Dynamic Reserves

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Background

Agenda

- Background
- Challenges with Dynamic Reserves MDCP Design
- Discuss nodal reserve market design
  - Generator Shift Factor Approach
- Next Steps

Project Background

- **The concept of Dynamic Reserves was first discussed in the 2021 Reserve Enhancements for Constrained Areas (RECA) study**
  - That initiative determined that the current static modeling of reserve regions and their associated requirements may not optimally reflect the varying needs of the grid to respond to changes in system conditions, such as consideration of the following:
    - Scheduling economic energy above 1,310 MW from individual suppliers when sufficient reserves are available, and/or
    - Shifting reserve procurements to lower-cost regions when sufficient transmission capability exists
- **The RECA study concluded that dynamically setting operating reserves requirements based on the single largest contingency system wide and using available transmission headroom was a feasible concept**
  - To dynamically set these requirements, the RECA study proposed formulations that were also considered during the 2022 Market Design Concept Proposed

Past Milestones

- **On 12/6/2022, the NYISO presented its Market Design Concept Proposal**
  - This proposal continued to explore and build upon the formulations from the RECA study; the fundamental formulations had not changed since first introduced during the RECA study
- **In early 2023, the NYISO kicked off the 2023 Market Design Complete phase of the project and identified several components that would be addressed to achieve Market Design Complete**
  - One of the topics for discussion was the setting of the reserve requirements, which included the determination of the interface topology and interface limits

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Current Progress

- **The NYISO identified several challenges to implementing the methodology introduced during the MDCP phase, and has identified an alternative method for determining dynamic reserve requirements, a “Generator Shift Factor Approach”**
  - Today’s presentation will outline the challenges identified and a qualitative description of the proposed approach
  - NYISO will present numerical examples to demonstrate this approach at the 9/14/23 MIWG

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Improvements upon Dynamic Reserves MDCP Design

Identified Challenges with MDCP Design

- **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 concept proposed in 2022 accounts for flows and available transmission capability across the NYISO's reserve area interfaces (*i.e.*, East, SENY, NYC, and LI) to deliver reserves
- **As this effort progressed, two key challenges were observed:**
  - How to accurately determine the interface limits and headroom
  - Ensuring that the new tradeoffs between energy and reserves don't compromise the reliability needs and send the proper pricing signals

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Identified Challenges with MDCP Design (continued)

- **The 2022 MDCP approach proposed to develop interface limits based on post-contingency thermal limits for the individual transmission lines that make up the defined interface**
  - These limits would be set by offline studies, to align with NPCC, NYSRC and Normal Operating Criteria requirements
  - These limits would be evaluated against net flow (load – gen) to determine the MW at risk following a contingency and to set the reserve requirement
- **As this effort progressed, several key assumptions were observed (continued on next slide):**
  - This approach assumes a unified shift factor across generation, for reserves
    - This assumes that generation dispatched at any physical location across the reserve area will provide the same post-contingency relief.
    - In actual operating conditions, each generator has a specific shift factor to each constraint. This determines the actual relief on a constraint that 1 MW from a resource can provide

Identified Challenges with MDCP Design (continued)

- **As this effort progressed, several key assumptions were observed:**
  - This approach assumes that all lines across the interface can be fully utilized, ignoring distribution factors between transmission lines
    - In practice, power does not flow evenly across all elements in a closed interface
  - The MDCP model required an alternative method for flow and headroom calculations for EAST requirements using a ratio share of Central East – VC to Total East flows
    - The East requirement is defined as the more limiting of an open interface voltage collapse limit or the closed interface total east.
    - The 2022 MDCP approach for determining transmission limits in the nested reserve areas is based a pipe and bubble model which posed challenges for the open interface

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Identified Challenges with MDCP Design (continued)

- **Based on the assumptions above, NYISO determined that:**
  - The transmission limits would likely need to be conservative (*i.e.*, more restrictive), which limits the effectiveness of Dynamic Reserves (example to follow)
  - The East constraints would need to be defined by an alternative methodology that considers voltage constraints and the non-symmetry of power flow across an open interface
- **These observations led the NYISO to revisit other options to solve for the reserve requirements**
- **The NYISO has identified an alternative method for determining dynamic reserve requirements, a "Generator Shift Factor Approach"**

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Examples for MDCP Challenges

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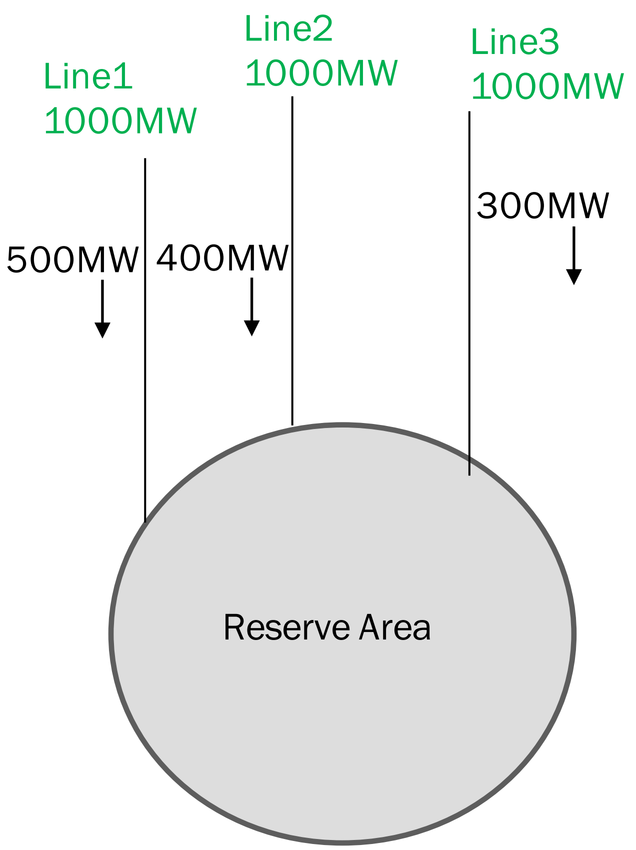
Interface Limit calculation

- **Assume a Reserve Area Interface comprising of 3 lines, each with limit of 1000MW**
- **N-1 Interface Limit & Import Capability Calculation**
  - What is (N-1) Interface Limit and Import capability
    - Depends upon line flows, distribution factors and other variables
  - Assume we lose Line 1, and the flows are not equally distributed across Line 2 and 3:
    - Assume 80% moves to Line 2, its new flow is 800MW
    - Assume 20% moves to Line 3, its new flow is 400MW
  - (N-1) limit calculations should account for these distributions and limitations of the uneven loading of lines
  - With only 200MW of headroom left on Line 2, how much more can the interface import?
    - Depends on many variables



Energy Reserves Tradeoff Examples

- **The MDCP design utilized a closed interface pipe and bubble model that calculated flow on an interface as the difference between load and gen. (*e.g.*, Load – Gen = Flow)**
- **The MDCP design would allow any unit within the Reserve area to trade 1MW of energy for 1MW of reserves.**
  - An incremental MW of energy from a unit with the Reserve Area would have resulted in one less MW of flow on the interface and therefore increased headroom and decreased reserve requirement by a MW
- **This "A MW for a MW" concept could result in under procurement of reserves, as demonstrated in subsequent slides**

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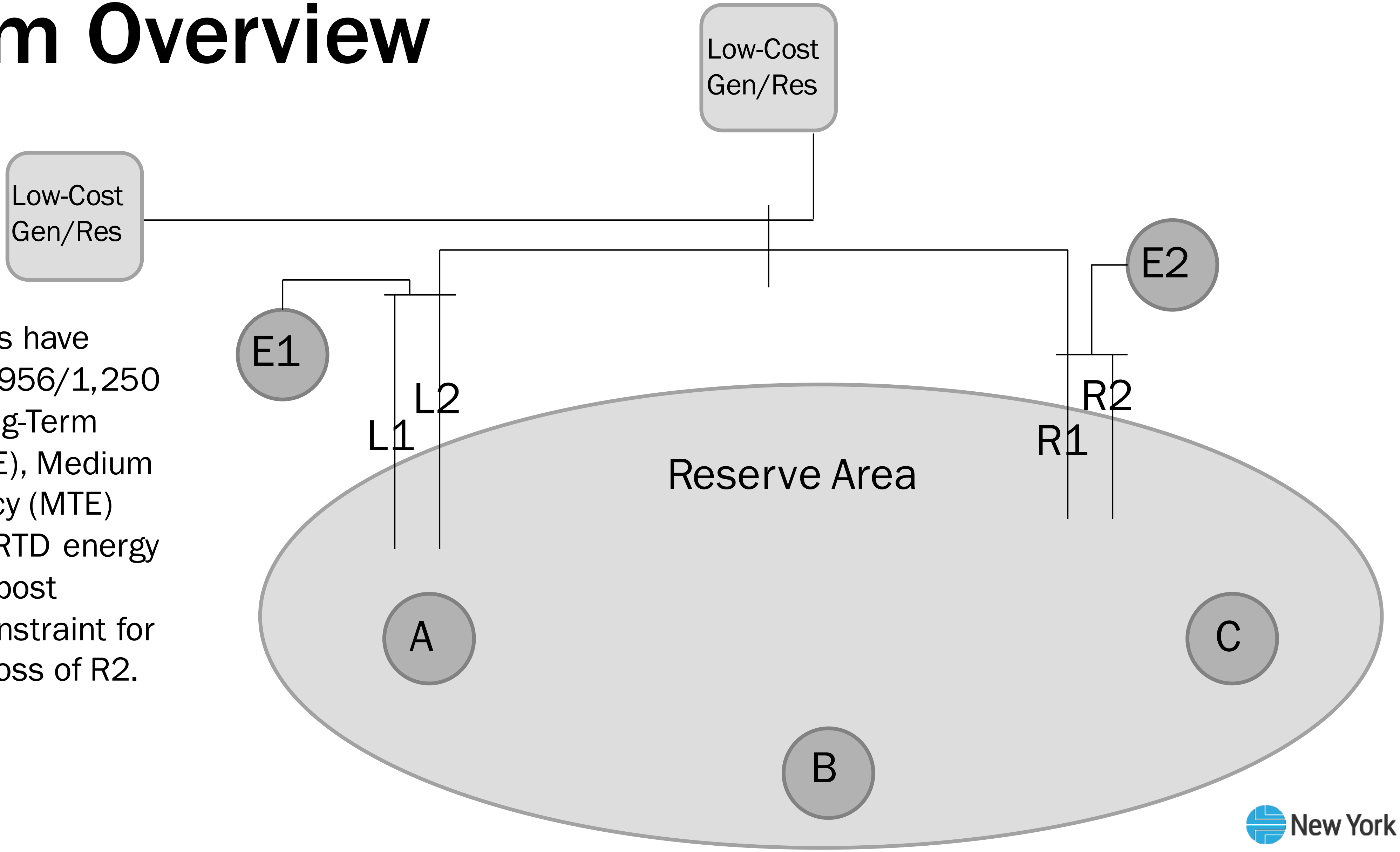
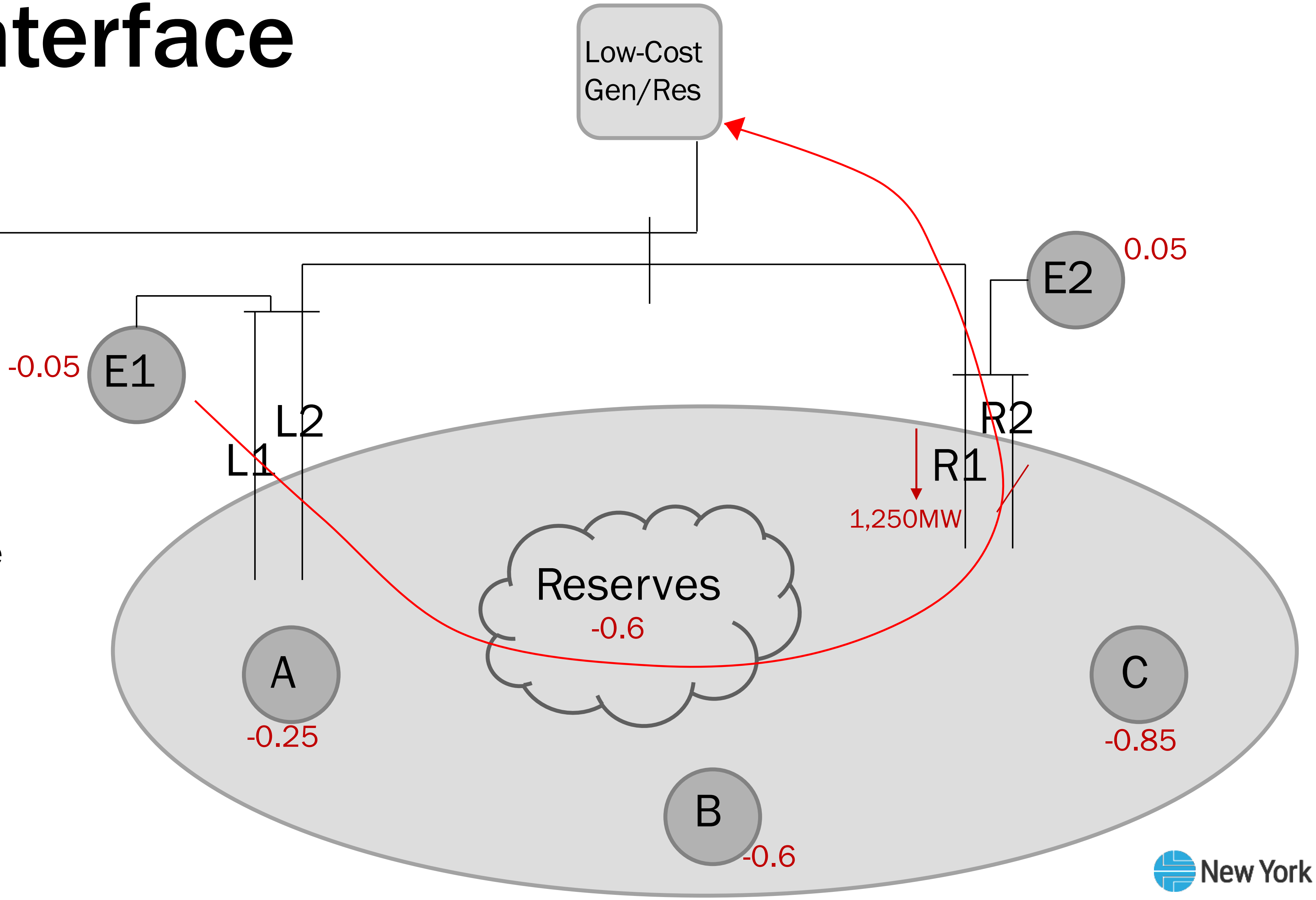
System Overview

- Assume all lines have ratings of 799/956/1,250 for Normal, Long-Term Emergency (LTE), Medium Term Emergency (MTE)
- Binding SCUC/RTD energy constraint is a post contingency constraint for R1 at MTE for loss of R2.



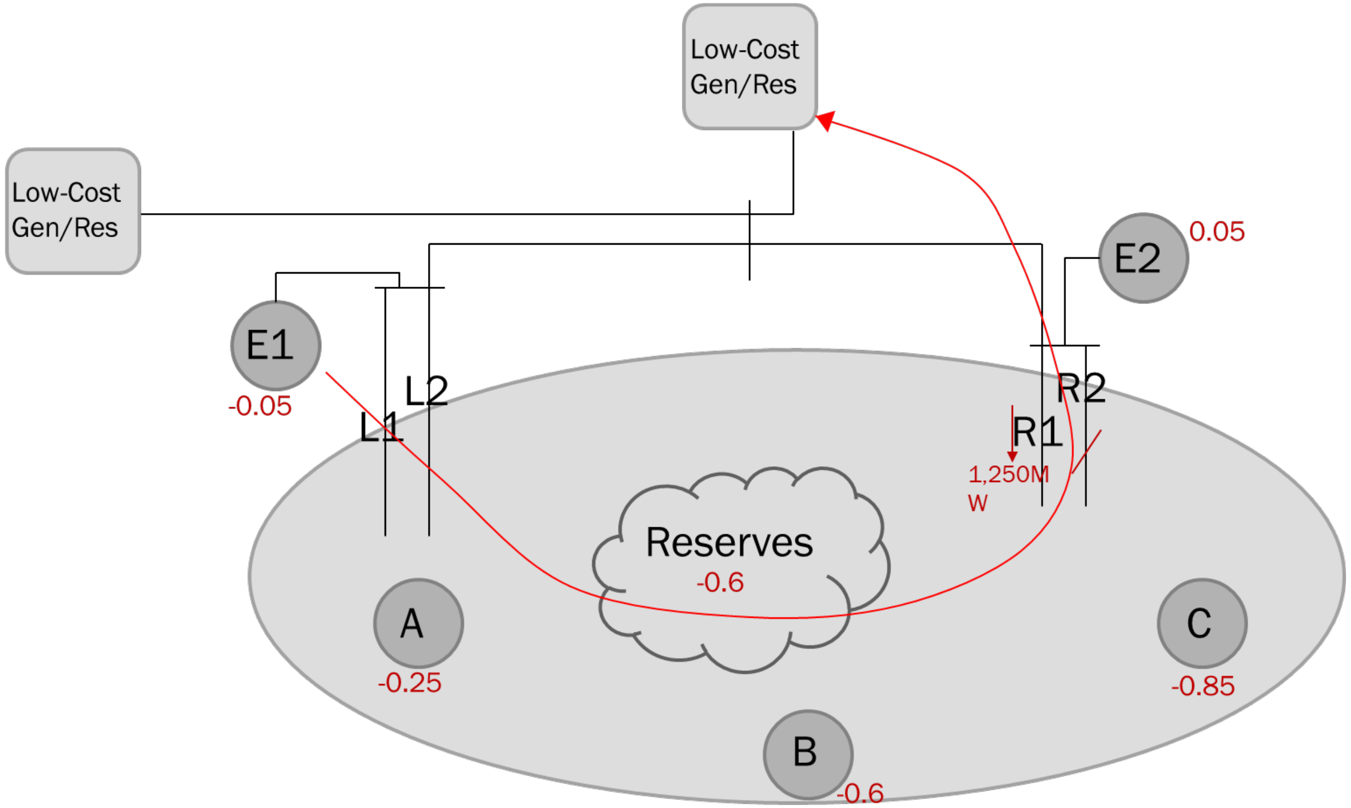
Binding Interface

- Reserve requirement is 490MW to restore interface to LTE
  - (1250-956)/0.6
- Reserve Shift Factor is the average shift factor of deployable resources in the Reserve Area and represents their ability to reduce flows on R1



A MW for a MW

- MDCP design would allow any unit within the Reserve area to trade 1MW of energy for 1MW of reserves. (Load – Gen < Limit)
- It is easy to see that A, which was not helping the R1 transmission constraint, could now dispatch up to solve reserves but not relieve the requirement much.
- Gen A increases 200MW, reducing flow on R1 by 50MW. However, reduction in flow for Reserve calculation is 200 MW
  - Flow = Load – Gen
  - New reserve requirement = 490 – 200 = 290 MW
- But actual requirement is 407MW
  - (1200-956)/0.6 = 407MW



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Generator Shift Factor Approach

Generator Shift Factors for Energy Scheduling

- **Each generator has a shift factor for any defined constraint**
  - Shift factors are determined dynamically for each interval in SCUC, RTC, and RTD
  - Factors considered when calculating a generator's shift factor include system topology, location of the Reference Bus
  - The shift factor measures the change in power flow resulting from the incremental injection of power from a particular generator, *i.e.*, the ability for a generator to effect flows on a line
- **Shift factors are used in energy scheduling to determine if generator injection would aggravate or relieve a constraint**
- **The shadow price for a constraint is the change in as-bid system production cost if the constraint is relaxed by 1 MW**
- **The congestion component of LBMP at each Generator Bus is based on the sum of the constraints, with (Generator Shift Factor on each constraint) * (Shadow Price of constraint)**

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Generator Shift Factors for Reserve Scheduling

- **NYISO investigated whether these individual generator shift factors could be used for reserve scheduling. The benefits of this approach include:**
  - Appropriately modelling the precise number of post-contingency MWs required to relieve transmission constraints
    - This would alleviate the need to provide static, conservative transmission limits and would more accurately model post-contingency conditions based on energy scheduling
  - Appropriately modeling the relief that each individual generator could provide against each constraint, as a generator’s shift factor measures the precise relief that a generator can provide based on current system conditions
    - This would alleviate concerns with uniform shift factors and distribution factors
  - Pricing the locational value of reserves for each generator and its contribution to post contingency congestion relief

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Generator Shift Factors for Reserve Scheduling: Proposed Concept

- **The NYISO would define a group of contingencies that would need to be monitored for post-contingency conditions**
  - For Loss of Transmission, the defined contingencies would ensure that flows across transmission lines are kept under applicable limits post-contingency, considering generator and load shift factors. This would be modeled similarly to how power flow constraints are modeled today.
  - For Loss of Generation, the defined contingencies would ensure that flows across transmission lines are kept under applicable limits following the loss of the generator given its shift factor on a given transmission line.
- **The Generator Shift Factor Approach would align the scheduling processes for energy and reserves**
- **The Generator Shift Factor Approach would allow the optimization to more precisely calculate the tradeoffs between energy and reserves compared to the Unity Shift Factor approach, as well as to more accurately calculate the amount of MW needed to relieve post-contingency flows**

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Foundation for Market Design Concepts

- **Energy scheduling constraints are formulated as follows:**
  - $\sum Shift\ Factors\ * (Gen\ and\ Load\ Schedules) \leq \text{Line Limit}$
    - 'Line Limit' is based on the normal limit for a base case constraints and LTE or MTE limits for a 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 which 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

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 (continued)

- **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

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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

Dynamic Reserves: Next Steps

Next Steps

- **The deliverable for 2023 is Market Design Complete**
- **Timeline to completion of MDC**
  - Discuss examples at 9/14 MIWG
  - Discuss remaining outstanding market design elements and tariff at September and October MIWG
  - Present MDC and tariff at November BIC

Questions?

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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: Preview of Draft Materials for Upcoming Discussions

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Generator Shift Factor Approach: Examples

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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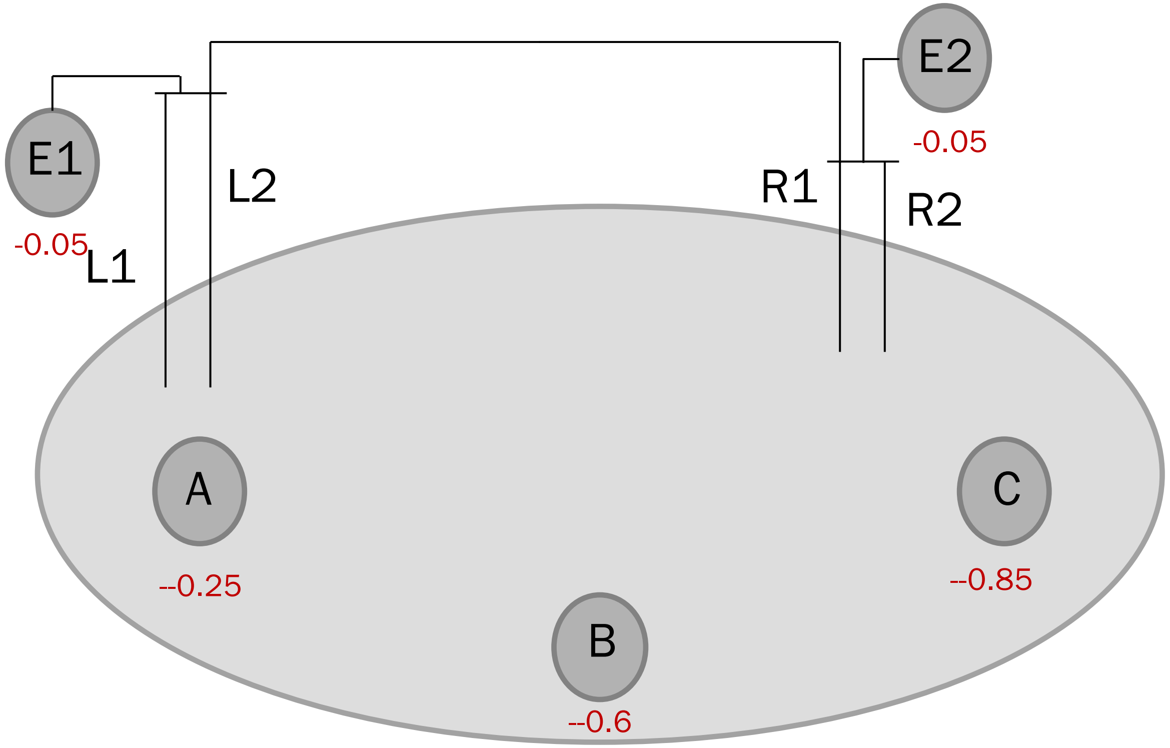
System Overview

- **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



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

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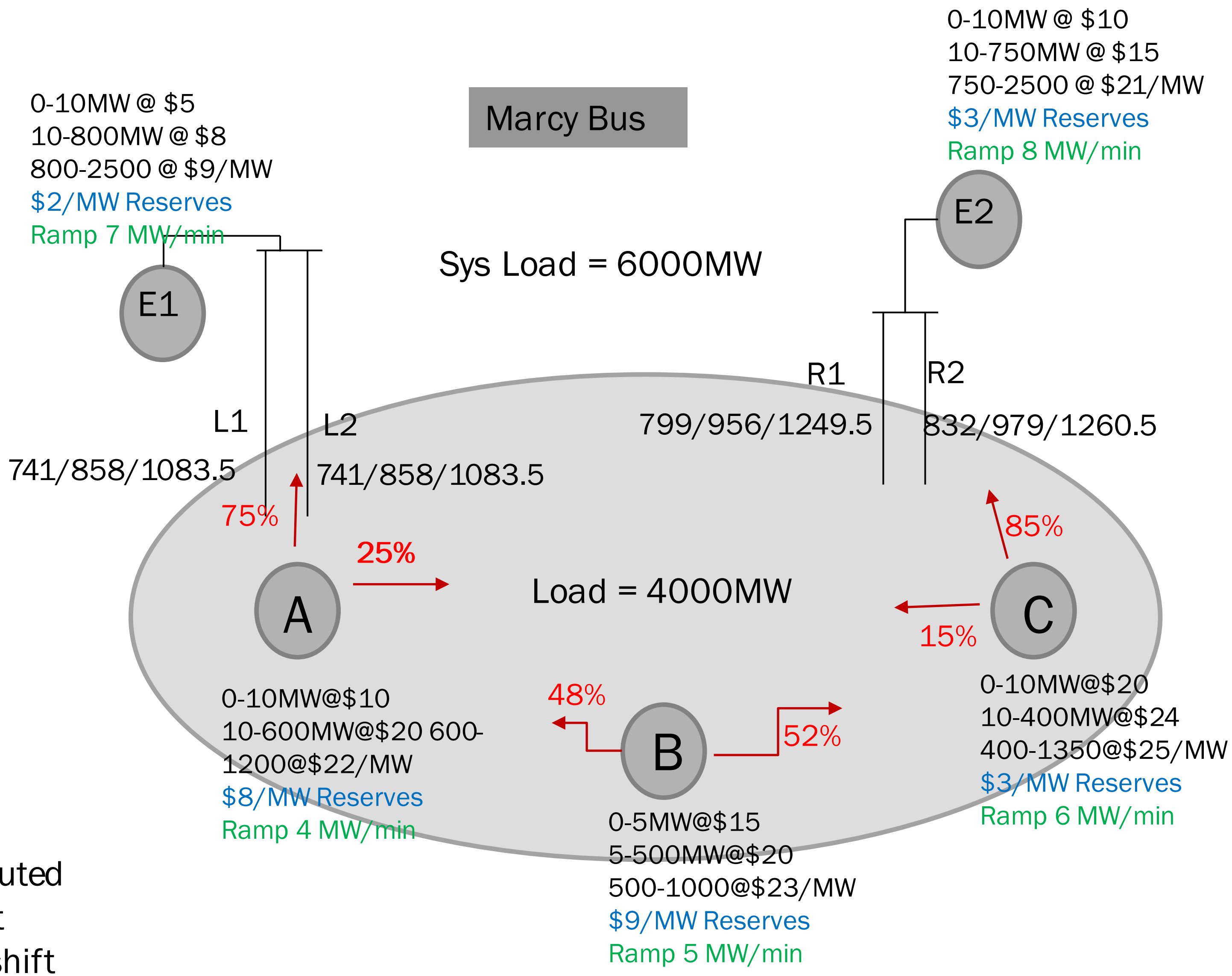
Model Setup

- Inside Gens have high negative shift factor on the interface lines
- Outside Gens have low shift factors on interface lines
- Base case generator shift factor assumption:

	L1/L2	R1/R2
A	-0.375	-0.375
B	-0.24	-0.24
C	-0.075	-0.075
E1	0.025	-0.025
E2	-0.025	0.025

- Load shift factors are assumed to be equally distributed across each line, with the pre-contingency load shift factor .25 for each line, and post-contingency load shift factor .33 for each line.
- Post contingency shift factor assumptions for Gens are listed on next slide

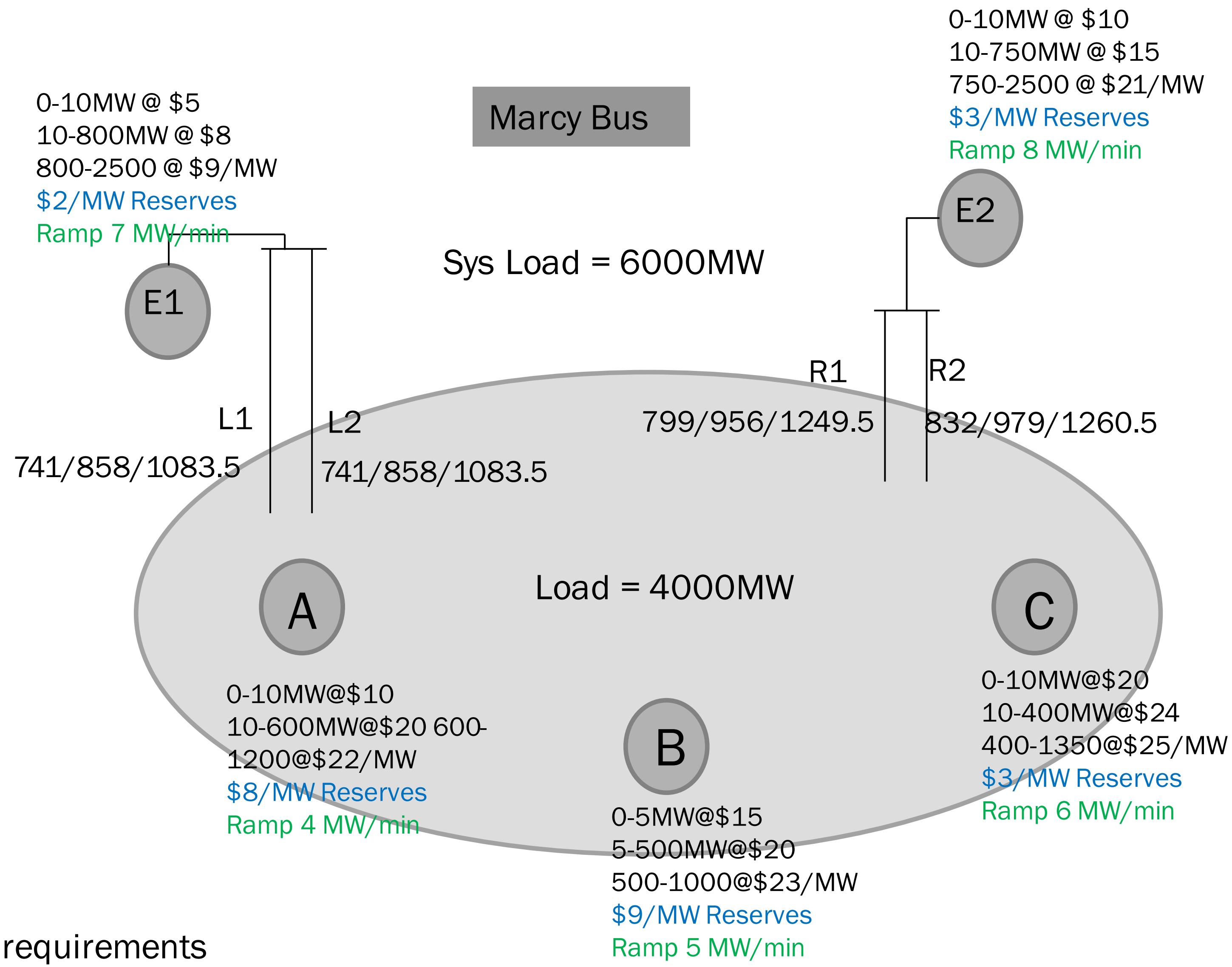


Model Setup (continued)

- Post-contingency case generator shift factor assumption:

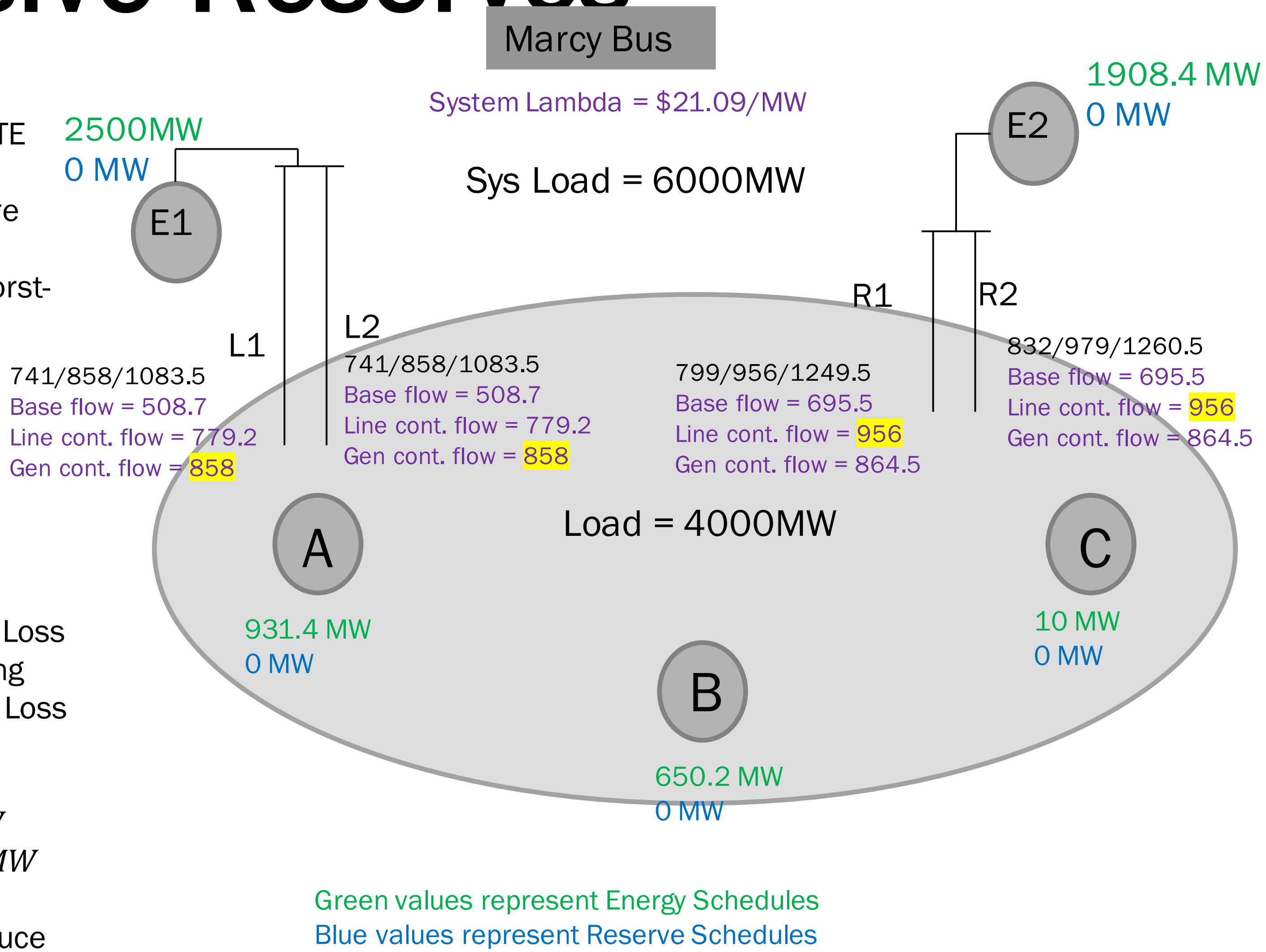
	Loss of L1/L2		Loss of R1/R2	
	L1/L2	R1/R2	L1/L2	R1/R2
A	-0.65	-0.175	-0.4	-0.2
B	-0.4	-0.3	-0.3	-0.4
C	-0.1	-0.45	-0.125	-0.75
E1	0.05	-0.025	0.025	-0.05
E2	-0.05	-0.025	-0.025	0.05

- These examples focus on calculation of local reserve requirements only



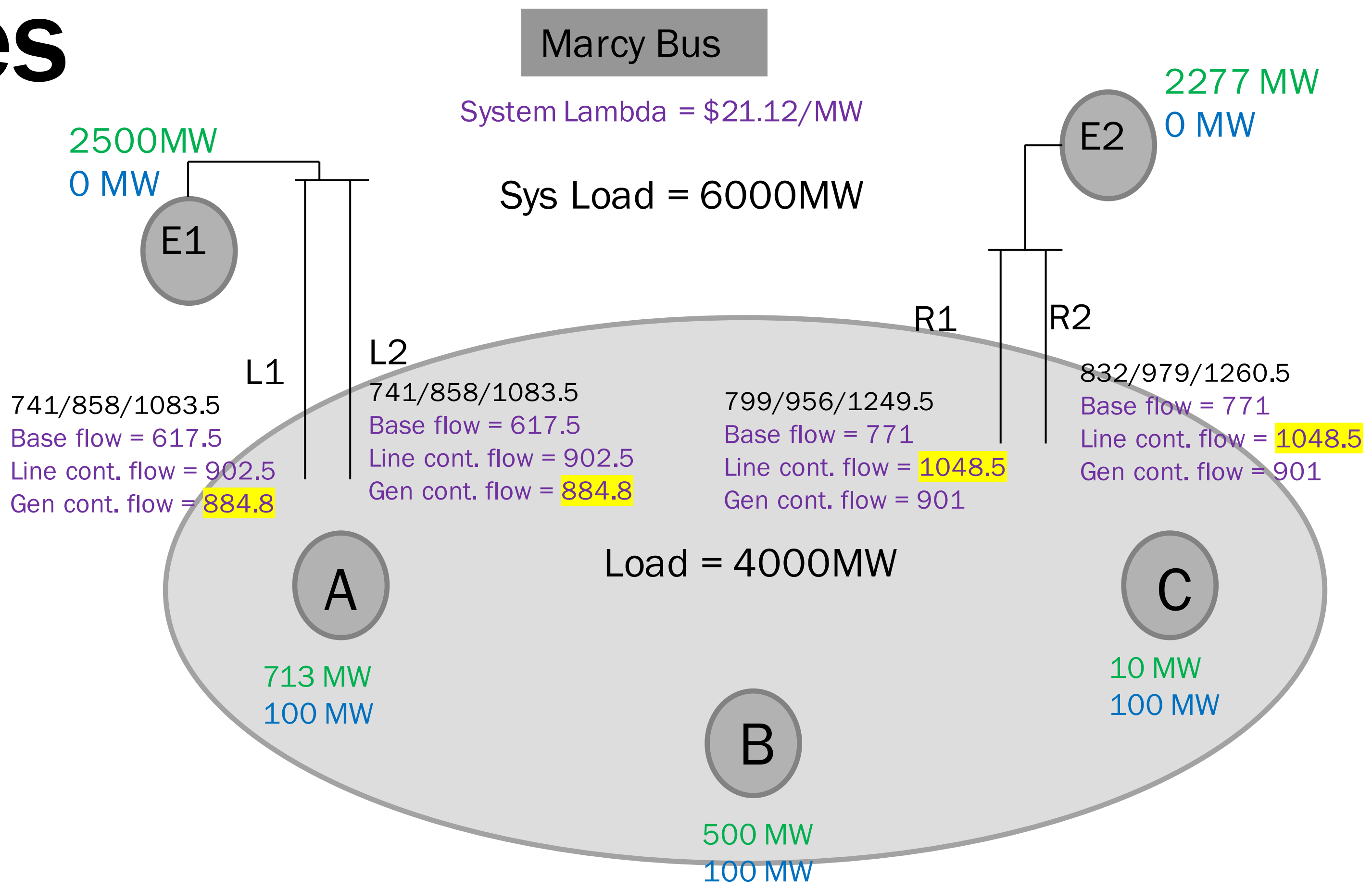
Example 1 : Expensive Reserves

- This example represents NYC, where energy can be scheduled to MTE limits
- No binding transmission constraints since post-contingency flows are below LTE
  - The contingency flows shown for each line represent the worst-case flow across all contingency scenarios
- 10T procurement is 0 MW
  - Reserve Shadow price
    - For Loss L1_R1 = $5.18/MW
    - For Loss_GenA_L1 = $1.46/MW
- Energy prices
  - System Lambda = $20.8/MW
  - $LBMP_A = 21.09 + 0.175 * 5.18 = \$22/MW$
    - 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
  - $LBMP_B = 21.09 + 0.3 * 5.18 + .24 * 1.46 = \$23/MW$
  - $LBMP_C = 21.09 + 0.45 * 5.18 + 0.075 * 1.46 = \$23.5/MW$
  - $LBMP_{E1} = 21.09 + .025 * 5.18 - 0.025 * 1.46 = \$21.18/MW$
  - $LBMP_{E2} = 21.09 - .025 * 5.18 + 0.025 * 1.46 = \$21/MW$
- The reserve requirement is 0 MW because energy redispatch to reduce flow below LTE is less expensive than procuring Reserves
- The LBMP results in all units being made whole



Example 2: Higher availability of Inexpensive reserves

- Reserve bids are reduced to \$0.5/MW; \$0.6/MW, \$0.7/MW, \$0.01/MW, \$0.02/MW for Gens A, B, C, E1, and E2 respectively
- Ramp rates for Gen A, B & C is increased to 10MW/min each
- 10T procurement is 300 MW
    - Reserve Shadow price
        - For Loss L2_R1 = \$5/MW
- Energy prices
    - System Lambda = \$21.12/MW
    - $LBMP_A = 21.12 + 0.175 * 5 = \$22/MW$
    - $LBMP_B = 21.12 + 0.3 * 5 = \$22.6/MW$
    - $LBMP_C = 21.12 + 0.45 * 5 = \$23.4/MW$
    - $LBMP_{E1} = 21.12 + .025 * 5 = \$21.25/MW$
    - $LBMP_{E2} = 21.12 - .025 * 5 = \$21/MW$
- *Reserve prices*
    - $ResPrice_A = .175 * 5 = \$0.87/\text{MW}$
    - $ResPrice_B = .3 * 5 = \$1.5/\text{MW}$
    - $ResPrice_C = .45 * 5 = \$2.25/\text{MW}$
- The LBMP and Reserve prices results in all units being made whole



Green values represent Energy Schedules
Blue values represent Reserve Schedules

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