Challenges and Opportunities for Applying Advanced Optimization Techniques to Large Scale Electricity Market Systems

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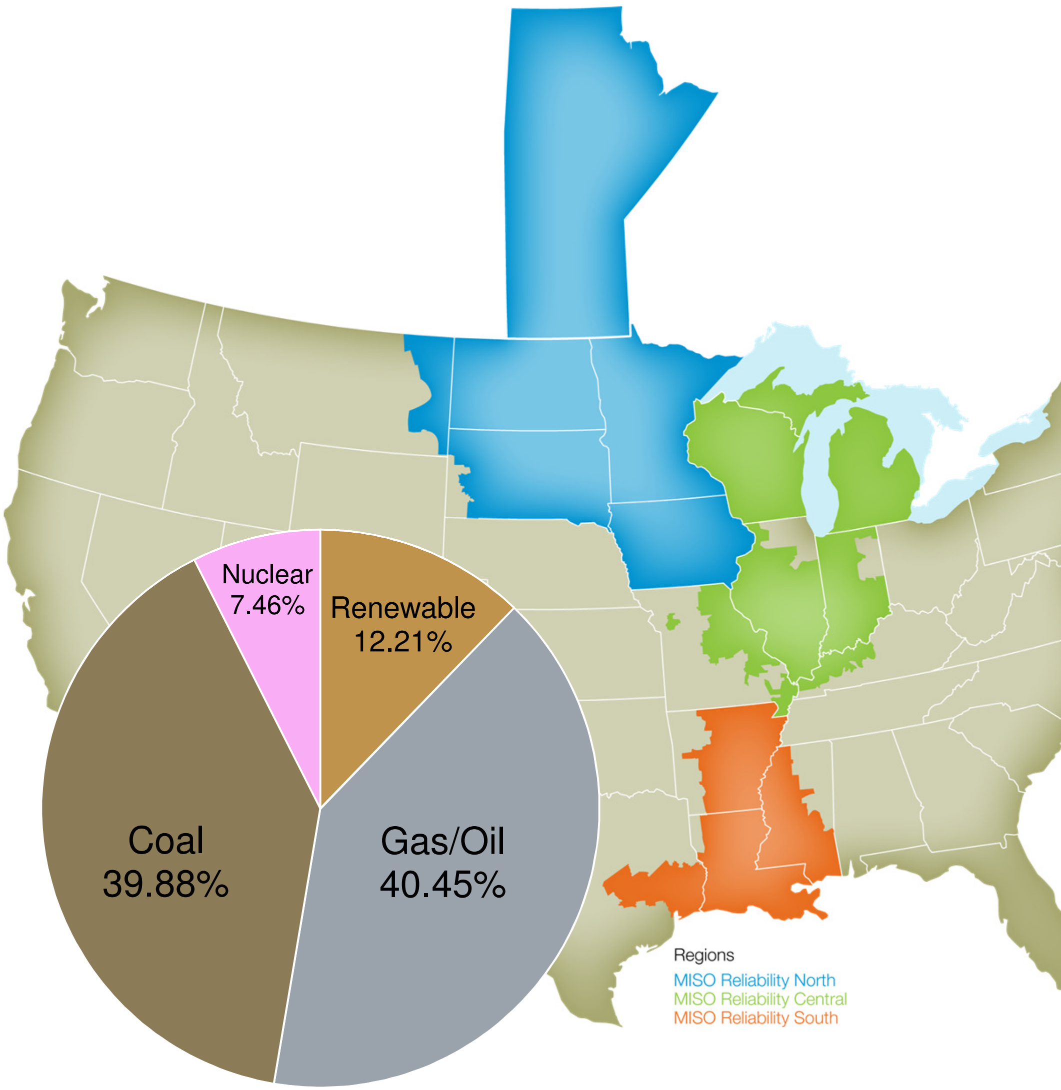
MISO Facts



Key Statistics

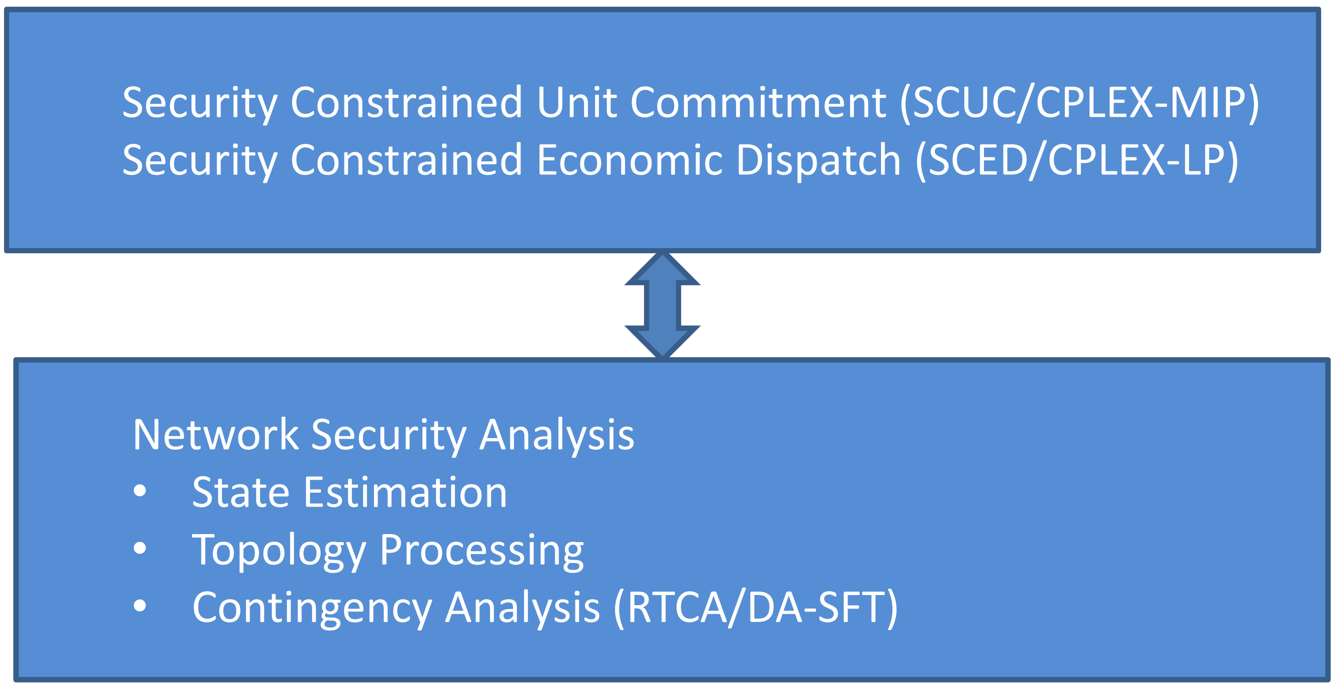
Market Participants	408
MWs of Generating Capacity (Mkt)	178,140
Peak Load (MW)	132,893
Generating Units (Market)	1390
Network Buses	43,962
Miles of Transmission Lines	65,800
Square Miles of Territory	900,000
States Served	15 Plus Manitoba Province, Canada
Millions of People Served	42

Unique Challenges of MISO Market System

Large network and market model with diverse resources and equipment types	• 43,962 network buses • 1,390 generating units with 178,140 MW capacity (market) • Large number of transmission constraints: ~200/h in DA case • Phase shifters, HVDC, combined cycles, storages, ……
Large number of pricing nodes and market activities	• 2440 pricing nodes • Virtual transaction volumes tripled in the past few years
Managing higher level of uncertainties	• Wind capacity: 2005 - 500MW 2013 - 12,000MW • Loop flows and transactions
Tight market clearing window	• Targeted to reduce day-ahead clearing window from 4 hours to 3 hours for better gas-electricity coordination

MISO Market Clearing System from Alstom

- Iterations between SCUC/SCED and network applications
  - Impossible to include full network models for base case and N-1 contingencies
    - SCUC and SCED use CPLEX to solve MIP and LP



Market Clearing Process

Simplified market model requires manual actions and iterations

- DC power flow model in day-ahead
  - Developed tools to analyze and account for differences between AC and DC flows
  - Required manual commitment for voltage issues

Other iterative business processes

- Iteration with Independent Market Monitors (IMM) for mitigations

"What-if" analysis on commitment justifications

- Avoid participants' dispute on "out-of-the-money" resources.
- May lead to adjustment on disputable commitment results due to MIP gap
  - e.g. not committing wind units with close to 0 cost since the impact to the objective is less than MIP gap

Market Clearing Process

- Prepare and adjustment to case inputs from operators
- Adjustment from IMM
- “What-if” analysis

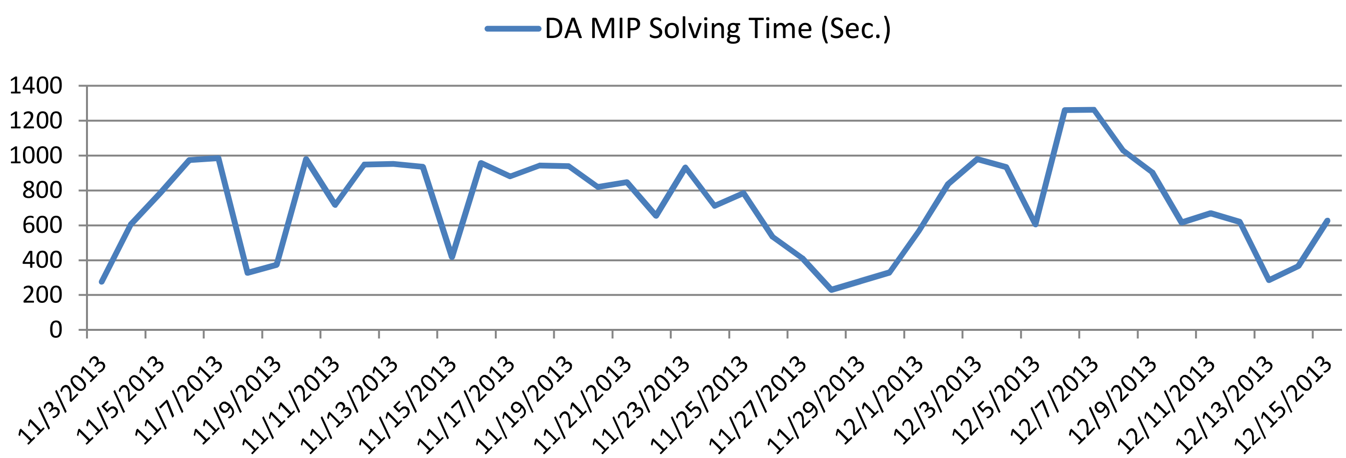
Security Constrained Unit Commitment (SCUC)
Security Constrained Economic Dispatch (SCED)

Network Security Analysis

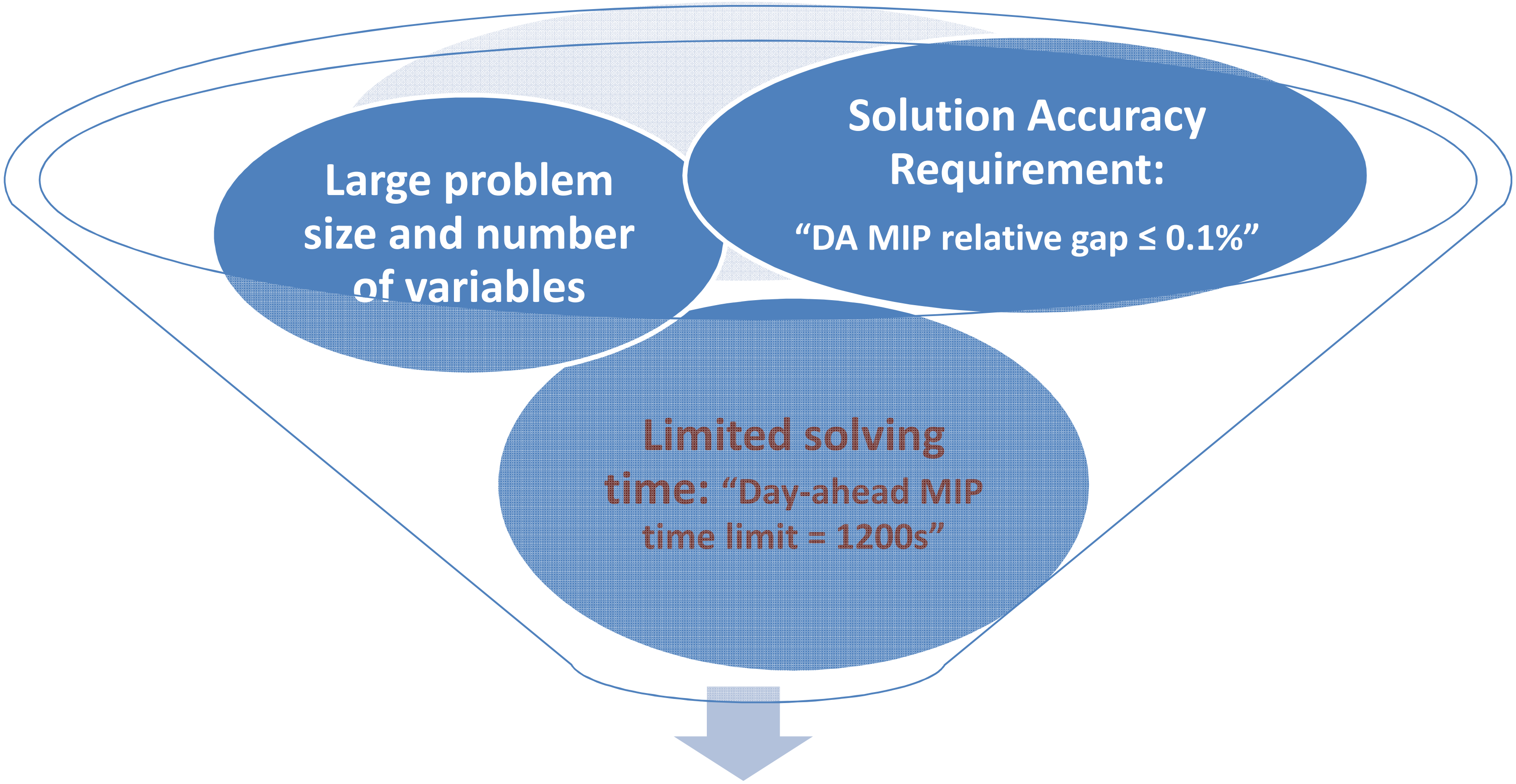
- State Estimation
- Contingency Analysis (RTCA/SFT)
- Topology Processing

MIP Solver Based SCUC

- MIP solvers
  - "Branch & bound" + "heuristics"
  - Feasible solution (upper bound) and lower bound
    - MIP gap to indicate the quality of the solution
- Observations
  - MIP solvers can solve very reliably most of the time
    - MISO SCUC problems are mostly solved with heuristics at the root node
    - Uncertainty of solving time depending on when the heuristics are triggered
  - MIP solvers may solve with large gap at the time limit for a small percentage of cases



Challenge for MIP Solvers



Small percentage of DA cases solved with large MIP gaps

Primarily driven by large number of **transmission constraints** and **virtuals**

Experience from MISO DA SCUC

Number of binaries:

Not the single contributor of performance challenges

- Without transmission constraints, MISO DA cases can solve in ~100s

Very dense matrices from **transmission constraints** and **continuous virtual variables** can drive performance challenge

- Bad performance cases happened under a large number of virtuals and transmission constraints

MIP may not solve faster even if it is fed with a better initial solution

- Does not work well when multiple iterations are required
- Need to develop algorithm to solve SCUC incrementally in order to improve DA clearing process

R&D Activities to Improve DA SCUC Performance

Long term: working with R&D groups on the optimization solver side

- Shared sample bad performance cases in MPS format with MIP solver vendors
  - Some improvement from parameter tuning and new heuristics
- Also added “indicators” to mark transmission constraints and virtuals for the R&D groups to explore new algorithms
- Exploring hardware options (MISO-IT/IBM)
- No silver bullet solution yet

Developed backup solving approaches (MISO/Alstom)

- LR based approach and decomposition based approach
- Lack of good low bound and gap information
- MIP solver will still be the primary solving approach

Developing approaches for improving DA processes (MISO/Alstom)

- Solution polishing and incremental SCUC solving: “LR + Reduced MIP”
- Commitment justification: “Relaxed MIP + sub-gradient ”
- Improving the iteration between SCUC/SCED and Network Applications

Future Market Development

- Configuration based combined cycle (CC) modeling
  - Lots of interests from participants
  - Prototype case study on MISO testing cases prior to South Region integration
    - 27 CC groups - about 1150 resources
  - Critical to tighten binary constraints
    - MIP solving time initially increased from ~200s to ~1300s
      - The number of binary variables increased by ~70%
      - By tightening the constraints, the solving time can be significantly reduced to ~500s
  - After south integration
    - ~50 CC groups - 1390 resources
- R&D plan:
  - Further improvement of the optimization model
  - Explore the possibility of combining LR based approach with MIP solver

Future Market Development

- Voltage and local reliability (VLR) commitment
  - Significant amount of work on manual commitment for south region load pockets with complicated rules

Option	Load Maximums	Description
A	Up to 2411	one 230kv unit
B	… 2590	one 230kv unit and (M2 or N3)
C	… 2827	one 230kv unit and (both M2 and N3)
D	… 2950	two 230kv units
E	…	…..

  - Exploring to incorporate the rules into SCUC by adding binary variables and constraints
  - Eventually: ACOPF?
    - Is it possible to have localized AC model for VLR commitment?
- Voltage control
  - Minimize losses and optimize voltage profiles

Future Market Development

- Virtual spread product in DA
  - Expect significant increase of virtual volumes
- Phase shifter control
  - Real world needs to incorporate phase shift control for proper dispatch and pricing
  - Preliminary investigation:
    - Modeling of post-contingency control can result in significant increase of variables and phase shifter flow constraints. For each phase shifter:
      - One angle variable under base case
      - One angle variable under each contingency
      - One phase shifter flow constraint under base case
      - One phase shifter flow constraint under each contingency
    - Nonlinear by nature: dead band, tap steps
    - Optimize phase shifter may avoid expensive re-dispatching

Future Market Development

- Robust optimization and stochastic unit commitment
  - Collaborated with Alstom and University of Florida on applying robust optimization to MISO Look-ahead Commitment
    - Increase of continuous variables and constraints
    - Master problem becomes harder and harder to solve
      - The third iteration of the Master problem takes extremely long time to solve
    - A long way to go for production implementation
    - RAC problem is much more challenging

Summary

- Large scale RTO/ISO: increased societal benefit
- Requirement of advanced modeling and computational techniques on market clearing engines
  - More resource and network equipment mixes:
    - Combined cycle, HVDC, phase shifter, storage, ……
  - Increased problem size and variables
  - Increased number of transmission constraints, pricing nodes and financial activities that can drive dense matrix
  - Increased uncertainty
- Need more collaboration
  - Across multiple disciplines
  - Between industry and academia