# Robust and Dynamic Reserve Requirements (1.3)

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# Acknowledgment


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- Thanks to Arizona State University
  - Provided additional support to fund another student for this project
- Thanks to my two students:
  - PhD Student Joshua Lyon (Industrial Engineering)
  - PhD Student Fengyu Wang (Electrical Engineering)


- Clarification: While this talk is in the Markets track, this research is for any setting (vertically integrated utilities and within market settings)

# Outline

- Motivation and Background
- Project Achievements
- Day-Ahead Scheduling Process
- Daily Dynamic Reserve Zones
- Future Work
- References
- Appendix

# Motivation and Background

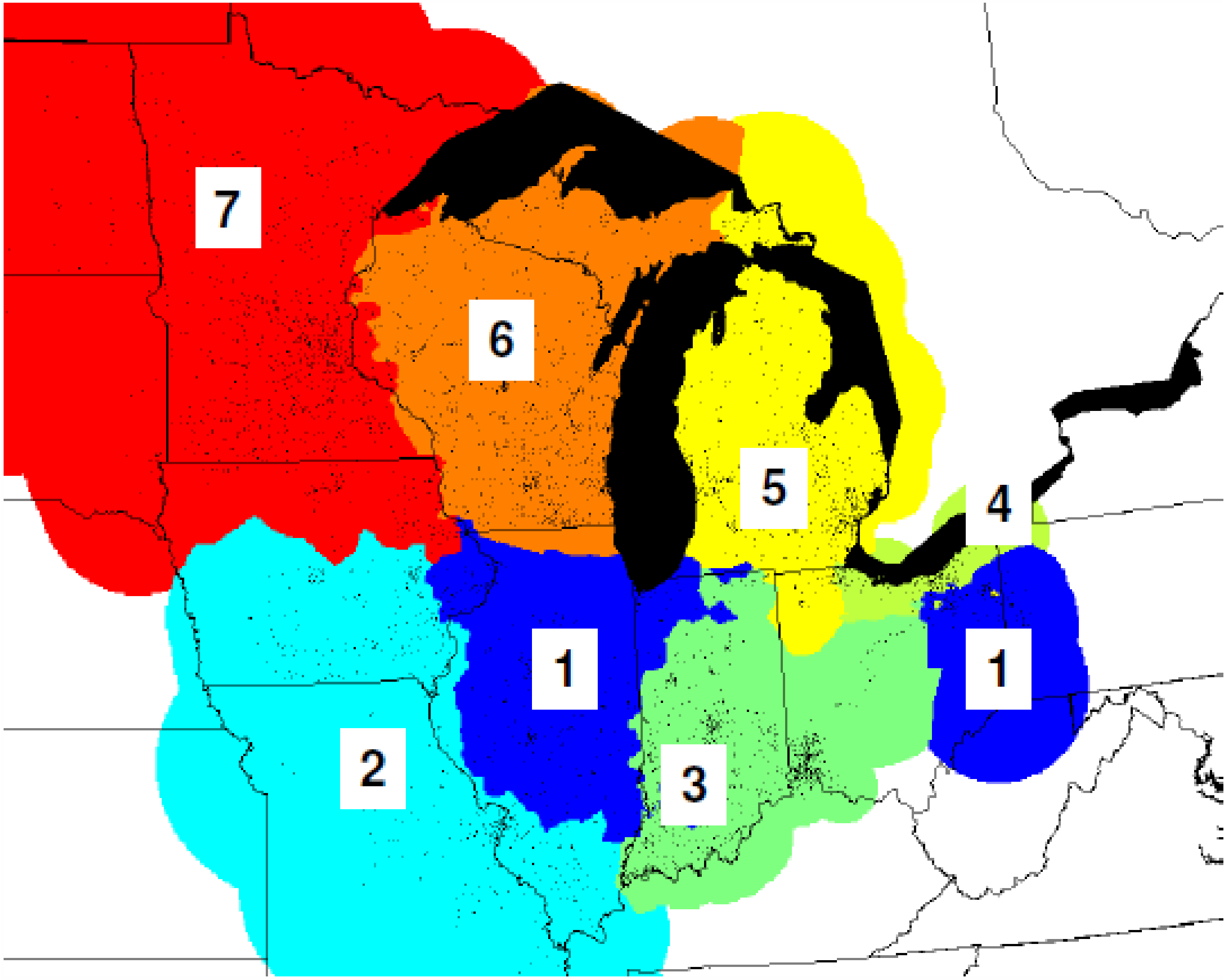
**Motivation:**

- Improve existing reserve policies (improve economic efficiency and reliability)
- Create reserve policies for renewable resources
- Opportunities to improve existing reserve rules for markets or vertically integrated environments

**Background:**

- Existing reserve requirements (contingency / spinning and non-spinning reserve) are imposed inside of day-ahead unit commitment to ensure sufficient backup capacity
  - Do not guarantee N-1 because congestion may prevent reserves from being deliverable
- Ensuring sufficient and **deliverable** reserves (quantity + **location**) will be increasingly more difficult with renewables

# Map of the Midwest ISO

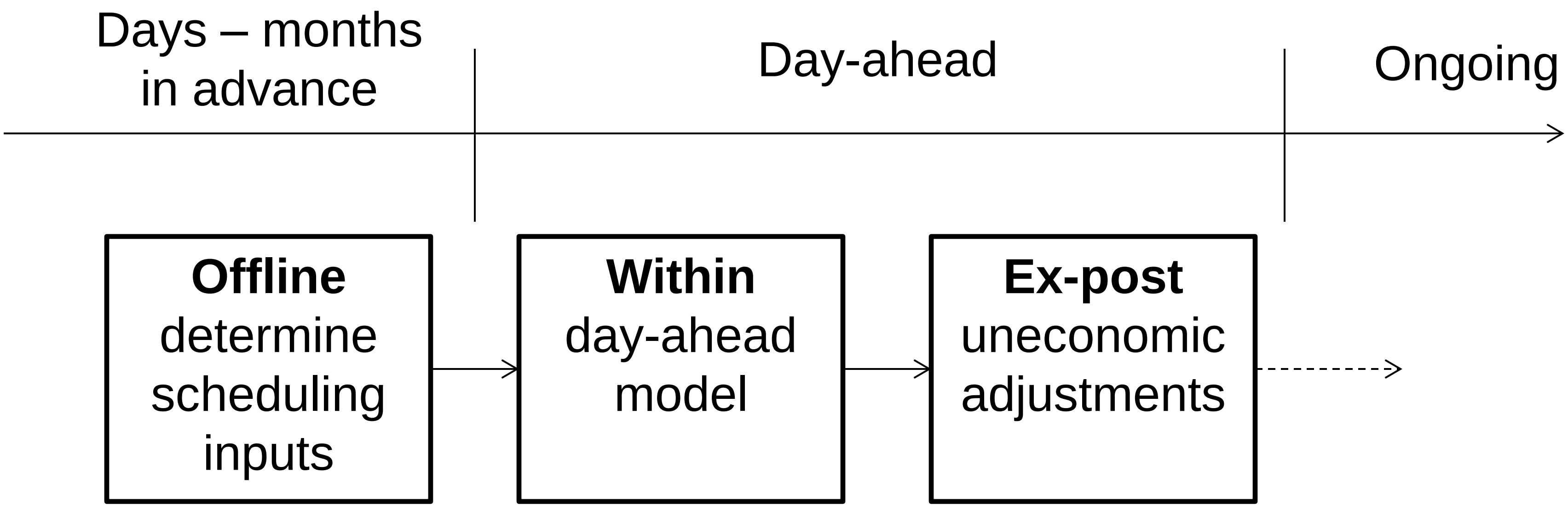



(Area 1 is part of PJM)

# Project Achievements

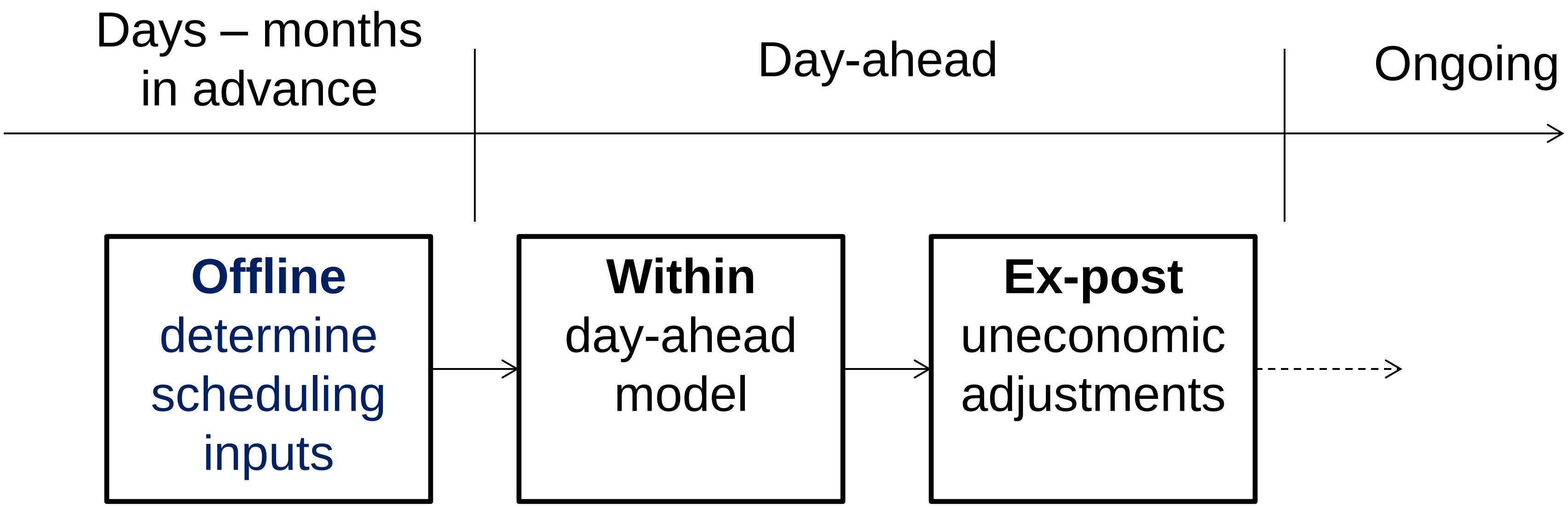
- Develop systematic ways to determine dynamic reserve requirements (zones and levels)
  - Improved reserve location/deliverability
  - Transitioned from static to dynamic (operational state dependent) rules
  - Developed reserve rules for renewable resources
  - Developed reserve rules for network topology changes
  - Results: improvements in economic efficiency (reduces costly uneconomic adjustments) and reliability/reserve deliverability

# Path to Reliability



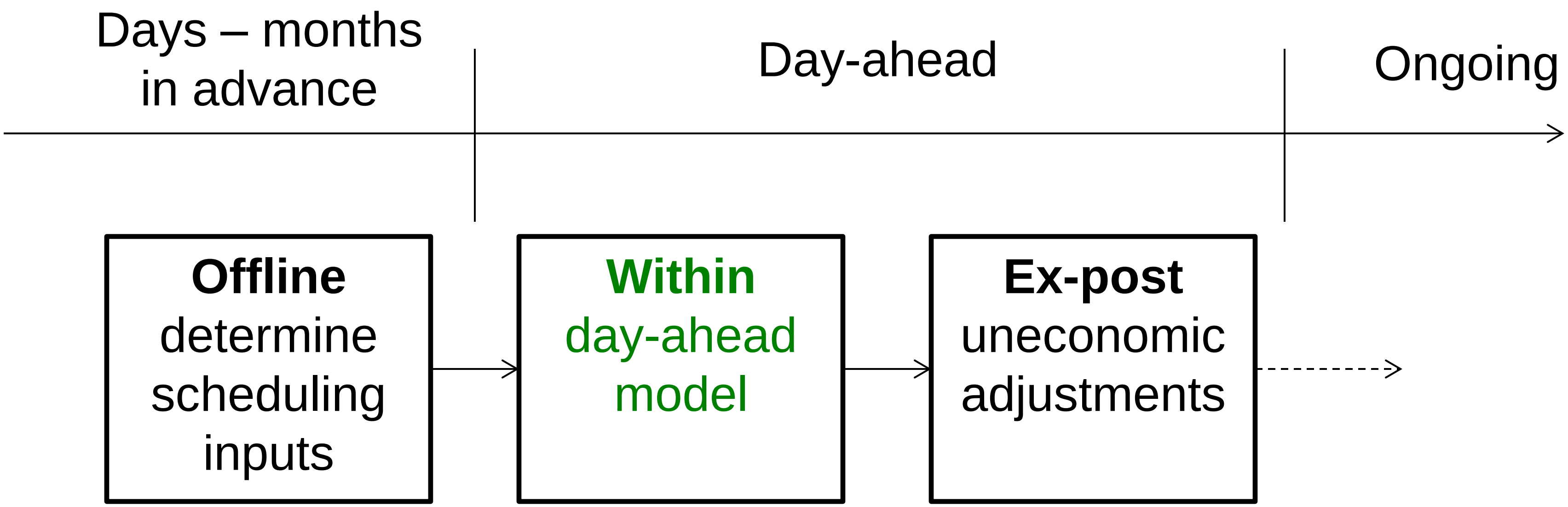

- Due to computational limitations, approximations are made for the day-ahead scheduling process (offline approximations as well as within the day-ahead model)
- Approximations are checked and corrected in an ex-post stage

# Path to Reliability



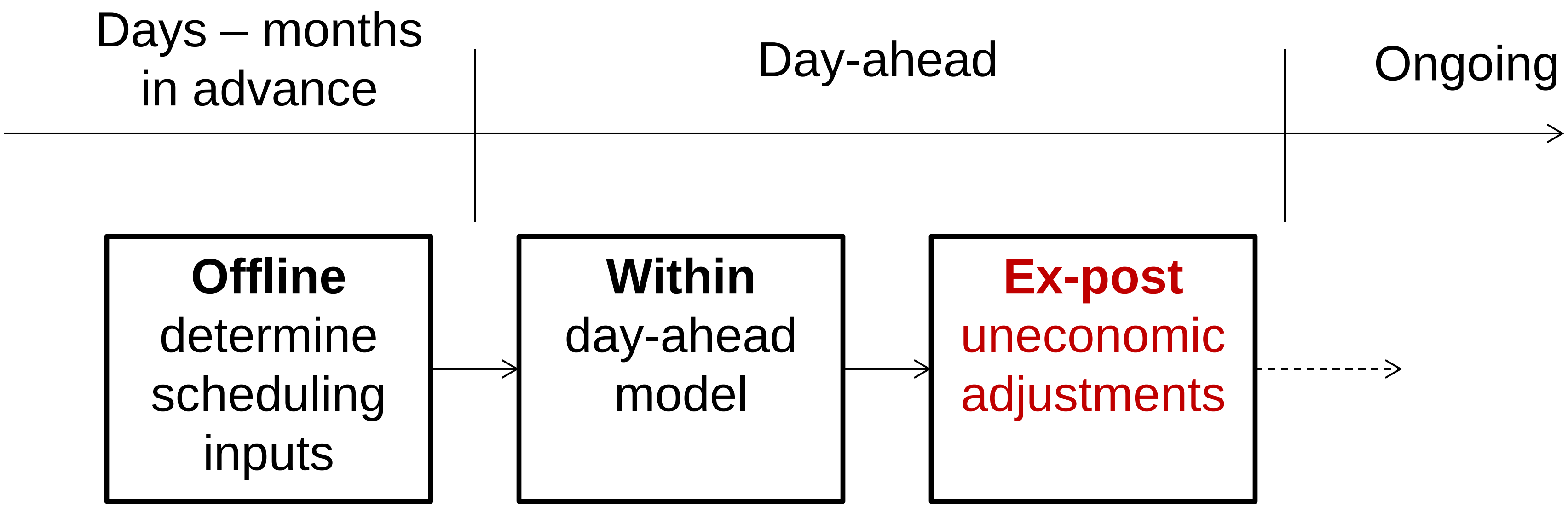

- Transmission constraints / transfer capabilities
- Nomograms
- **Reserve requirements** (**zones** and levels)
- Reliability must run (RMR)

# Path to Reliability




- Deterministic unit commitment
- **Reserve policies as a function of congestion**

# Path to Reliability




Modeling:

- Contingency analysis
- Uncertainties (e.g., wind)

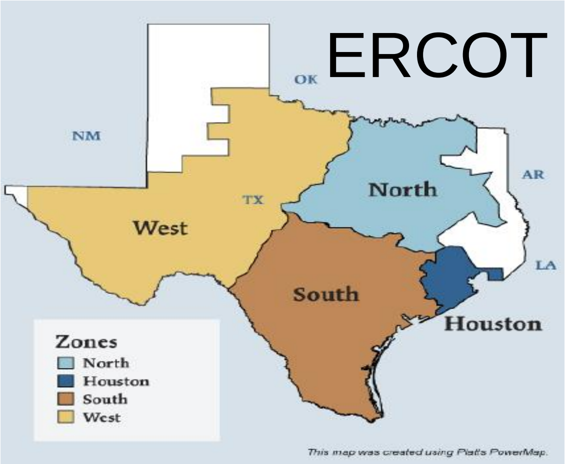
Actions:

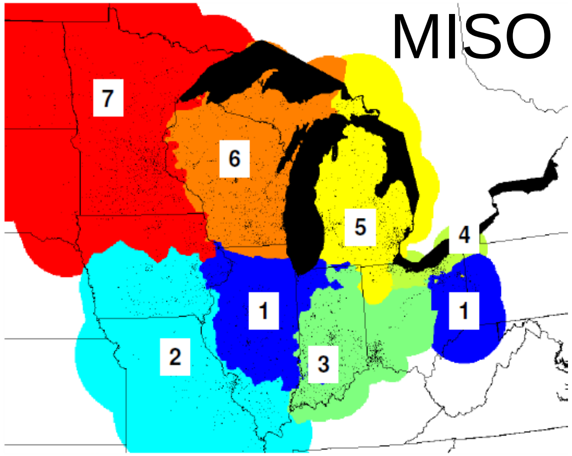
- **Reserve disqualification (reserve down flags)**
- RMR, out-of-sequence units

# Daily dynamic reserve zones (offline)

# Current Industry Practices: Reserve Zones

- Reserve zones are usually determined by identifying critical transmission bottlenecks
- Zones treated as static (seasonally)
- Zones in Texas (i.e., ERCOT):
  - Each generator/load within the zone has a similar impact on commercially significant constraints (CSC) [1]
  - Statistical clustering methods used to define zones
- Similar approach taken by MISO [2]



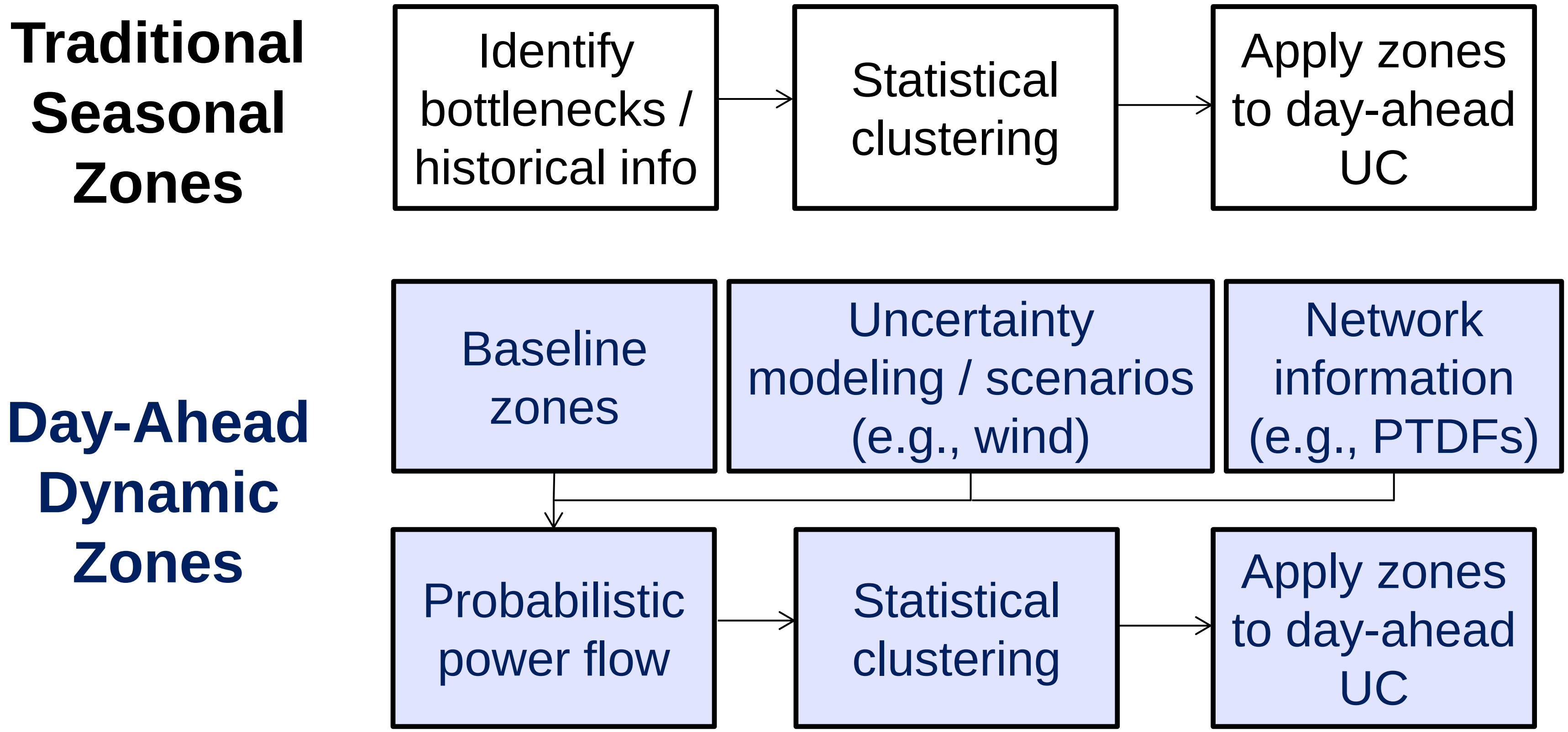




(Area 1 is part of PJM)

[1] ERCOT, "ERCOT Protocols, Section 7: Congestion Management," [Online]. July, 2010.
[2] Personal discussion with James Mitsche, President, PowerGEM, June 2012.

# Zone Determination Procedures

Reserve rules that fail to achieve N-1 require costly uneconomic adjustments / out of market corrections (operators manually adjust schedule)




Based on day-ahead probabilistic representation of operational state to reduce those corrections

# Day-Ahead Dynamic Zones

- Solved a 24HR day-ahead UC (IEEE 118 test system) with:
  - Traditional reserves: zones based on MISO's zone method
  - Two-stage stochastic program: 10 selected wind scenarios
  - Proposed dynamic reserves: zones based on probabilistic power flow
  - For each approach, reserve > max(largest contingency, NREL 3+5 rule)
- Performed contingency analysis on N-1 and 1000 wind scenarios across 12 days from January to March = **5 Million simulations**
- **Expected violations** occur only when reserve is not deliverable due to congestion (inside contingency analysis), which then requires ***out-of-market corrections / uneconomic adjustments*** **[3]:**

| | Traditional Seasonal (3 Zones) | Stochastic Programming (Single Zone) | Daily Dynamic Reserve Zones (3 Zones) |
|---|---|---|---|
| Expected Violations (via contingency analysis) | 17.0 MW | 20.6 MW | **10.6 MW** |
| Solution Time | 18 s | 339 s | **26 s** |

[3] Fengyu Wang and Kory W. Hedman, "Dynamic reserve zones for day-ahead unit commitment with renewable resources," *IEEE Transactions on Power Systems,* submitted.

# Future Work

- Currently testing policies on large-scale networks (FERC/PJM 15,000-bus test case)
- Model refinement based on industry feedback – please contact me if you would like to provide additional feedback or you would like further information (kory.hedman@asu.edu)
- Optimal coupling of robust and dynamic reserve policies with stochastic programming

# References

[3] F. Wang and K. W. Hedman, “Dynamic reserve zones for day-ahead unit commitment with renewable resources,” *IEEE Transactions on Power Systems,* submitted.

[4] F. Wang and K. W. Hedman, “Reserve zone determination based on statistical clustering methods,” *NAPS2012*.

[5] J. D. Lyon, K. W. Hedman, and M. Zhang, “Reserve requirements to efficiently mitigate intra-zonal congestion,” *IEEE Transactions on Power Systems*, submitted.

[6] J. D. Lyon, M. Zhang, and K. W. Hedman, “Dynamic reserve zones for distinct scenarios,” In preparation.

[7] J. D. Lyon, K. W. Hedman, and M. Zhang, "Embedding reserve zone partitioning into unit commitment,” In preparation.

# Appendix

# Reserve policies as a function of congestion (within)

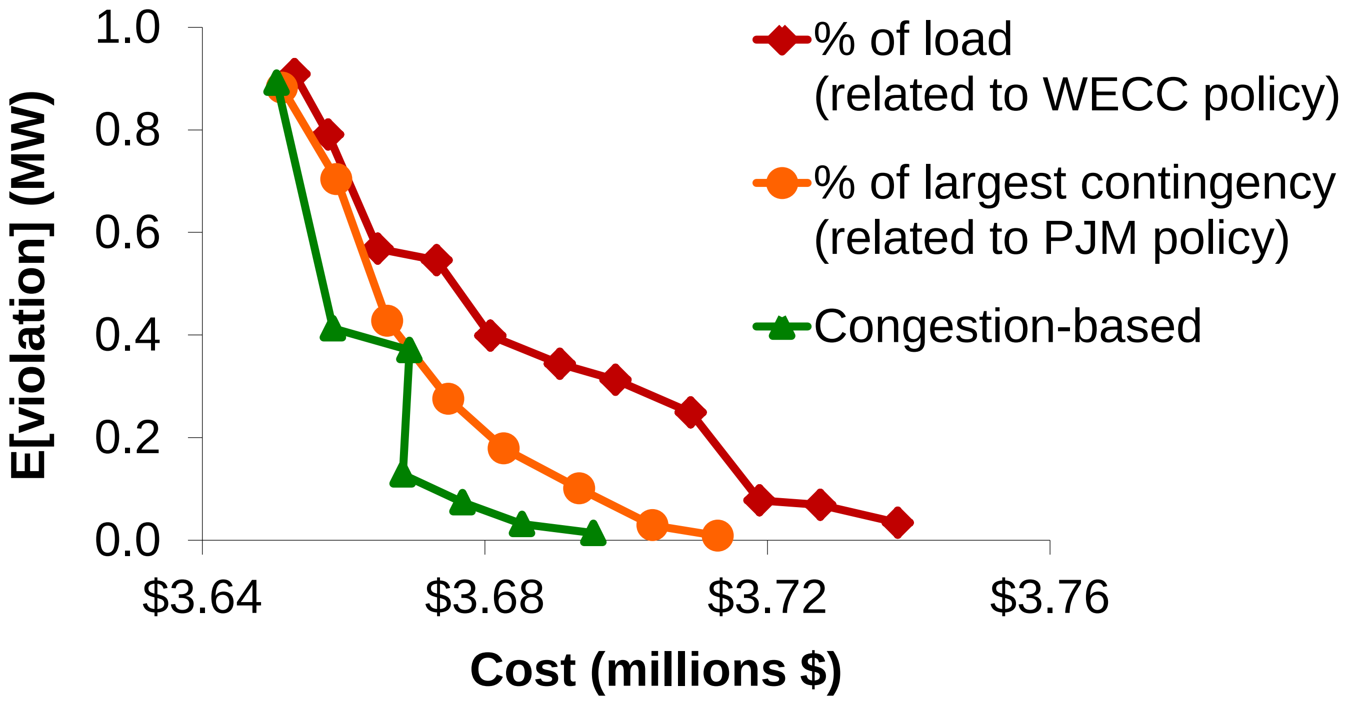
# Reserve Rules Related to Congestion

- Congestion on zone interfaces dictates the ability to share reserve between zones
  - ISONE models reserve sharing as a function of congestion [8]
- Most policies ignore intra-zonal congestion
- New policies can better reflect system stress by relating reserve to congestion
  - The option to increase reserve or decrease congestion is embedded in the optimization algorithm
  - Design so increments in reserve and decrements in congestion have similar effects on reliability

[8] T. Zheng and E. Litvinov, “Contingency-based zonal reserve modeling and pricing in a co-optimized energy and reserve market,” *IEEE Transactions on Power Systems*, vol. 23, no. 2, pp. 277–286, May 2008.

# Reserve as a Function of Congestion

- Day 352 of IEEE 73 bus test system
  - Policies tested with different levels of conservatism
  - Pareto dominant solutions attributable to reducing congestion




[5] Joshua D. Lyon, Kory W. Hedman, and Muhong Zhang, “Reserve requirements to efficiently mitigate intra-zonal congestion,” *IEEE Transactions on Power Systems,* submitted.

# Reserve disqualification / down flag policies (ex-post stage)

# Reserve Disqualification

- MISO, ISONE manually disqualify reserve located behind transmission bottlenecks (reserve disqualification and reserve down flags respectively)
- Ongoing work [6]:
  - Propose a generalized reserve down flag procedure
  - Determined via mathematical programming
  - Applied on a per-scenario basis
  - Can be used as a procedure to implement uneconomic adjustments
  - Can be embedded inside deterministic unit commitment (via a decomposition algorithm)
  - **Complement stochastic programming with dynamic reserve policies**

[6] Joshua D. Lyon, Muhong Zhang, and Kory W. Hedman, "Dynamic reserve zones for distinct scenarios," In preparation.