13 - .025 * 5$	$ 21.00

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Example 2 Results: Generator Reserve Pricing

- The reserve procurement in this example was 300 MW.
- Calculating the nodal generator reserve price illustrates that scheduling reserves on Generators A, B, and C was economic

	Shadow Price Loss of L2 on R1	Shift Factor on R1 for Loss of L2	Reserve Price Formation	LBMP
Generator A	5	-0.175	$0.175 * 5$	$ 0.88
Generator B	5	-0.3	$0.3 * 5$	$ 1.50
Generator C	5	-0.45	$0.45 * 5$	$ 2.25
Generator E1	5	-0.025	$.025 * 5$	$ 0.13
Generator E2	5	0.025	$-.025 * 5$	- $ 0.13

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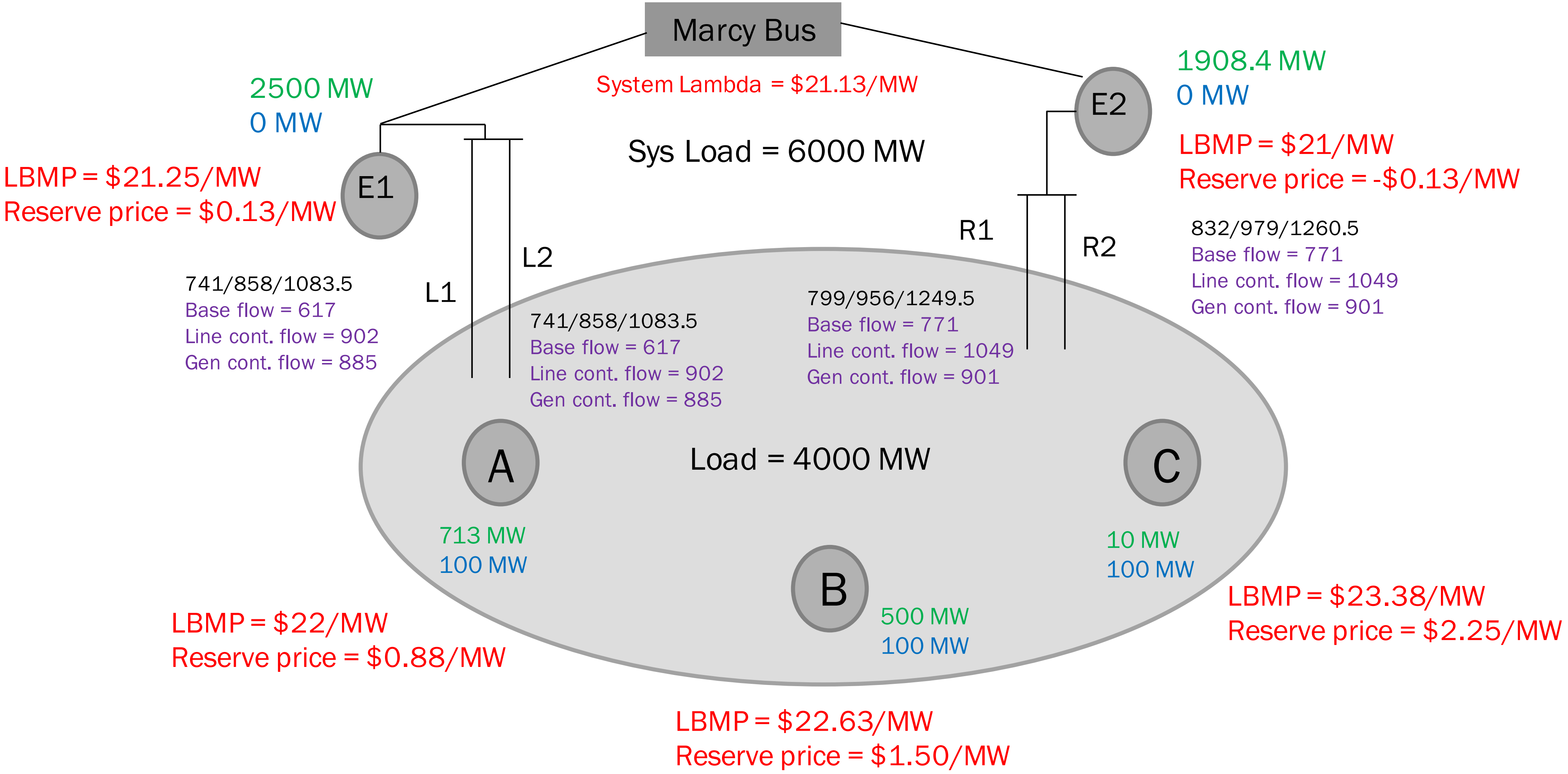
Example 2: Results



Green values represent Energy Schedules
Blue values represent Reserve Schedules

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Energy and Reserve Pricing Under the Generator Shift Factor Approach

Energy and Reserve Pricing Under the Generator Shift Factor Approach

- **As demonstrated in the examples above, the Generator Shift Factor Approach will result in several changes to reserve price formation and generator LBMP formation**
  - Reserve prices will be calculated at nodal level, not zonal
  - Reserve prices at a particular node will reflect the shadow cost of all the reserve constraints that a unit at this node can help provide relief
    - The concept of cascading of reserve shadow prices across reserve areas as it exist today will no longer exist
  - The generator LBMP will include the reserve constraint shadow price in the congestion component
    - This is how transmission congestion is included in generator LBMP today
    - This reflects the value of a generator's energy to provide relief on the reserve constraint

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NYISO’s Reserve Market

- **In addition, these changes will result in fundamental differences to NYISO’s reserve market, compared to the existing market, notably:**
  - There will no longer be defined reserve areas. The reserve areas as defined today provide a locational signal based on specific interfaces across NYCA. The use of a generator’s shift factor is an indication of the locational value of a specific generator to meeting the reserve constraint
  - The reserve constraints that will be defined under Dynamic Reserves will be based on the transmission lines of those key interfaces which factor into reserve area definitions
  - There will no longer be a static reserve requirement for each reserve area, reserves can be held to meet multiple reserve constraints and therefore cannot be quantified as a single reserve requirement
    - The amount of reserves procured in any given location can be interpreted to be the amount of reserves needed to maintain appropriate post-contingency line limits on all transmission lines that we are securing for reserves

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Next Steps

Next Steps

- **The deliverable for 2023 is Market Design Complete**
- **Timeline to completion of MDC**
  - Review market design elements and comments at 9/18/23 MIWG
  - Discuss remaining outstanding market design elements and tariff at September and October MIWGs
  - Present MDC and tariff at November BIC

Questions?

Our Mission & Vision

Mission

Ensure power system reliability and competitive markets for New York in a clean energy future

Vision

Working together with stakeholders to build the cleanest, most reliable electric system in the nation

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Appendix: Post-Contingency Generator Shift Factors

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Model Setup: Post-Contingency Generator Shift Factors for Generator B and Generator C

Generator B - Loss of L1			
L1	L2	R1	R2
N/A	-0.4	-0.3	-0.3
Loss of L2			
L1	L2	R1	R2
-0.4	N/A	-0.3	-0.3
Loss of R1			
L1	L2	R1	R2
-0.3	-0.3	N/A	-0.4
Loss of R2			
L1	L2	R1	R2
-0.3	-0.3	-0.4	N/A

Generator C - Loss of L1			
L1	L2	R1	R2
N/A	-0.1	-0.45	-0.45
Loss of L2			
L1	L2	R1	R2
-0.1	N/A	-0.45	-0.45
Loss of R1			
L1	L2	R1	R2
-0.125	-0.125	N/A	-0.75
Loss of R2			
L1	L2	R1	R2
-0.125	-0.125	-0.75	N/A

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Model Setup: Post-Contingency Generator Shift Factors for E1 and E2

Generator E1 - Loss of L1			
L1	L2	R1	R2
N/A	0.05	-0.025	-0.025
Loss of L2			
L1	L2	R1	R2
0.05	N/A	-0.025	-0.025
Loss of R1			
L1	L2	R1	R2
0.025	0.025	N/A	-0.05
Loss of R2			
L1	L2	R1	R2
0.025	0.025	-0.05	N/A

Generator E2 - Loss of L1			
L1	L2	R1	R2
N/A	-0.05	0.025	0.025
Loss of L2			
L1	L2	R1	R2
-0.05	N/A	0.025	0.025
Loss of R1			
L1	L2	R1	R2
-0.025	-0.025	N/A	0.05
Loss of R2			
L1	L2	R1	R2
-0.025	-0.025	0.05	N/A