Survey of Adoption of Dynamic Reserve Practices

ESIG's 2022 Meteorology and Market Design for Grid Services Workshop

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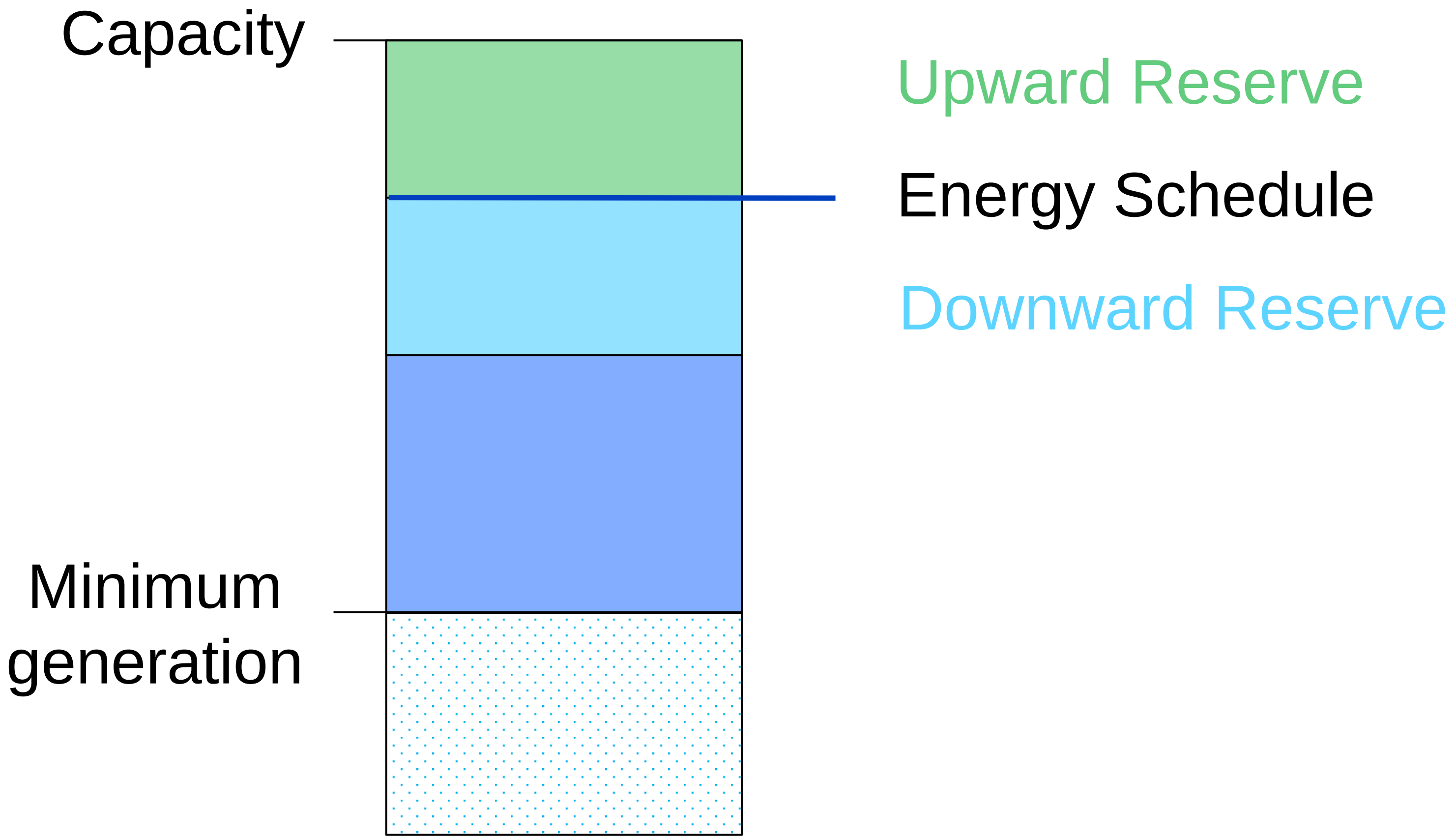
Definitions

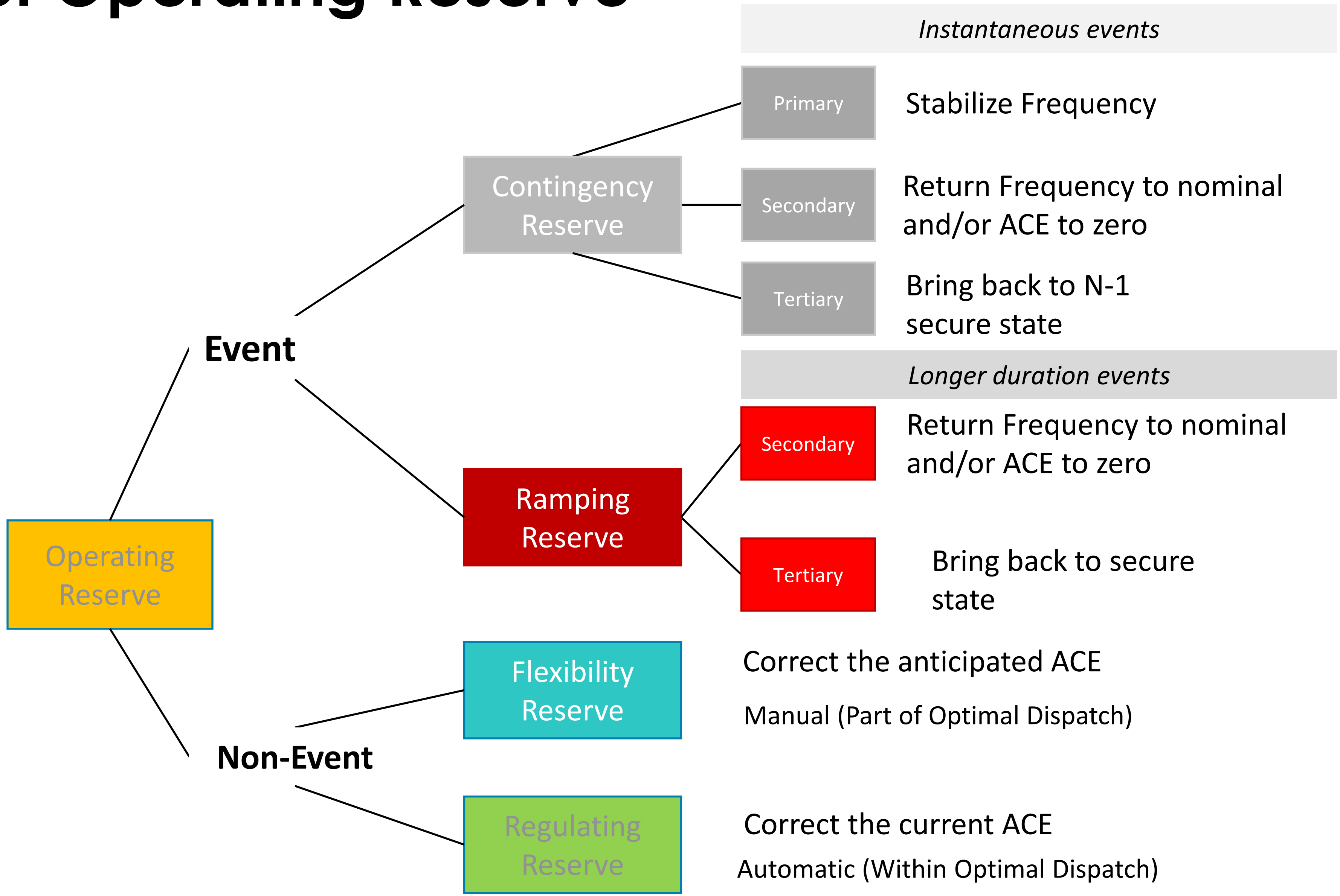
Definition of Operating Reserve

- Operating reserve is the Active Power Capacity that is held above or below expected average energy schedules to respond to changing system conditions under operational time frames.



Source: *Video Tutorial - Illustrating Operating Reserve Needs and Methods: Operational Support Tools to Help Meet Variability and Uncertainty (Version 3.0).* EPRI, Palo Alto, CA: 2019. 3002017371.

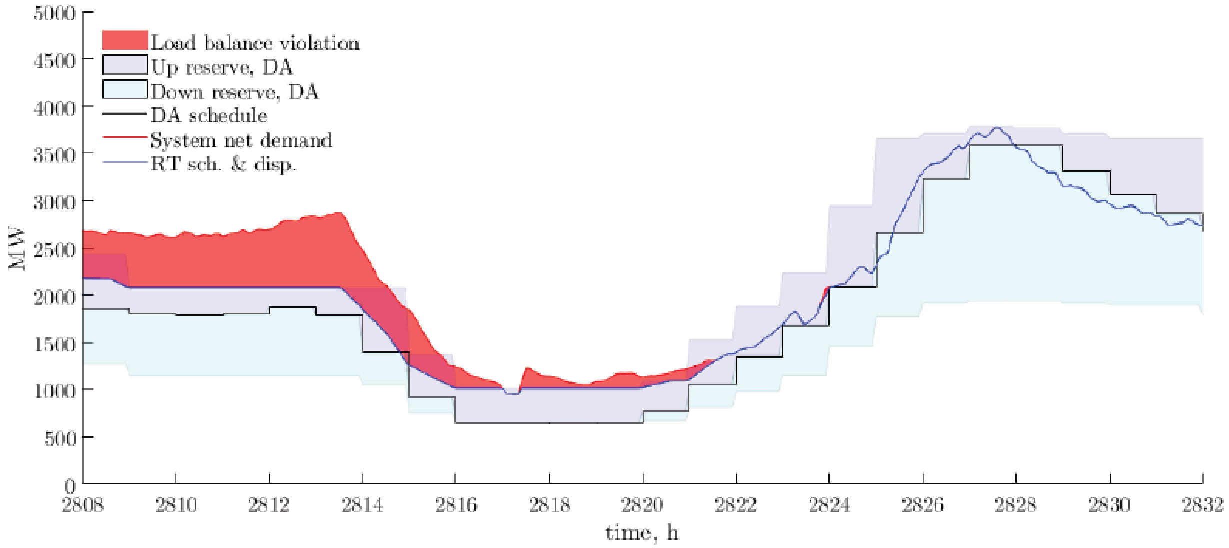
Types of Operating Reserve



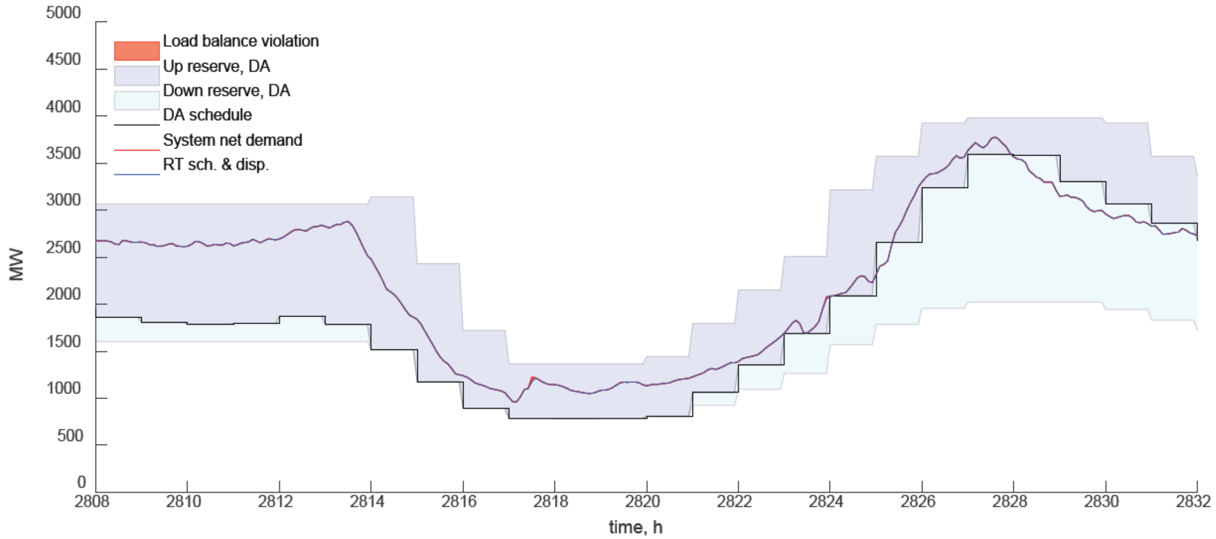
Source: *Video Tutorial - Illustrating Operating Reserve Needs and Methods: Operational Support Tools to Help Meet Variability and Uncertainty (Version 3.0).* EPRI, Palo Alto, CA: 2019. 3002017371.

Definition of Dynamic Reserve Requirement

- Dynamic reserve requirement refers to reserve requirement that change based on system conditions. To the best possible extent, it provides the reserve when needed and reduces the requirement when it is potentially not needed.
- Unlike static reserve (or rule-of-thumb) requirement, dynamic reserve requirement is <u>not fixed</u> and <u>not independent of system conditions</u>.



Static Reserve



Dynamic Reserve

Source: *Probabilistic Dynamic Reserve Determination and Risk Assessment: 2019 Technical Update.* EPRI, Palo Alto, CA: 2019. 3002016312.

Overview of Existing Dynamic Reserve Products

Short-term Ramp Products

MISO's Ramp Capability Product

CAISO's Flexible Ramping Product

SPP's Ramp Capability Product

High-level Comparison of Short-term Ramp Products

	MISO	CAISO	SPP
Product Name	Ramp Capability Product - Up Ramp Capability and Down Ramp Capability	Flexible Ramping Product - Flexible ramping up and flexible ramping down	Ramp Capability Product - Ramp Capability Up and Ramp Capability Down
Time Requirement	10 minutes	15 minutes, 5 minutes	20 minutes
Quantity Requirement Method	Expected variability + 1075 MW	Expected variability + 95th percentile of uncertainty	Net load changes plus TBD percentile of uncertainty
Quantity Requirement	Large range depending on time of day. Up to 2,000 MW for upward ramp capability.	Also varies significantly. Up to about 350 MW for upward ramp capability.	TBD
Included Market or Process	Day-Ahead Market, real-time look ahead commitment, and Real-Time Market	Fifteen Minute Market and Real-Time Dispatch Market	Day-ahead, RUC, and real-time

Note: TBD means to be determined.

Source: *Wholesale Electricity Market Design in North America–Reference Guide: 2021 Review.* EPRI, Palo Alto, CA: 2022. 3002021813.

Long-term Ramp Products

EirGrid's Ramping Margin

MISO's Short-term Reserve

High-level Comparison of Long-term Ramp Products

	EirGrid	MISO	CAISO (Not Effective Yet)	SPP (Not Effective Yet)
Product Name	Ramping Margin – Ramping Margin 1, Ramping Margin 3, and Ramping Margin 8	Short-term Reserve	Imbalance Reserve	Uncertainty Product
Time Requirement	1, 3, and 8 hours	30 minutes	15 minutes but focused on day-ahead	1 hour
Quantity Requirement Method	Expected variability + uncertainty	Dynamically determined offline through loss of generation and flow constraints	Based on forecast differences between Day-Ahead Market and Fifteen Minute Market	Forecasted net obligation change and net obligation forecast error

Source: *Wholesale Electricity Market Design in North America–Reference Guide: 2021 Review.* EPRI, Palo Alto, CA: 2022. 3002021813.

CAISO and SPP's products are not effective yet

Dynamic Contingency Reserves

ISO/RTO	Requirement Definition
ISO-NE	Ten-minute reserve must be greater than or equal to the largest first contingency loss. May add a non-performance factor to increase requirement based on historic performance. (1500 to 1770 MW).
SPP	The minimum contingency reserve is equal to the most severe single contingency in SPP Reserve Sharing Group multiplied by an hourly scaling factor (set to no lower than 1.2 but can be increased in real-time). (around 1500 MW, half spinning).
ERCOT	Requirement is posted for four-hour blocks and is a function of anticipated system inertia, primary frequency response, diurnal load and wind patterns, and average temperature. (2300 MW to 3200 MW, max 60% demand response). Reserve can be increased when anticipated temperature can be greater than 95 Fahrenheit.
CAISO	The minimum requirement is equal to the greater of (1) the single largest contingency (2) the sum of 3% of CAISO hourly integrated load plus 3% of CAISO hourly integrated generation and (3) sum of pre-selected list of PV resources multiplied by percentage value such as 15% and (4) load forecast based requirements. (700 MW to 1100 MW).
AESO	The minimum requirement is equal to the greater of (1) the single largest contingency and (2) the sum of 3% of AESO hourly integrated load plus 3% of AESO hourly integrated generation. Also, may be reduced through reserve sharing group. The most severe single contingency in AESO is currently 466 MW.

Source: *Wholesale Electricity Market Design in North America–Reference Guide: 2021 Review.* EPRI, Palo Alto, CA: 2022. 3002021813.

(Static) Contingency reserve is typically equal to the largest first contingency loss in the system

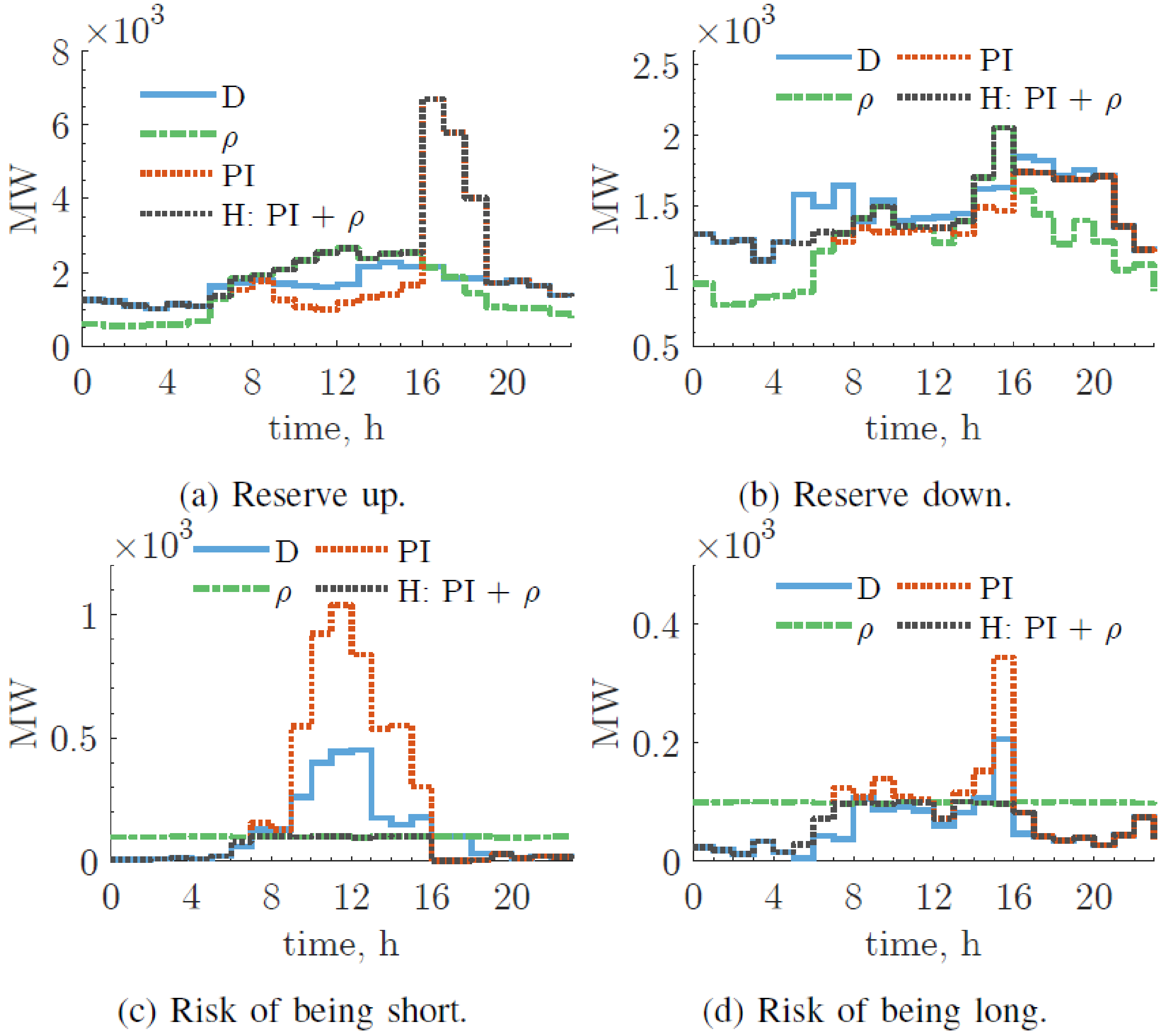
Methods to Determine Dynamic Reserve Requirement

Methods to Determine Dynamic Reserve Requirement

- Using probabilistic forecasts
  a) Recursive approaches
     - Based on historical information on the characteristics of the deviations for different forecasts and operating conditions
     - Probabilistic information (from the anticipated forecast) is compared against the historical deviations to predict the reserve requirements needed to accommodate future deviations
  b) Anticipative approaches
     - Rely more heavily on the shape and properties of the probabilistic forecast
     - Drawback: Information is not compared against any historical equivalent conditions
  c) Hybrid methods
     - Combine the benefits of both the recursive and the anticipative approaches

- Using iterative approach
  - Iteration is done to include risk adjustments accounting for different likelihoods of contingency scenarios

EPRI's CAISO Case Study



(a) Reserve up.
(b) Reserve down.
(c) Risk of being short.
(d) Risk of being long.

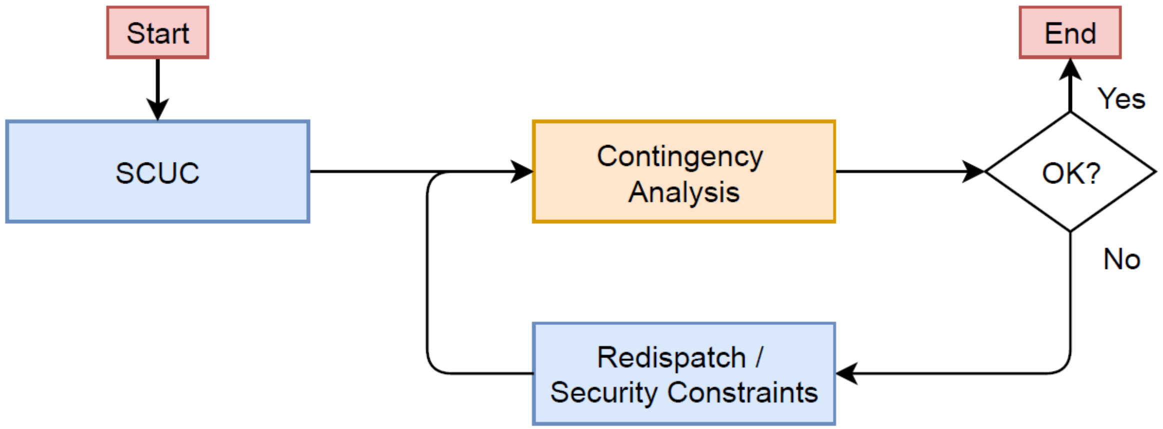
- Hybrid approach outperformed the other approaches.
- It combines the benefits of both the historical and probabilistic forecast information.
- It retains the benefits of the deterministic rules while also attaining the benefits of the probabilistic approaches when these detect potentially risky conditions.

Legend:
D (Deterministic) – Recursive
PI (Prediction Interval) – Anticipative
PI + ρ – Hybrid, where ρ is the risk

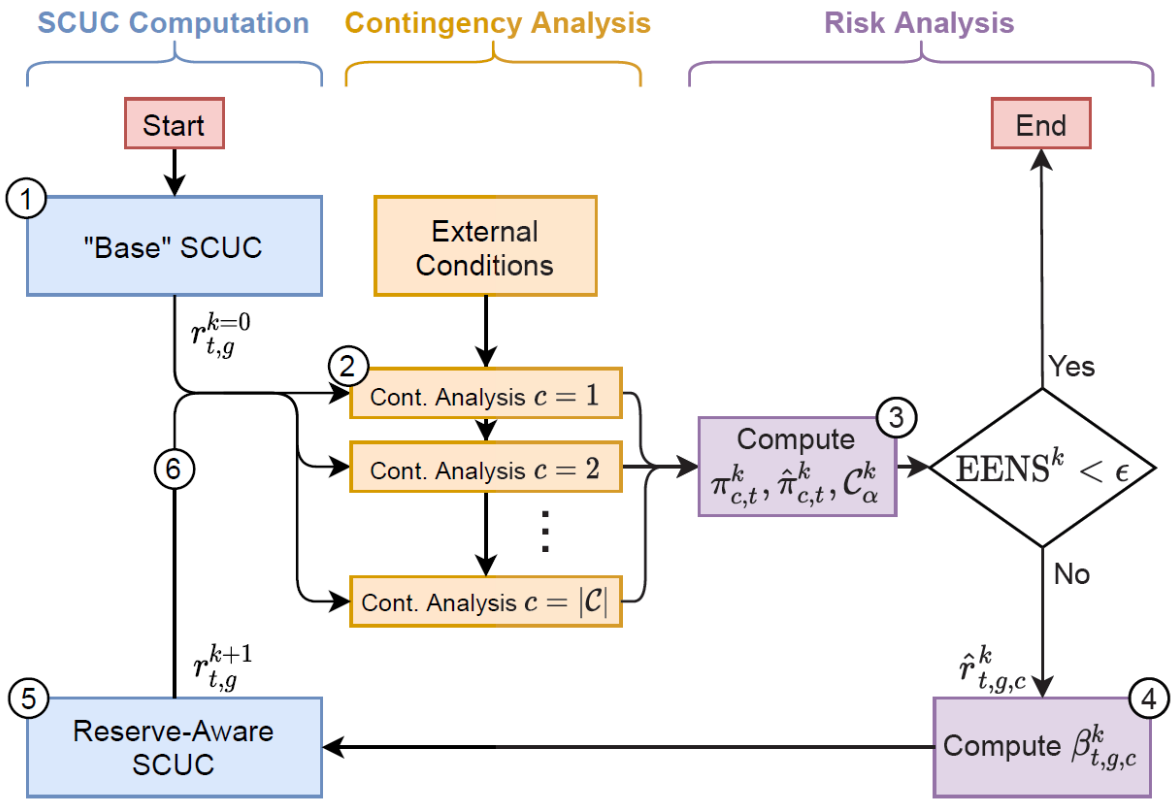
Source: N. Costilla-Enriquez, M. Ortega-Vazquez, A. Tuohy, A. Motley, and R. Webb. 2021. Operating Dynamic Reserve Dimensioning Using Probabilistic Forecasts. https://arxiv.org/pdf/2108.09362.pdf.

EPRI's GLMC Case Study

Flowchart of current practice SCUC with contingency analysis and heuristic corrections



Flow diagram for activation factors training

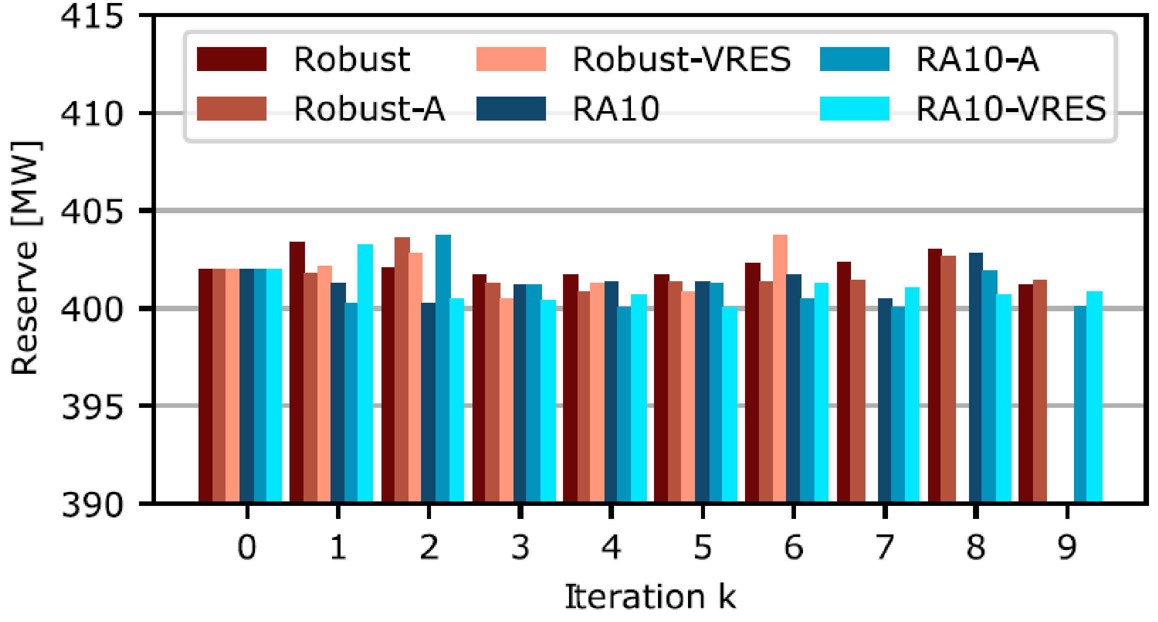


Source: R. Mieth, Y. Dvorkin, and M. Ortega-Vazquez. *Risk-Aware Dimensioning and Procurement of Contingency Reserve.* 2021. https://arxiv.org/abs/2106.00144.

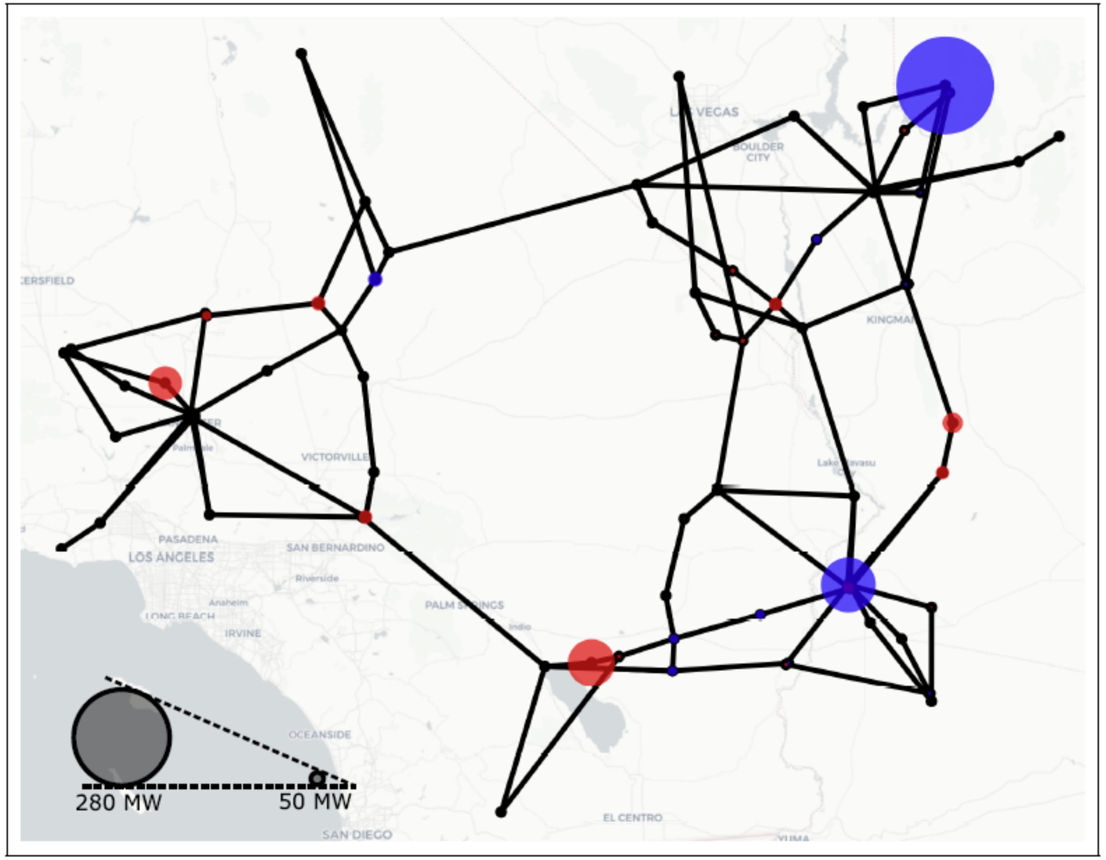
The flow diagram on the right allows risk adjustments to account for different likelihoods of contingency scenarios

EPRI's GMLC Case Study

Total average hourly reserve for all cases and all iterations



Allocation of total average hourly reserve



Source: R. Mieth, Y. Dvorkin, and M. Ortega-Vazquez. *Risk-Aware Dimensioning and Procurement of Contingency Reserve.* 2021. https://arxiv.org/abs/2106.00144.

The above figures illustrate example results across scenarios simulated

Summary

Summary

- Operating reserve is the Active Power Capacity that is held above or below expected average energy schedules to respond to changing system conditions under operational time frames. This can be categorized as event and non-event.
- Dynamic reserve requirement refers to reserve requirement that change based on system conditions.
- Existing dynamic reserve products can be classified into three groups: short-term ramp products, long-term ramp products, and dynamic contingency reserves. Examples are:
  - Short-term ramp products: MISO’s Ramp Capability Product, CAISO’s Flexible Ramping Product and SPP’s Ramp Capability Product
  - Long-term ramp products: EirGrid’s Ramping Margin and MISO’s Short-Term Reserve
  - Dynamic contingency reserves: Requirements vary across ISO/RTOs
- Dynamic reserve requirement can be determined using probabilistic forecasts—recursive, anticipative, and hybrid approach—or iterative approach.
  - Using probabilistic forecasts: EPRI’s CAISO case study indicates the hybrid approach outperformed the other approaches because it combines the benefits of both the historical and probabilistic forecast information.
  - Using iterative approach: EPRI’s GMLC case study demonstrates how dynamic contingency reserves can be estimated using the inclusion of reserve activation factors that are learned over time.

References

1. N. Costilla-Enriquez, M. Ortega-Vazquez, A. Tuohy, A. Motley, and R. Webb. 2021. *Operating Dynamic Reserve Dimensioning Using Probabilistic Forecasts.* https://arxiv.org/pdf/2108.09362.pdf.
2. R. Mieth, Y. Dvorkin, and M. Ortega-Vazquez. *Risk-Aware Dimensioning and Procurement of Contingency Reserve.* 2021. https://arxiv.org/abs/2106.00144.
3. *Probabilistic Dynamic Reserve Determination and Risk Assessment: 2019 Technical Update.* EPRI, Palo Alto, CA: 2019. 3002016312.
4. *Ramping Margin Requirements in Scheduling.* EirGrid and SONI. 22 September 2021. https://www.sem-o.com/documents/general-publications/Ramping_Margin_Requirements_in_Scheduling.pdf.
5. *Short Term Reserve Primer.* MISO. https://cdn.misoenergy.org/STR%20Primer%20202210310530762.pdf.
6. *Video Tutorial - Illustrating Operating Reserve Needs and Methods: Operational Support Tools to Help Meet Variability and Uncertainty (Version 3.0).* EPRI, Palo Alto, CA: 2019. 3002017371.
7. *Wholesale Electricity Market Design in North America–Reference Guide: 2021 Review.* EPRI, Palo Alto, CA: 2022. 3002021813.

Together…Shaping the Future of Energy®

MISO's Ramp Capability Product

- Composed of Up Ramp Capability and Down Ramp Capability products
- Procured in the Day-Ahead (DA) and Real-Time (RT) markets
- Set to manage net load variations and uncertainties ten minutes beyond dispatch target
- System-wide Up and Down Ramp Capability requirements based on two components:
  - Net Load Uncertainty is a calculated value based on load forecast error, wind generation forecast errors and dispatchable resources not following set points.
  - Net Load Change is a calculated value based on load forecast change, wind generation change and Net Scheduled Interchange (NSI) change.

CAISO's Flexible Ramping Product

- Market-based product composed of flexible ramping up (FRU) and flexible ramping down (FRD) capacities
- Procured in the Real-Time Unit Commitment (RTUC), which includes the Fifteen Minute Market (FMM), and the Real-Time Dispatch (RTD) markets
- Reserved from scheduling or dispatch in the current market to address uncertainty that may materialize in real time
- Implemented to address the operational challenges of maintaining power balance in the real-time dispatch and insure against insufficient ramp capability in real time that may result in extreme prices
- The upward and downward requirements determined based on the 2.5 and 97.5 percentiles of the histograms of the net load errors
  - The histograms are based on historical variations from load and variable energy resource forecasts using a rolling data set of the last 40 days.

SPP's Ramp Capability Product

- Consists of Ramp Capability Up and Ramp Capability Down products
- Procured in the Day-Ahead Market and the Real-Time Balancing Market (RTBM), which operates on continuous 5-minute basis
- Implemented to address the uncertainties with increasing variable energy resources and reduce the frequency and the impact of price spikes that can be attributed to ramp deficiencies
- Requirements calculated based on forecasted net load changes and historical net load forecast error over a rolling 20-minute period
  - 20-minute period covers 10 minutes for traditional real-time solution look ahead and an additional 10 minutes for ramp and net load optimization.
  - Requirements are averaged per hour, into a single hourly requirement for Ramp Capability Up and a single hourly requirement for Ramp Capability Down.

EirGrid's Ramping Margin

- Represents the increased megawatt (MW) output that can be delivered by the service horizon time and sustained for the product duration window
- Defined by both the minimum ramp-up and output durations

Category	Delivered Within	Maintained For
Ramping Margin 1 (RM1)	1 Hour	2 Hours
Ramping Margin 3 (RM3)	3 Hours	5 Hours
Ramping Margin 8 (RM8)	8 Hours	8 Hours

- Implemented to maintain a level of dispatchable generation and demand that can ramp to replace renewable generation in the event that it is below forecast
  - Wind and solar (over) forecast error
- Requirement calculated on an on-going basis that feeds into the Long-Term Schedule (LTS) to ensure sufficient ramping margin is scheduled to meet the varying requirements
  - LTS runs every four hours and produces up to 30 hours of unit commitment schedules.

EirGrid's Ramping Margin Formulation

$$RMR_{t(R)} = LSI_{(t+R)} + LFE_{(t+R)} + \max\left(RR_{(t+R)}, Uncert_{t(R)}\right) + Tie_{uncert} - IC\_Cap_{(t+R)}$$

Where

- *t is the scheduling interval*
- *R is the ramping margin category interval, (RM1 (t+1), RM3 (t+3), RM8 (t+8))*
- *$RMR_{t(R)}$ is the Ramping Margin Requirement for interval "t" for ramping margin category interval "R"*
- *$LSI_{(t+R)}$ is the Largest Single Infeed in scheduling interval "t+R"*
- *$LFE_{(t+R)}$ is the Load Forecast Error in scheduling interval "t+R"*
- *$RR_{(t+R)}$ is the Replacement Reserve in scheduling interval "t+R"*
- *Uncert is the variable generation uncertainty forecasted for each reserve category "R" in scheduling interval "t"*
- *Tie_uncert - Tie Line uncertainty flow, default value for each reserve category "R"*
- *$IC\_Cap_{(t+R)}$ is the interconnector capability in scheduling interval "t+R"*

Source: *Ramping Margin Requirements in Scheduling.* EirGrid and SONI. 22 September 2021. https://www.sem-o.com/documents/general-publications/Ramping_Margin_Requirements_in_Scheduling.pdf.

MISO’s Short-term Reserve

- MISO’s new product implemented in 2021
- A 30-minute rampable generation capacity product provided by online or offline resources to be converted to energy within the STR deployment period (30 minutes)
- Co-optimized with energy and ancillary services products
- Separately addresses market-wide, sub-regional and local short-term reserve needs
- Aligns with the Independent Market Monitor (IMM) recommendations to implement a 30-minute product to incorporate Voltage and Local Reliability (VLR) and Regional Dispatch Transfer (RDT) commitments into the market
- Local and sub-regional STR needs (or requirements) determined by using Reserve Procurement Enhancement (RPE) constraints
  - RPE constraints are determined dynamically based on the loss of generation elements and associated change in flow, and the flow limits.
  - The market wide STR requirement will be initially set at 1.5 times the largest generator contingency.