Dynamic Reserve Policies for Market Management Systems

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CERTS Annual Review
August 5, 2014

Arizona State University

Outline

- Key Takeaway Points
- Overview of Existing Day-Ahead SCUC
- Existing Reserve Policies
- Dynamic Reserve Policies
- Primary Objectives of Proposed Work
- Brief Overview of Results
- Summary
- Appendix: Prior and Ongoing Work

Key Takeaway Points

Key Takeaway Points

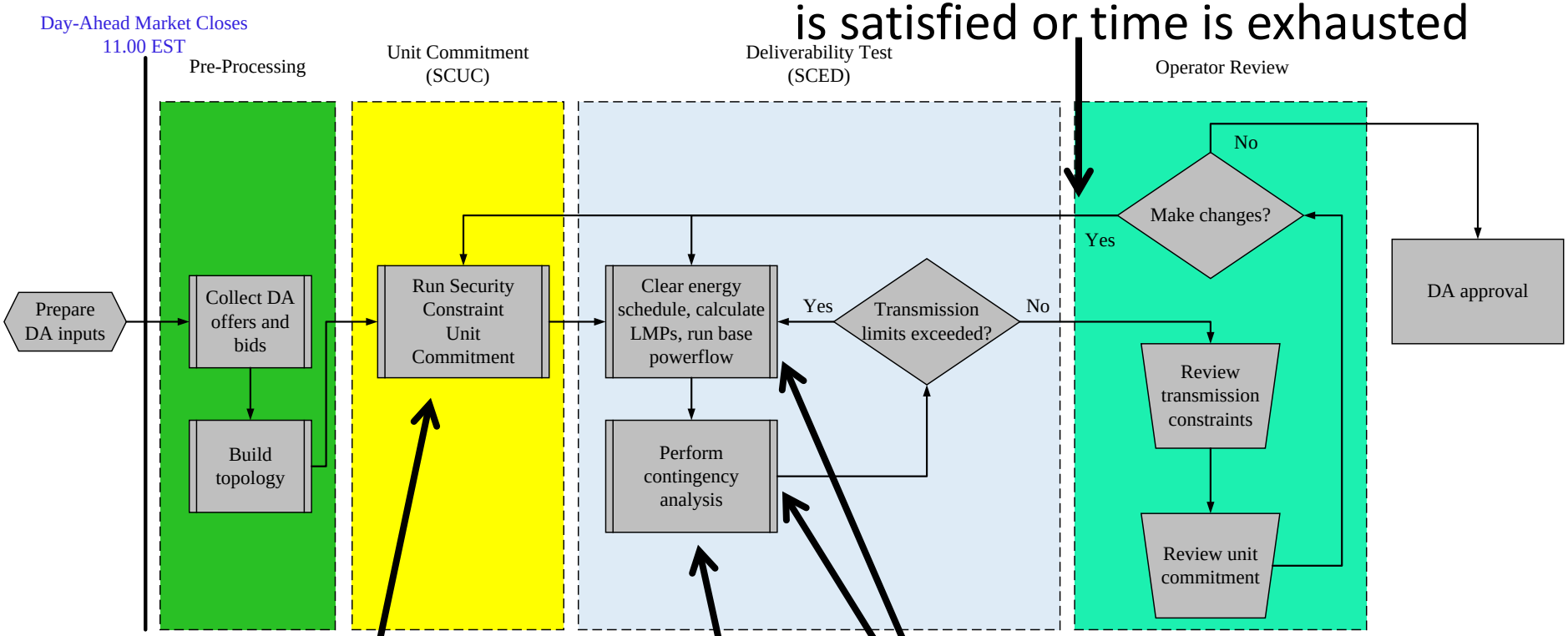
- Existing models: deterministic (not stochastic); typically linearized AC
- SuperOPF Goal: enhance optimization engines by capturing AC, uncertainty, FACTS, demand, storage, …
- Question: can we explicitly represent everything?
- No - Curse of dimensionality
- What to represent? What to approximate?
  - This project: operating reserves (10 min reserves)
  - Focus: Heuristic methods that can improve deterministic and stochastic SCUC

"Between the idea and the reality… falls the shadow"
T.S. Elliot

Overview of Existing Day-Ahead Market Management Systems

Day-Ahead Scheduling in Midcontinent Independent System Operator (MISO)

Iterative process until operator is satisfied or time is exhausted



Mixed integer linear programs

Reliability assessment

Linear program

MISO Day-Ahead Scheduling Procedure

[1] Aaron Casto, "Overview of MISO day-ahead markets," *Midwest ISO*, [Online]. Available: http://www.atcllc.com/oasis/Customer_Notices/NCM_MISO_DayAhead111507.pdf.

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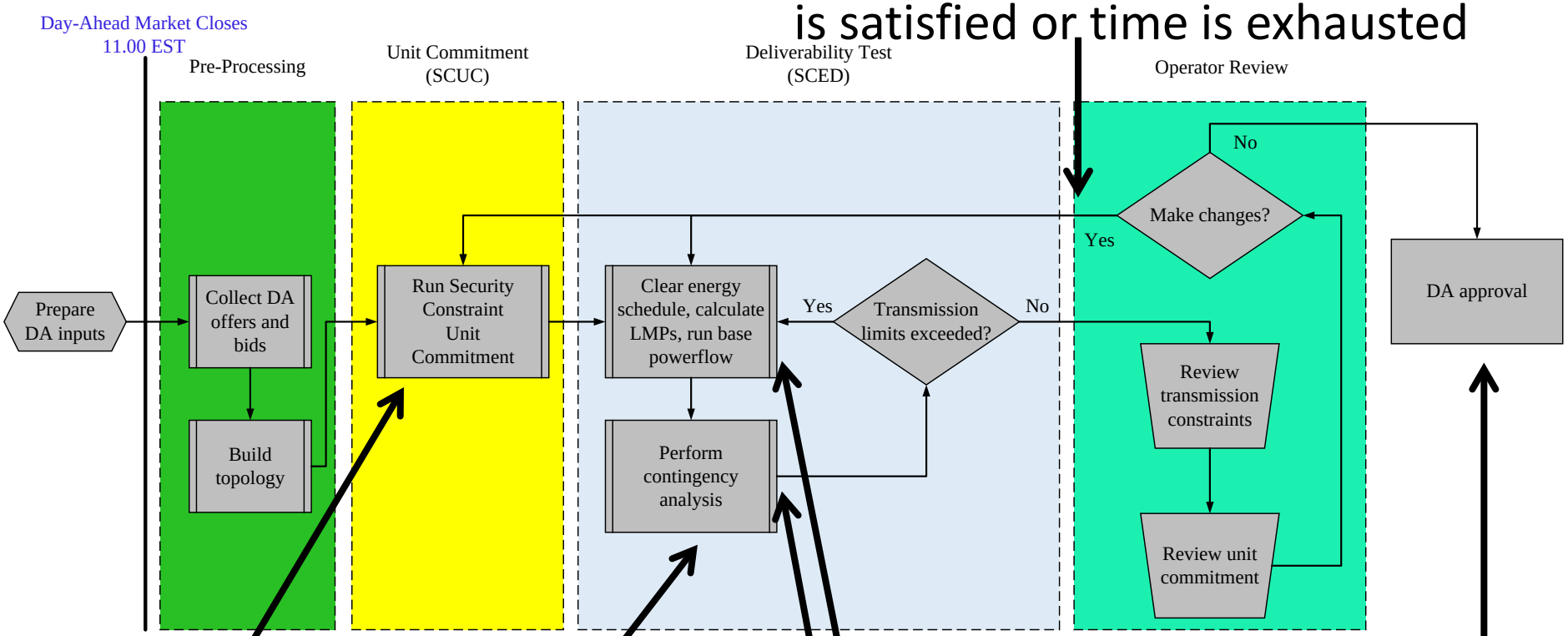


Interface limits
Nomograms

Subset of contingencies

DC Approximate, not AC; limited iterations

Final Day-Ahead Market Solution

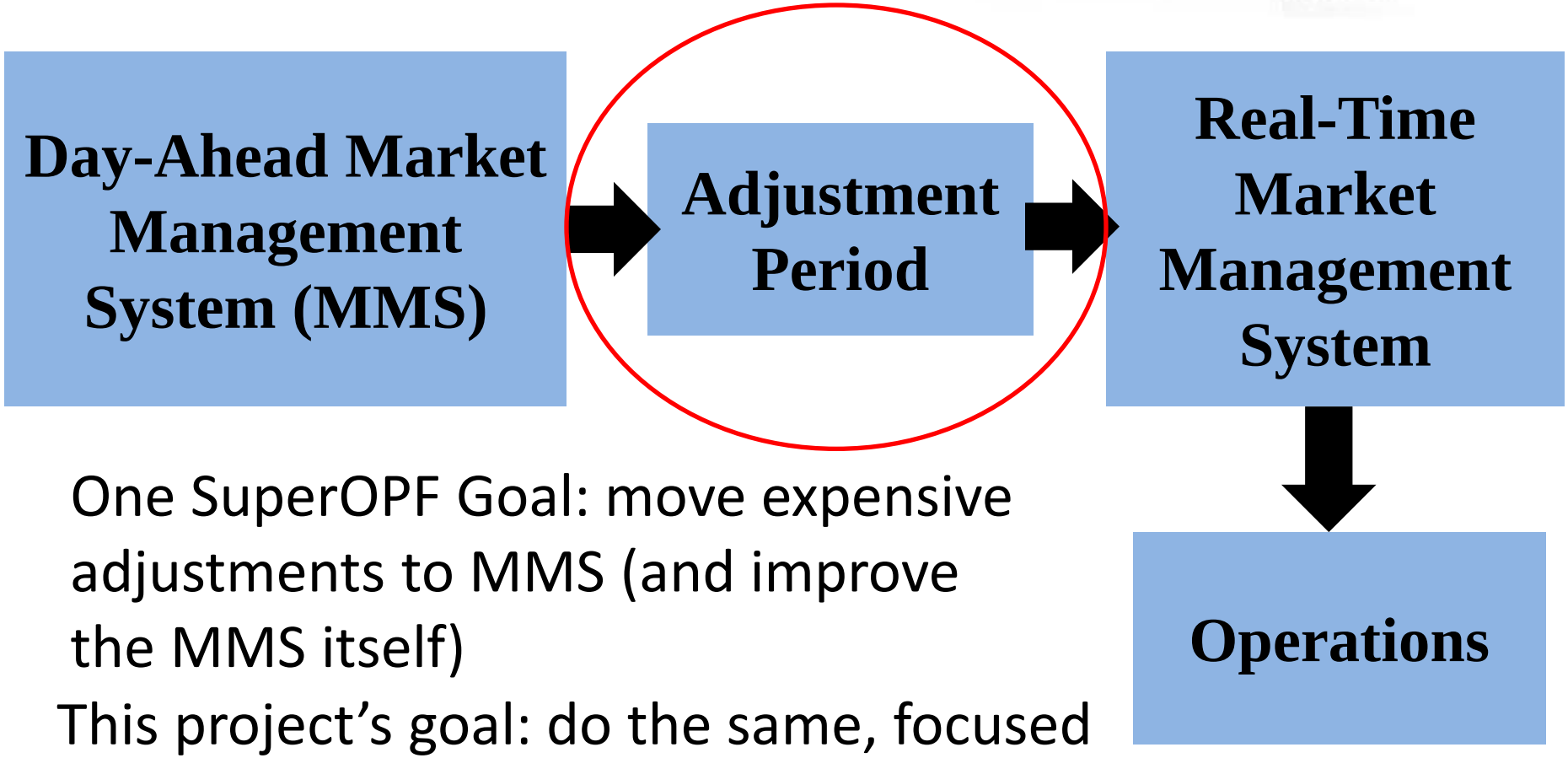
Final Day-Ahead Market Solution

What is guaranteed within the market SCUC solution?

- AC feasible?
- N-1?
- Renewable uncertainty?
- Stability?

Approximations within SCUC models result in either infeasible solutions that must be corrected outside of the market engine or overly conservative solutions

Market Adjustment Process



One SuperOPF Goal: move expensive adjustments to MMS (and improve the MMS itself)

This project's goal: do the same, focused on reserve requirements (and later merge this with stochastic programming)

Adjustment Period

Market operators must adjust market solutions to create realistic, feasible solutions

- Many different terms: Uneconomic adjustments; supplemental dispatch; out-of-merit capacity; out-of-merit energy; exceptional dispatches; reserve disqualification; reserve downflags
- We call these adjustments: out-of-market corrections
- Accounting for such corrections is key when evaluating new algorithms

Existing Reserve Policies

Operating Reserve Quantity

- Ad-hoc rules
- Typical 10-minute operating reserve quantity requirements in SCUC/SCED:
  - Single largest contingency
  - Proportional to demand/renewables
- CAISO:
  - Largest contingency
  - 5% of load met by hydro + 7% load met by non-hydro

Reserve Location

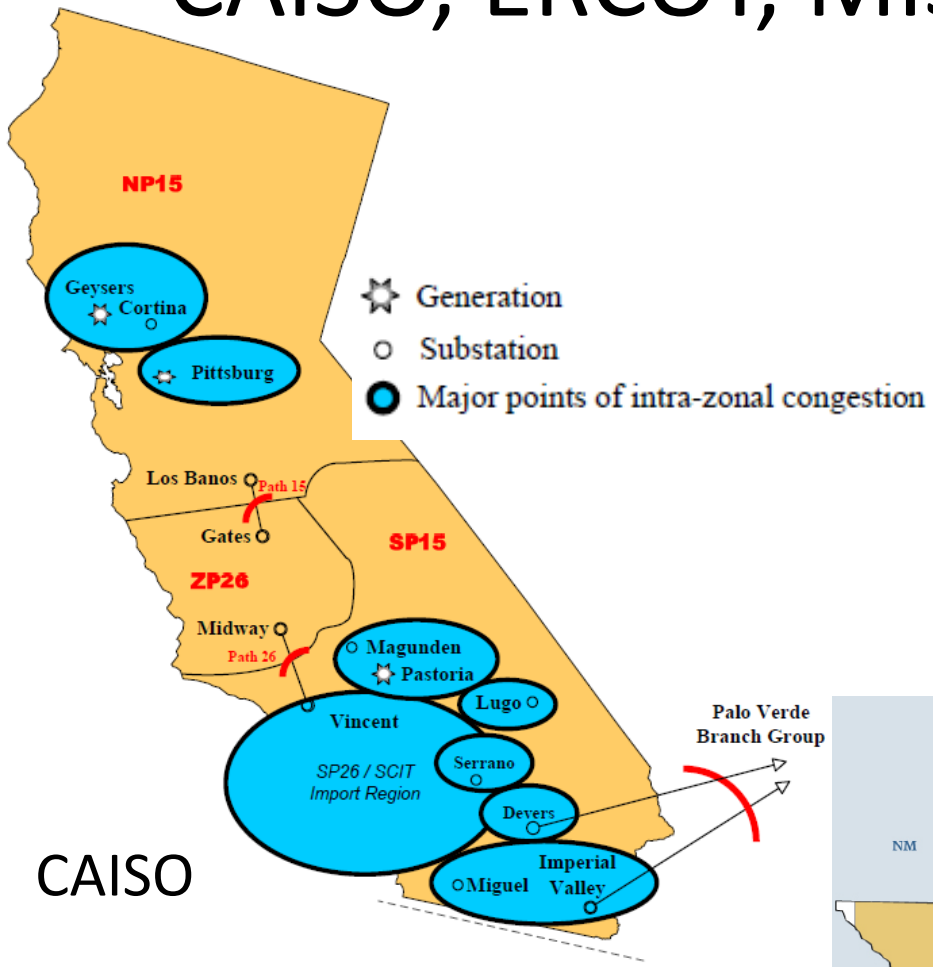
- Stochastic programming
  - Implicitly locate reserve (and determine quantity)
  - Curse of dimensionality
  - Stakeholder issues; Pricing issues
- Reserve zones
  - Traditionally based on ad-hoc rules such as utilities ownership, or geographical boundaries, and treated as static
  - Blindly choose reserve inside reserve zones
  - It is assumed that reserve can be delivered without congestion inside the zone

MISO's Reserve Zones

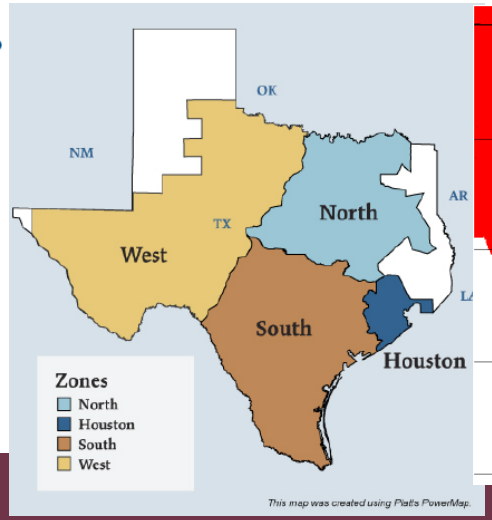
- Evaluated quarterly
  - Little to no change has been made
- Software created by Dr. James Mitsche (Founder, PowerGem)
  - Identify key transmission bottlenecks
  - Use historical power flow information
  - Group generators (zones) based on generators that have similar PTDFs associated to the key transmission bottlenecks
- ERCOT has a similar procedure by identifying: Commercially Significant Constraints (CSCs)

CAISO, ERCOT, MISO's Reserve Zones

- CAISO has 3 reserve zones
- Their reserve rules do not account for intra-zonal congestion
- Intra-zonal congestion is account for by other rules



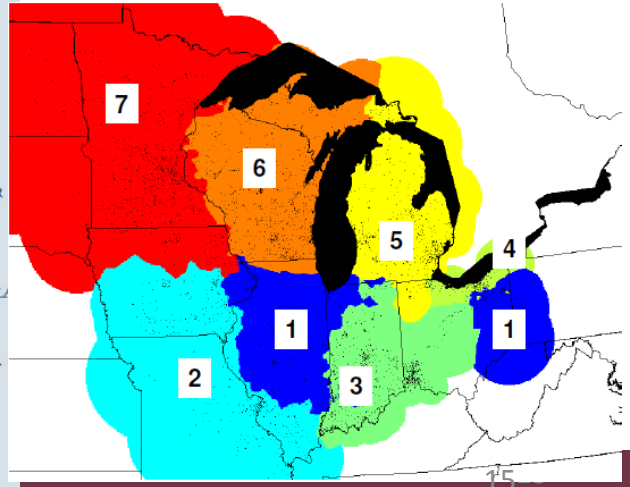
CAISO



ERCOT

Area 1 is a part of PJM

MISO



Dynamic Reserve Policies

Background

- Existing reserve requirements (contingency / spinning and non-spinning reserve) inside SCUC:
  - Do not guarantee N-1 because congestion may prevent reserves from being deliverable (voltage is also an issue)
- Ensuring sufficient and **deliverable** reserves (quantity + **location**) will be increasingly more difficult with renewables
- Potential solutions:
  - Implement stochastic programming — Computational challenge
  - Use existing reserve requirements/increase reserve quantity — Costly
- **Best solution: a balanced approach** that combines advanced reserve policies with stochastic programming algorithms

Dynamic Reserve Policies

- Dynamic reserve policies:
  - Reserve requirements that adjust with operating state
  - Improve *deliverability* of reserves
- Dynamic reserve zones:
  - Identify critical bottlenecks and set of generators to respond to contingencies (or renewable scenarios)
  - Adjust daily or hourly
- Reserve response sets:
  - Response set (zone) identified for critical scenarios (identify set of generators to respond)

Prior and Ongoing Work

Extension of a project funded by the PSERC DOE Future Grid Initiative

- Dynamic Reserve Zones
- Reserve Response Sets
- Market Implications and Pricing

- Future work will be an extension of prior work with the following objectives
- Summary of prior work is provided in Appendix

Primary Objectives of Proposed Work

Proposed Work

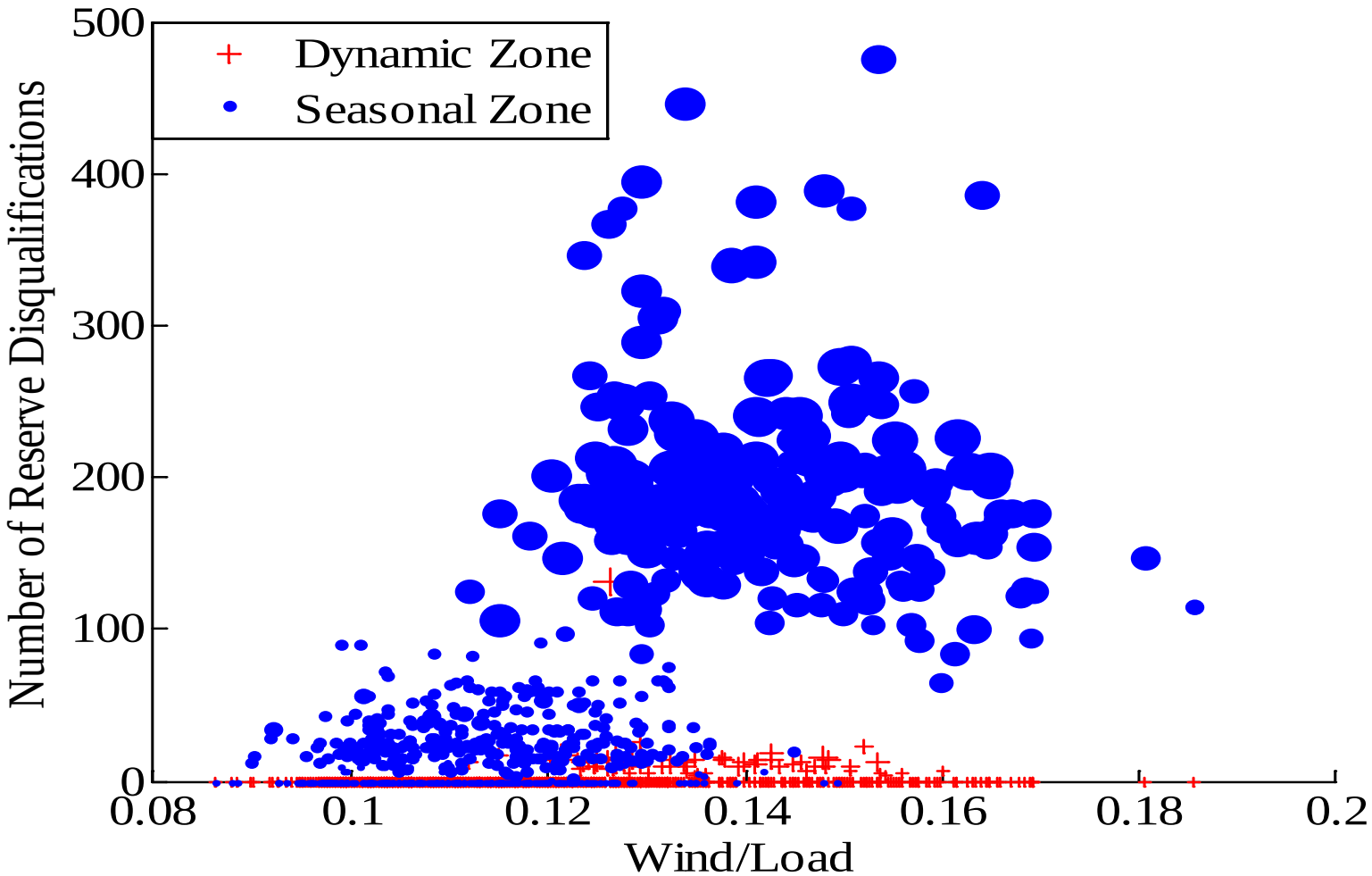
- Create algorithms that mimic ad-hoc reserve disqualification procedures used today
- Create dynamic reserve zones
- Reduce the need for expensive out-of-market correction
- Examine market implications

Potential Future Work

- Ultimate goal: expert systems based approach that balances deterministic policies with stochastic programming for improved solution quality and scalability
  - Prior work on this effort for Jean-Paul Watson in association to his ARPA-E Stochastic UC with Progressive Hedging Project
- Improve scalability and convergence
- Minimize the uncertainty needed to be explicitly represented within stochastic programs

Brief Overview of Results

Numerical Results: Dynamic Zones



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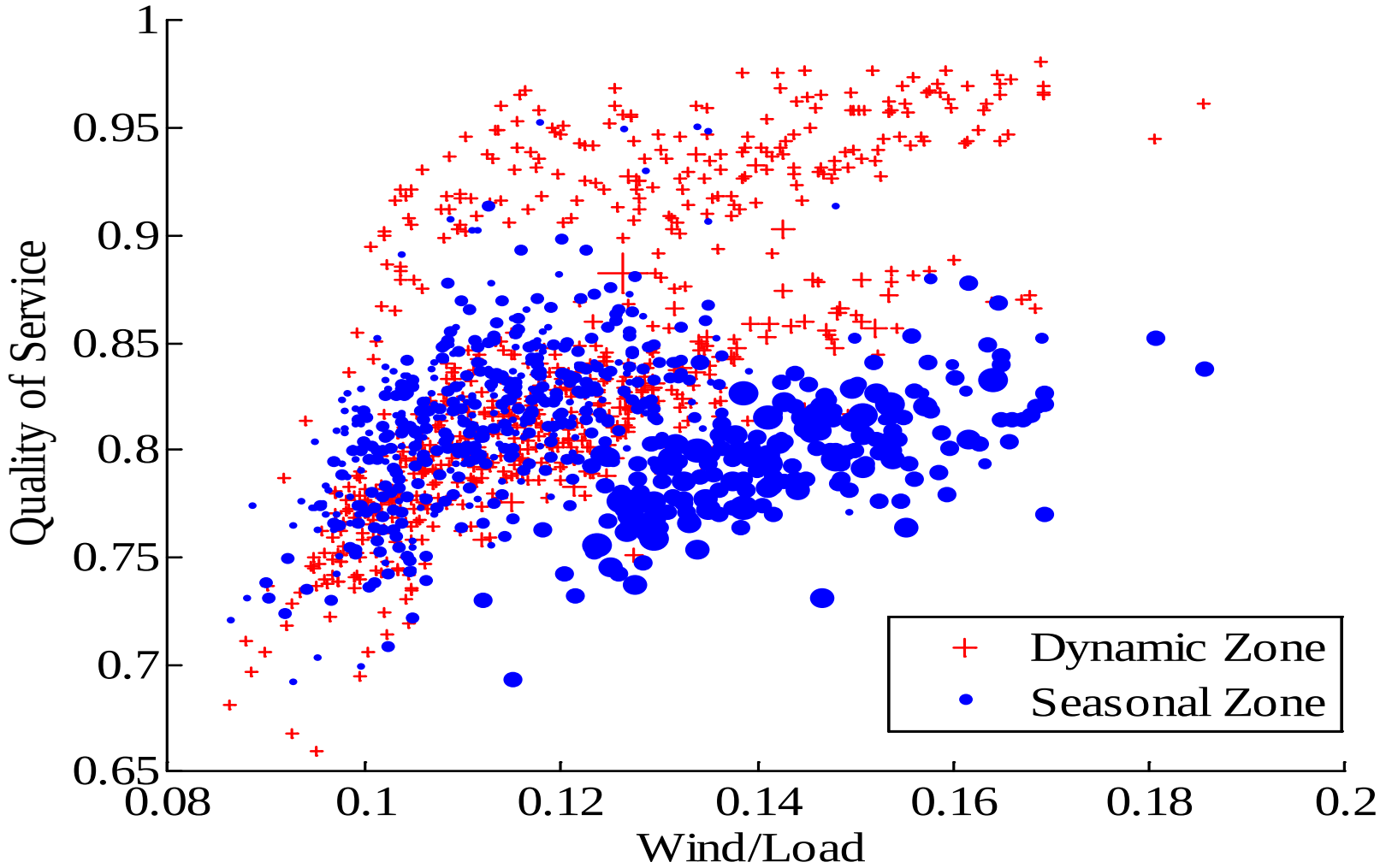
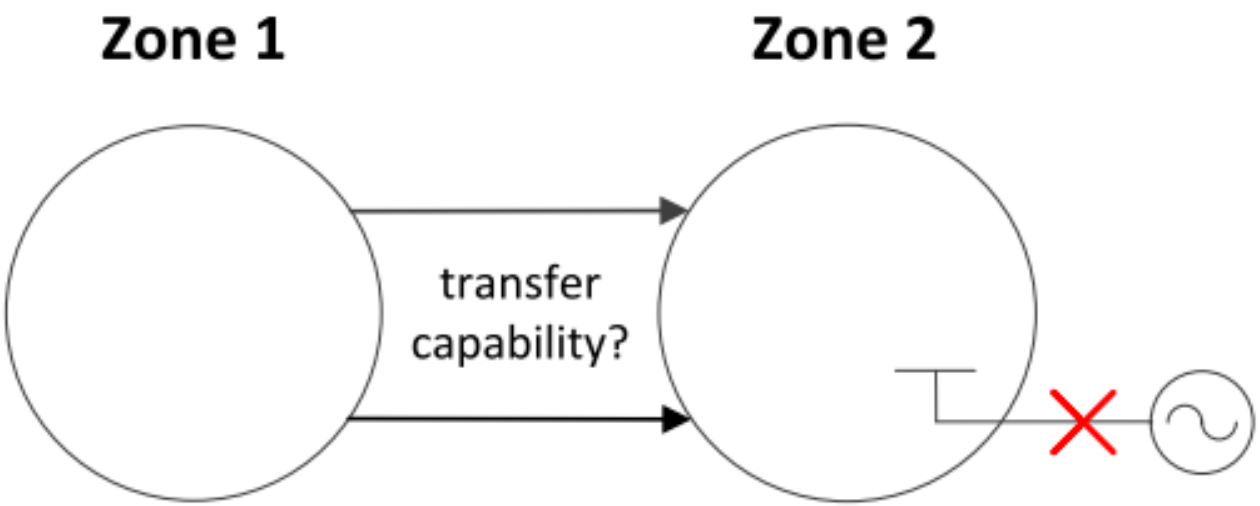


Zonal reserve requirements

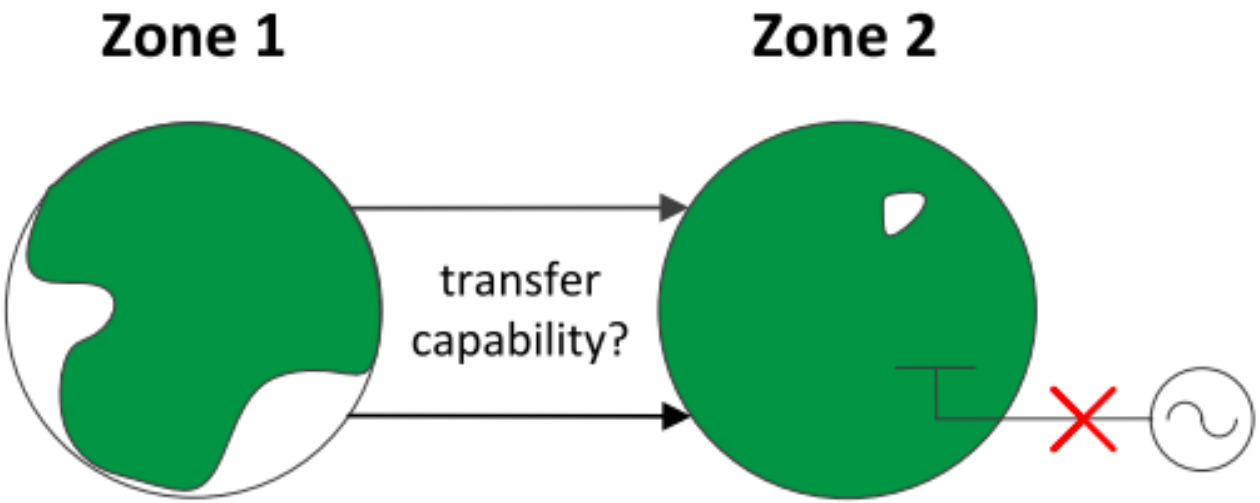
- Common assumptions:
  - No congestion within zones
  - Limited reserve sharing capability



10-minute reserve ≥ largest contingency – import capability

Reserve disqualification

- Operators manually disqualify reserves behind transmission bottlenecks
- Requirements met by remaining reserves



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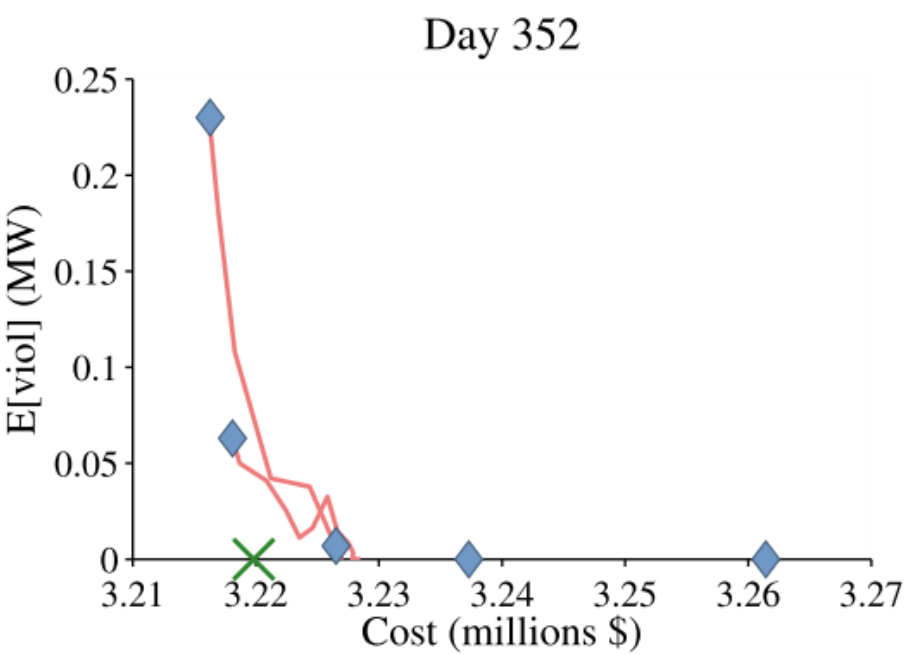
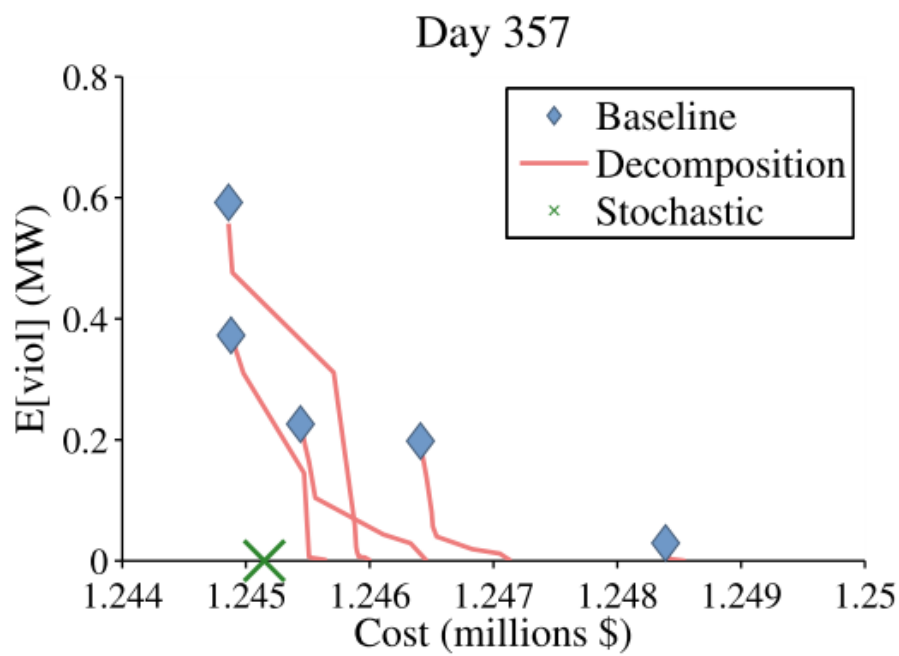
Reserve Response Sets – Heuristic Algorithm

- IEEE RTS96 Test Case
- Heuristic algorithm takes unreliable solutions and creates reliable SCUC solutions at lower costs than traditional static policies





Summary

Summary

- Model complexity will grow with computational complexity
- Smart, well-designed reserve policies will benefit SuperOPF initiative
- Expert systems balanced with advanced optimization algorithms
  - Can improve efficiency while also improving scalability
- Commercial grade changes to planning, operational planning, and real-time operational optimization software will include such expert system based approaches

Questions?

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Appendix: Separate Topic: HPC Based Real-Time Contingency Analysis Open Source Tool

Multi-Threaded Real-Time Contingency Analysis (Open Source) Tool with Post-Contingency Corrective Actions

Tool Development

- Multi-threaded HPC based AC Power Flow Real-Time Contingency Analysis (RTCA) Package
- Open Source; Java based; reads PSS/E .RAW
- Expanded Dr. Robin Podmore's Open Source AC Power Flow tool to create multi-threaded RTCA package (Thanks to IncSys and PowerData)
  - **The RTCA tool developed at ASU will be integrated within Workforce Training and Simulation Platform (we are collaborating with Dr. Podmore to integrate this within PowerSimulator)**

Test Data Source

TVA

- Developed 72 PSS/E .RAW input files based on TVA data for testing (3 days)
- Network (neighboring systems: equivalent)
  - Roughly: 1,800 buses; +2,100 branches; +300 gen; 180 switchable shunts; 1,800 contingencies; 60 interconnection points
- PJM: Ongoing work: solving a 15,000 bus PJM system model with >20,000 contingencies (168 PSS/E .RAW files from one week of operation)

Computational Performance: TVA

Computational results for the real-time contingency analysis package

- Contingency analysis is conducted on a 64-bit system, i7-3770 CPU 3.40GHz, 16 GB RAM
- All 72 contingency analysis runs: **50-70 seconds**
- Parallel implementation (on 4 cores): 3x improvement (additional HPC testing ongoing)
- Validated against PSS/E Contingency Analysis
  - Similar results (AC PF algorithms are not exactly the same)

Appendix: Prior and Ongoing Work

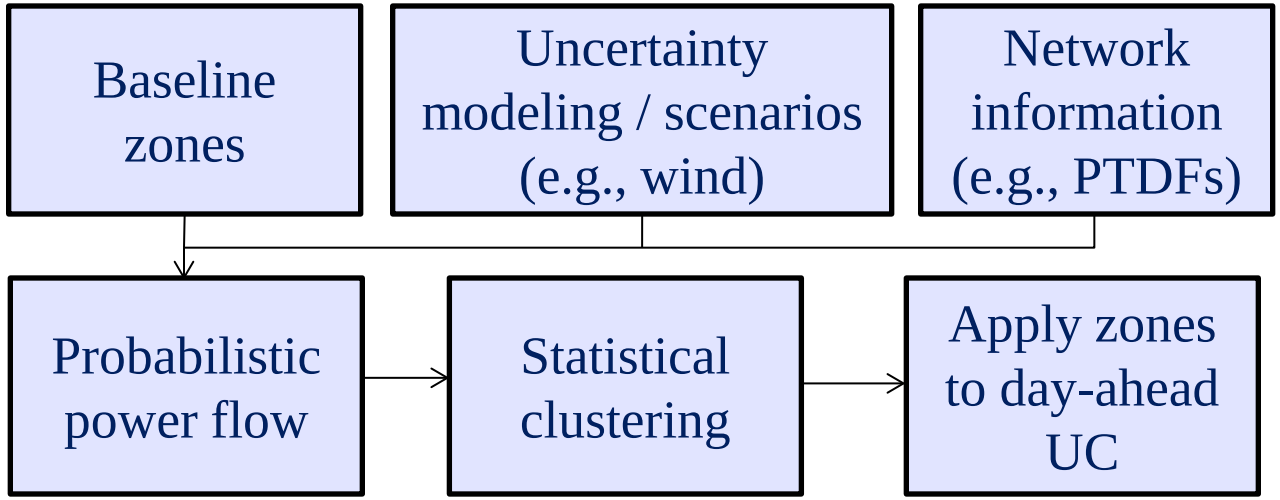
Dynamic Reserve Zones for SCUC with Renewables

Zone Determination Procedures

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

Traditional (MISO) Zones

Day-Ahead Dynamic Zones



Test Case

- Day-ahead UC (Modified IEEE 118 test system) :
  - Traditional reserves: zones based on MISO's method
  - Two-stage stochastic program: 10 selected wind scenarios
  - Proposed dynamic reserves: zones based on probabilistic power flow
- Performed contingency analysis on N-1 and 1000 wind scenarios across 12 days from January to March = **5 Million simulations**

Numerical Results

Expected Load Shedding (MW) and Expected Cost ($million)

	Deterministic UC			Stochastic UC	
	Seasonal	Daily	Daily (Prob.)	Single zone	Daily (Prob.)
Wind + N-1 (MW)	13.5	13.13	10.45	20.37	9.62
Total (MW)	17.022	15.68	10.535	20.532	9.63
Expected Cost	0.702	0.701	0.698	0.698	0.689
Improvement	-	0%	1%	1%	2%

Value of Lost Load=$3,000/MW

Numerical Results

Average solution time (s)

Deterministic UC			Stochastic UC	
Seasonal	Daily	Daily (Probabilistic)	Single Zone	Daily (Probabilistic)
18.3	22.7	25.5	338.8	505.4

Reserve Response Sets

Zonal reserve requirements

- Common assumptions:
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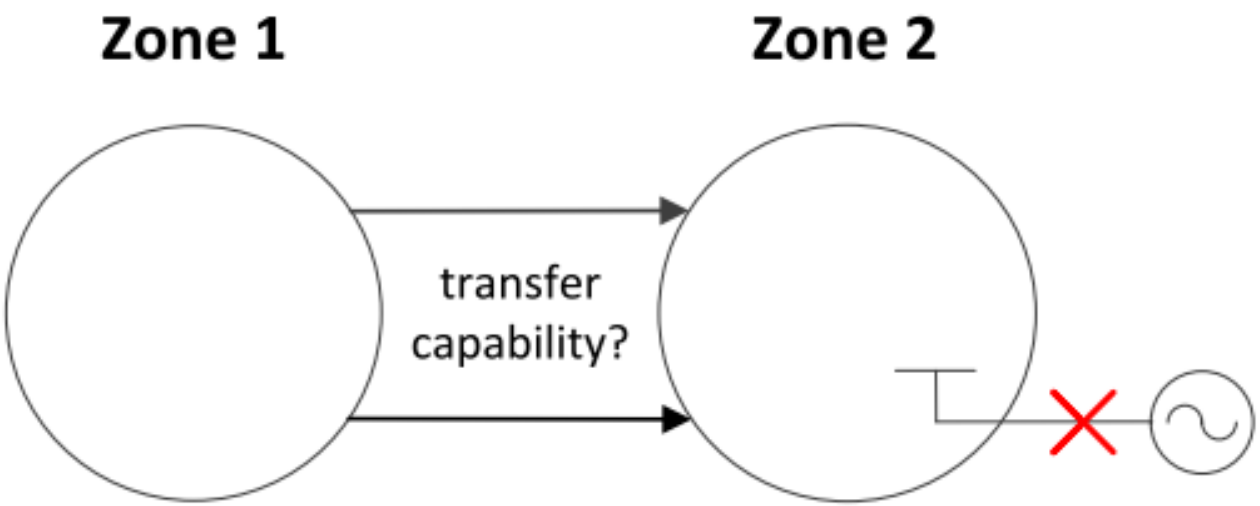

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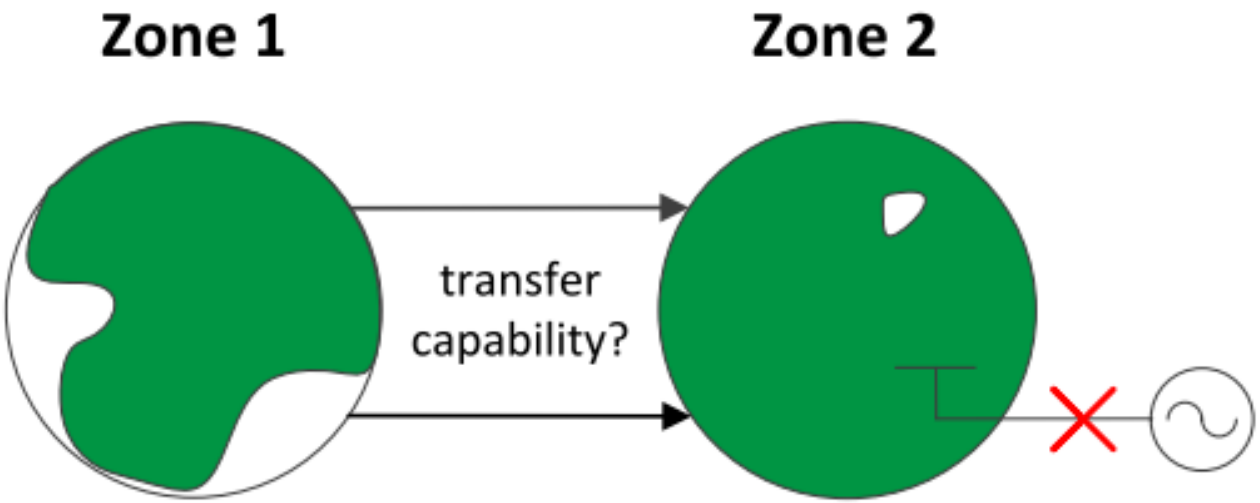

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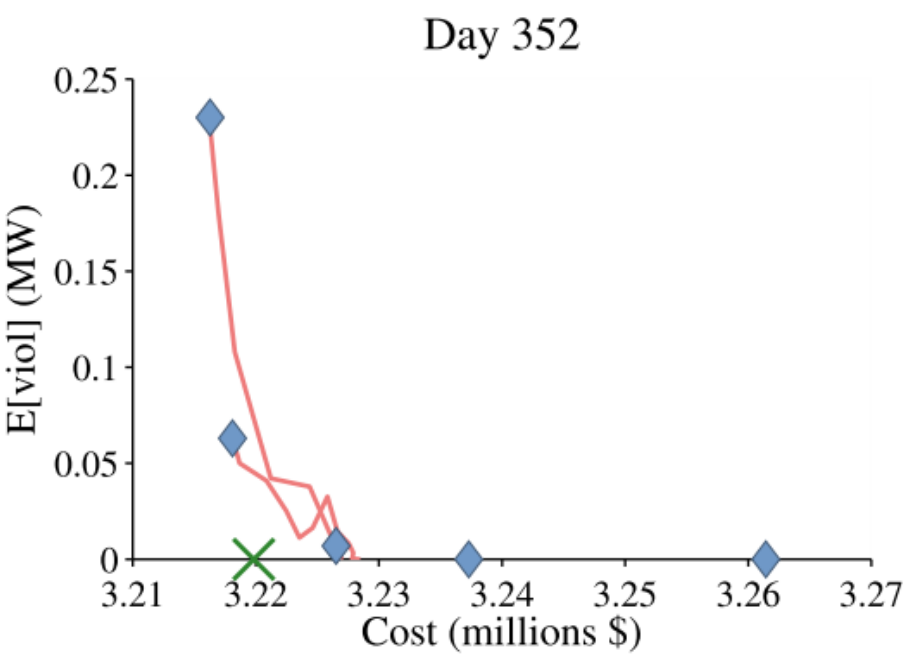
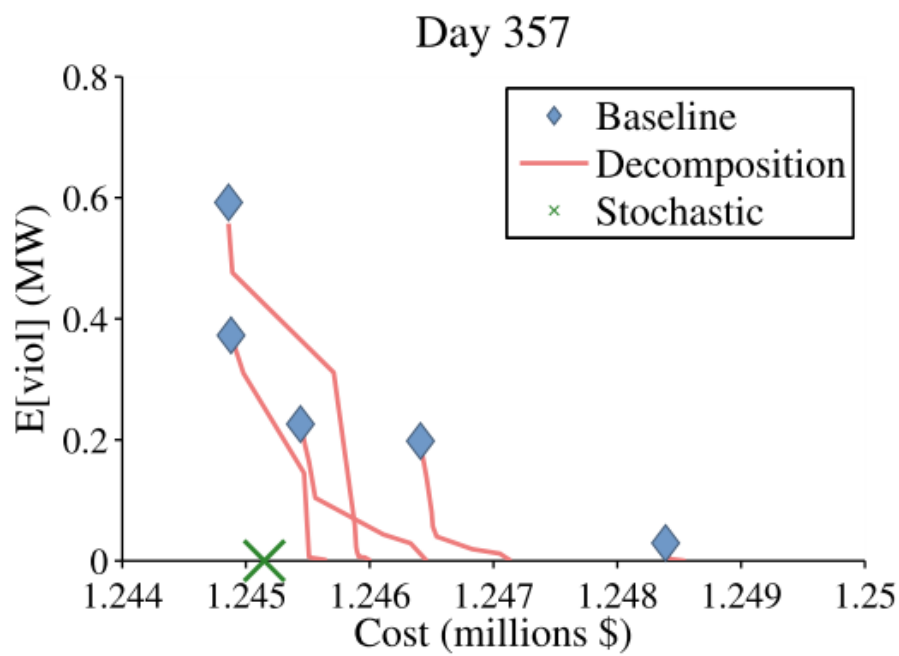
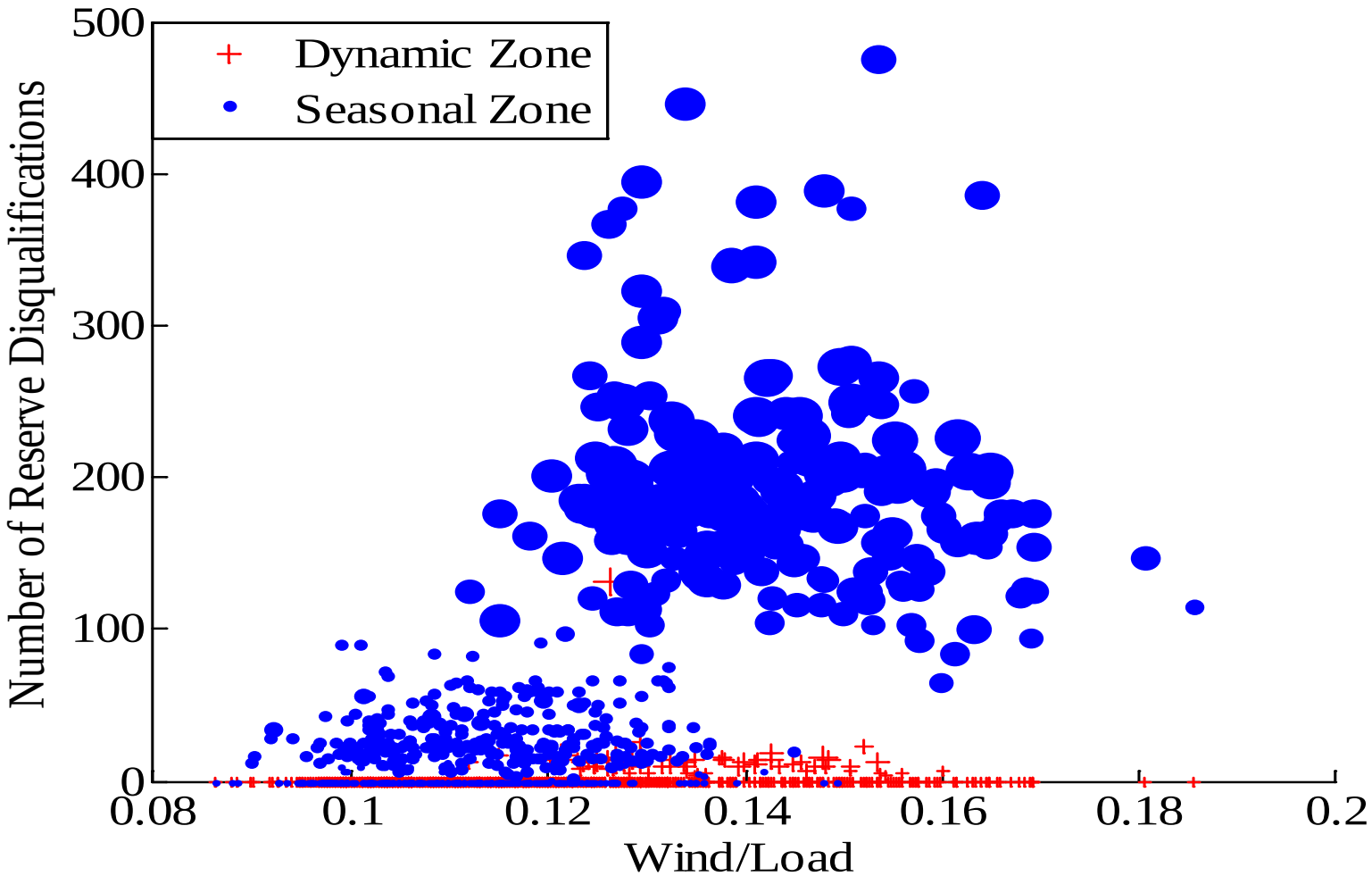




Market Implications and Pricing with Dynamic Reserve Policies

Numerical Results



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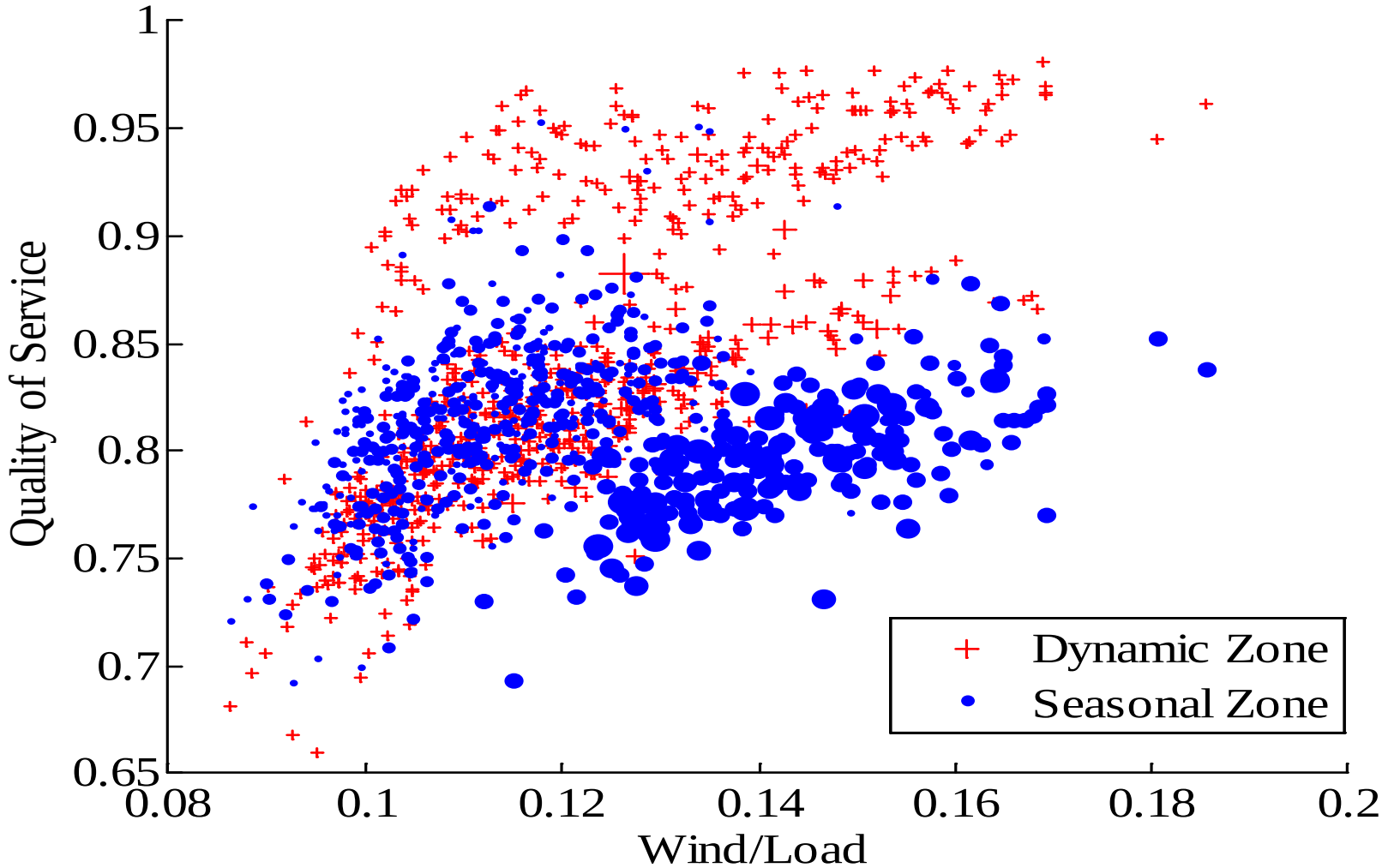

Numerical Results

	Seazonal Zone	Dynamic Zone
Initial Violations (MW)	304.99	1.94
#DQs	68	1.2
QOS	0.81	0.841
Production Cost	$1,903,388	$1,899,407
Load Payment	$7,855,149	$8,055,584
Energy Revenue	$7,161,551	$7,348,346
Reserve Revenue	$117,939	$144,466

Expected load shedding with wind (MW)

	Deterministic UC			Stochastic UC	
Date	Seasonal	Daily	Daily (Prob.)	Single Zone	Daily (Prob.)
2-January	6.5 (4.7, 116)	0.684 (2.1, 24)	0.36 (1.9, 14)	0.12 (0.6, 13)	0.09 (0.57, 10)
9-January	0	0	0	0	0
14-January	6.16 (3.5, 109)	0	0	0.31 (1.5, 15)	0
24-January	8.44 (4.6, 121)	0.16 (1.2, 11)	0	0.16 (0.9, 11)	0
5-February	0	0	0	0.1 (0.4, 11)	0
7-February	0	0	0	0.62 (1.0, 31)	0
14-February	0	0	0	0.64 (1.1, 30)	0
22-February	0	0	0	0	0
3-March	5.7 (3.3, 93)	8.55 (4.2, 132)	0	0	0
11-March	12.08 (6.5, 132)	7.52 (5.4, 87)	0.66 (1.3, 33)	0	0
14-March	0	0	0	0	0
26-March	3.38 (5.2, 41)	13.68 (8.5, 127)	0	0	0

α (β, δ): α represents the expected load shedding (MW), β represents the number of scenarios that have a violation per one thousand scenarios, and δ represents the largest violation (MW) from any single hour across the entire day.

Expected load shedding with wind and N-1 contingencies (MW)

	Deterministic UC			Stochastic UC	
Date	Seasonal	Daily	Daily (Prob.)	Single Zone	Daily (Prob.)
2-January	15 (2.5, 150)[2]	13.5 (3, 138)	10.7 (2.2, 109)	25.4 (3.2, 249)	9 (1.9, 117)
9-January	14.6 (2.4, 112)	12.2 (2.4, 90)	12.1 (2.3, 90)	21.6 (3, 235)	10.3 (2.6, 90)
14-January	11.7 (1.6, 142)	9.7 (1.5, 109)	7.7 (1.2, 90)	16.8 (2.6, 235)	5.4 (1.1, 84)
24-January	16.8 (3, 156)	20.2 (3.2, 212)	11.5 (2.6, 133)	30.2 (4.2, 270)	10.5 (2.3, 130)
5-February	15.6 (2.8, 183)	14 (2, 142)	13.1 (2.2, 118)	31.1 (3.8, 284)	12.5 (2, 121)
7-February	15.4 (3.4, 186)	14.4 (3.2, 187)	12.8 (3, 110)	30.3 (3.6, 280)	12.3 (2.5, 105)
14-February	15.4 (2.4, 193)	15.4 (2.4, 193)	9.6 (1.6, 111)	20.1 (3, 275)	9.3 (1.6, 107)
22-February	12.9 (2, 145)	13 (2, 148)	11.2 (1.6, 82)	20.8 (3, 287)	10.7 (0.6 , 90)
3-March	7.7 (1.2, 108)	8.5 (1.3, 158)	7.9 (1.4, 108)	8.9 (1.4, 132)	7.5 (1.2, 103)
11-March	11 (1.7, 157)	10.6 (1.6, 149)	7.2 (1.2, 87)	11.7 (1.8, 189)	8.3 (1.4, 87)
14-March	11.8 (2, 171)	12.1 (2, 183)	11.7 (2, 169)	12.7 (2, 90)	10.8 (2, 158)
26-March	14.1 (2.4, 142)	14 (2.4, 142)	9.9 (1.7, 120)	14.8 (2.4, 166)	8.8 (1.6, 124)

α (β, δ): α represents the expected load shedding (MW), β represents the number of scenarios that have a violation per one thousand scenarios, and δ represents the largest violation (MW) from any single hour across the entire day.