Robust and Dynamic Reserve Requirements (1.3)

Kory W. Hedman
Arizona State University
(Kory.Hedman@asu.edu)
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  • 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

Days – months in advance  
Day-ahead  
Ongoing

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

Days – months in advance

Offline
determine scheduling inputs

Within
day-ahead model

Ex-post uneconomic adjustments

Day-ahead

Ongoing

- Deterministic unit commitment
- Reserve policies as a function of congestion
Path to Reliability

Days – months in advance

Offline
- determine scheduling inputs

Day-ahead

Within day-ahead model

Ex-post uneconomic adjustments

Ongoing

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]

Zone Determination Procedures

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

**Traditional Seasonal Zones**
- Identify bottlenecks / historical info → Statistical clustering → Apply zones to day-ahead UC

**Day-Ahead Dynamic Zones**
- Baseline zones → Uncertainty modeling / scenarios (e.g., wind) → Network information (e.g., PTDFs)
  - Probabilistic power flow → Statistical clustering → Apply zones to day-ahead UC

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]:

<table>
<thead>
<tr>
<th>Expected Violations (via contingency analysis)</th>
<th>Traditional Seasonal (3 Zones)</th>
<th>Stochastic Programming (Single Zone)</th>
<th>Daily Dynamic Reserve Zones (3 Zones)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.0 MW</td>
<td>20.6 MW</td>
<td>10.6 MW</td>
<td></td>
</tr>
<tr>
<td>Solution Time</td>
<td>18 s</td>
<td>339 s</td>
<td>26 s</td>
</tr>
</tbody>
</table>

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


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

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

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**