Short-Term Reserve Product in MISO

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Presented at ESIG 2022 Fall Technical Workshop, October 24, 2022

Midcontinent Independent System Operator (MISO) scope of operations

- MISO is an independent, not-for-profit, member-based organization responsible for operating the power grid across 15 U.S. states and the Canadian province of Manitoba.

- MISO's core responsibilities
  - Maintain reliability of bulk electric system
  - Administer Energy and Operating Reserves Market, including a Day-Ahead Market, a Real-Time Market and a Financial Transmission Rights (FTR) market
  - Transmission Expansion Planning
- MISO numbers
  - 189,421 MW market generation capacity
    - Wind in-service: 28,646 MW
    - Solar in-service: 1,872 MW
  - Historic Summer Peak: 127,125 MW
  - Historic Winter Peak: 109,336 MW

MISO's Reserve products and mechanisms address uncertainty

PRODUCT	TIME HORIZON OF UNCERTAINTY TO COVER	UNCERTAINTY ADDRESSED
Regulating Reserve	Seconds (0-5 minutes)	Uncertainty between real-time dispatch and actual load – intended for normal imbalance within 5-minute intervals
Contingency Reserve	10 minutes post-contingency event	Uncertainty caused by contingencies that create significant and immediate imbalances – NERC required recovery in 15 min
Ramp Capability	10-25 minutes	Uncertainty in upcoming interval due to net load uncertainty and contingencies
Short-Term Reserve[1]	Intra-day > 30 minutes, up to 3 hours	Intra-day uncertainty caused by net load uncertainty and contingencies
Post-Reserve Deployment Constraints	Applied to STR	Addresses sub-regional and zonal uncertainty

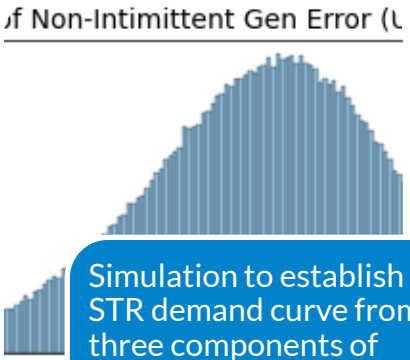
a. Regulating Reserve Requirement is about 400MW
b. Contingency Reserve Requirement is about 2,010MW
c. Short-Term Reserve Requirement (Effective December 7, 2021) varies by season and hour in a day

[1] **Y. Chen, "Addressing Uncertainties Through Improved Reserve Product Design," in IEEE Transactions on Power Systems, 2022**

Short-Term Reserve (STR) Fast Facts

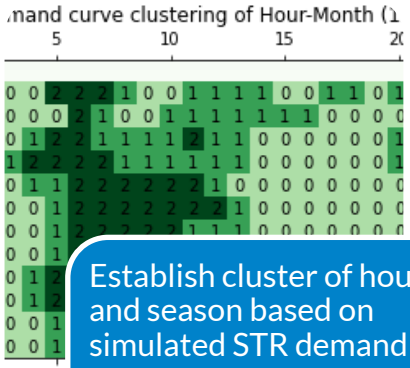
- Addresses market-wide, sub-regional and local short-term reserve needs via transparent price signal.
  - Reduce uses of out-of-market commitments in Reliability Assessment Commitment process.
- STR separately cleared in Day-Ahead and Real-Time markets and co-optimized with energy and other reserve products
  - For individual resource, cleared STR capacity may overlap with Contingency Reserve (CR) and Up Ramp Capability Product (RCP)
- Generation, Demand Response Resource Types I and II, Stored Energy Resource Type II, and External Asynchronous Resources may qualify to provide STR
  - Online dispatchable resources, excluding Dispatchable Intermittent Resources (DIR) and Intermittent Resources, may provide online STR
  - Offline resources that can reach their economic minimum output within 30 minutes, sustain output for 60 minutes and have a minimum run time of four hours or less may provide offline STR.

Process of establishing Short-Term Reserve (STR) Requirements



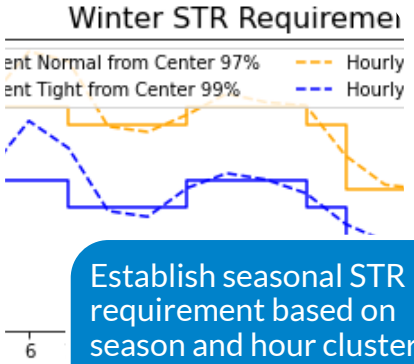
Simulation to establish STR demand curve from three components of uncertainty based on historical operational data

- Non-Intermittent Gen + RegMW
- Gen OU/Derate
- Real-Time Commitment



Establish cluster of hour and season based on simulated STR demand curve

- 3 cluster of Hour (Low/Medium/High)
- 2 season (Summer/Winter)



Establish seasonal STR requirement based on season and hour cluster

- Normal Day (cover 97.14% risk)
- Additional adder for Tight Day (cover 99% risk)

System-wide Short-Term Reserve Dynamic Requirements for Winter 2022-2023

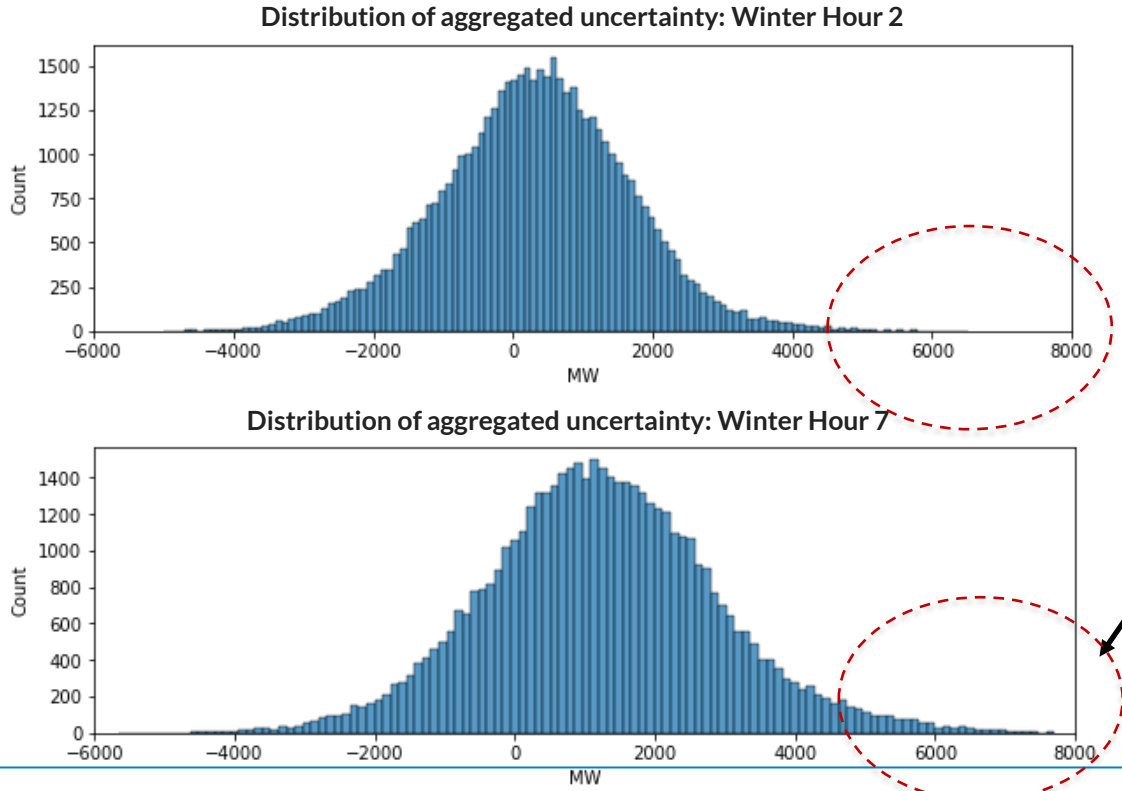
- Historical data used as input for STR demand curve simulation: 2019/01/01 to 2022/08/01
- Winter season definition based on clustering result: October to March
- System-wide Normal Day (97.14%):

  3500 / 4000 / 4300
- System-wide Tight Day (99%):

  Use Normal Day requirement + 800 MW as proxy

Hour	Label	STRMW 97.14% all Winter	STRMW 99% all Winter
0	Medium	4000	4800
1	Low	3500	4300
2	Low	3500	4300
3	Low	3500	4300
4	Low	3500	4300
5	High	4300	5100
6	High	4300	5100
7	High	4300	5100
8	Medium	4000	4800
9	Medium	4000	4800
10	Medium	4000	4800
11	High	4300	5100
12	High	4300	5100
13	Medium	4000	4800
14	Medium	4000	4800
15	Low	3500	4300
16	Low	3500	4300
17	Low	3500	4300
18	Low	3500	4300
19	Low	3500	4300
20	High	4300	5100
21	High	4300	5100
22	High	4300	5100
23	Medium	4000	4800

STR Dynamic Requirements cover different distribution of simulated uncertainty in High/Medium/Low hours

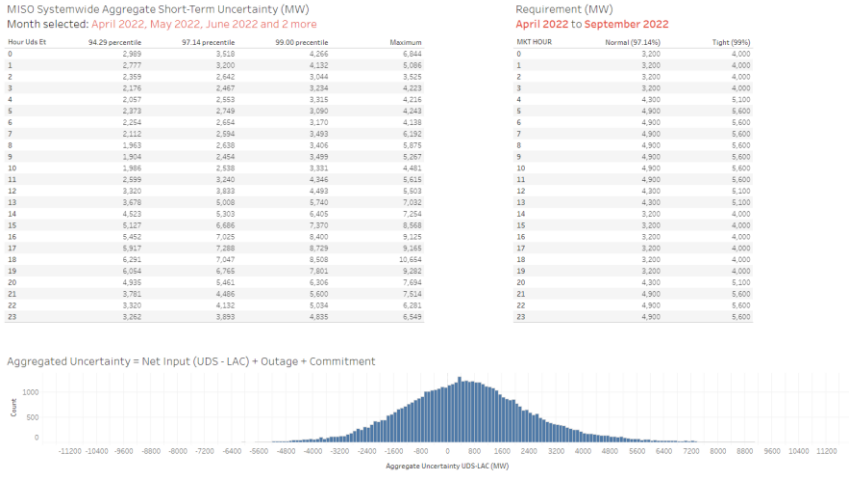


For example, Hour 7 is a simulated High uncertainty hour (with longer tail of uncertainty MW) compared with Hour 2 (Low uncertainty hour); hence the STR requirement is set higher for Hour 7.

Dashboards tracking Short-Term Reserve

Tracking STR cleared MW

Tracking STR Requirement against actual realized uncertainty



Ongoing and near-term future improvement

- Filing to Federal Energy Regulatory Commission for enhancing demand curves for the Short-Term Reserve (“STR”) and Up Ramp Capability products
  - Multi-step price range that increases the price of products under increasing degrees of scarcity conditions
- Evaluate and determine if higher granular STR requirement is needed, given the continuous evolving gen fleet/fuel mix in MISO footprint:
  - 4 cluster of Hour
  - 3 or 4 cluster of Season

Questions?