Mixed-Integer Programming Solution at the CAISO
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MIP at the CAISO

As part of its Market Redesign and Technology Upgrade (MRTU), the is implementing Mixed Integer Programming (MIP) Solution

In 2003 CAISO executed a Proof-of-Concept to ensure solution meets performance and solution requirements

Planned implementation date of April 1, 2008
MIP at the CAISO

- Large number of transmission constraints
  - Up to 2000 binding constraint for 24 intervals, 150 contingencies
- Nomograms
  - Simultaneous interface vs. interface limits or interface vs. generation output limits
- Ancillary Service and Energy Co-optimization
  - Decision to procure A/S based on resources constraints
- Dynamic ramp rates
  - Different ramp-rates at different operating levels
- Resource on/off decisions
  - Minimum up time, minimum down time, maximum starts/day
- Forbidden Region of Operation
  - Operating regions can be crossed but not maintained inside
- Energy Limitation Constraints
  - Maximum amount of energy or hours of availability
- Pump/Storage Modeling
  - Decision regarding pumping or generation operational mode
- Constrained Output Generator (COG) (Pmin=Pmax) Dispatch and Pricing
## Current vs. Planned Approaches

<table>
<thead>
<tr>
<th>Market Area</th>
<th>Current Approach</th>
<th>Planned Approach</th>
<th>Date of Planned Implementation of MIP</th>
<th>Estimated Annual Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real-time market look ahead</strong></td>
<td>LR used for 2 hour look ahead commitment and dispatch</td>
<td>MIP: 2 hour look ahead for dispatch. As long as 5 hours for commitment.</td>
<td>April 1, 2008</td>
<td>~$100,000-$1 million (0.1%-1%1 of 2006 RT Dispatch Costs and RT RMR Costs2: $97 million)</td>
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<tr>
<td><strong>Residual unit commitment</strong></td>
<td>Procedural based operator judgement advised by a MIP based UC with no network</td>
<td>Run a MIP, Full Network Model based on Residual Unit Commitment after Day-Ahead bid market.</td>
<td>April 1, 2008</td>
<td>~$100,000-$1 million (based on 0.1% - 1% of Total Minimum Load Costs for 2006: $106 million)</td>
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<tr>
<td><strong>Day-ahead market</strong></td>
<td>Linear Programming: No unit commitment, No Energy Optimization, Allocation of Transmission only using zonal model</td>
<td>Run a MIP based SCUC/SCED, Full Network Model program, Energy and A/S co-optimized</td>
<td>April 1, 2008</td>
<td>~$2.3-$23 million (Assumes an estimated 0.1%-1% reduction of $11.4 billion Energy and Ancillary Service)</td>
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<tr>
<td><strong>Capacity market</strong></td>
<td>None</td>
<td>Policy being considered</td>
<td>Policy being considered</td>
<td>No Estimate</td>
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<tr>
<td><strong>Ancillary service market</strong></td>
<td>Linear Programming sequential procured after Transmission Allocation</td>
<td>Run a MIP based SCUC/SCED, Full Network Model program co-optimized with energy</td>
<td>April 1, 2008</td>
<td>~$230,000-$2.3 million (0.1%-1%1 of 2006 A/S costs2 of $234 million)</td>
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<tr>
<td><strong>planning</strong></td>
<td>Powerflow studies</td>
<td>No immediate plans to incorporate MIP</td>
<td>No immediate plans to incorporate MIP</td>
<td>No Estimate</td>
</tr>
</tbody>
</table>
Facts about the MIP Solution and Testing Observations

- ~35,000 integer variables
- Up to 2000 Binding Constraints for 24 intervals
- DAM 24 hour simultaneous intervals run ~ 1 hour computing time
  - 2 passes, 1 – Market Power Mitigation / Reliability Requirements
  - 1 pass – Integrated Forward Market (Energy and A/S)
  - 1 pass – Residual Unit Commitment
  - 1 pass = 3-4 SCUC-NA Iterations, 1 scheduling run, 1 pricing run
- RT Unit Commitment up to 18-15 minute intervals ~ 12 minutes computing time
  - 2 passes, 1 – Market Power Mitigation / Reliability Requirements
  - 1 pass, Real-Time Unit Commitment and A/S procurement
  - 1 pass = 3-4 SCUC-NA Iterations, 1 scheduling run, 1 pricing run
- RT Dispatch up to 13-5 minute intervals ~ 2.5 minutes
  - 1 pass, Real-Time Dispatch
  - 1 pass = Security Constrained Dispatch
  - 1 scheduling run, 1 pricing run,
- MIP Gap ~ 0.2%-0.5% for 24 hour DA runs, Lower MIP Gaps can be achieved if allowed to run longer
- Observed more constraints enforced sometimes results in faster solution within MIP Gap
Future Market Initiatives That May Leverage MIP Capabilities

- Modeling of Combined Cycle Resources
  - Multiple Start-up functions
  - Start-up decisions of different stages of
- Demand Response
  - Curtailment Decisions
  - Shut-down constraints
  - Linkages between different demand
- Increase number of ramp rates
  - Different ramp-rates at different operating levels
- Enhance Forbidden Region with Hold-Time Constraints
  - Must stay above forbidden region for specified period of time
- Application of Priorities
  - Possible replacement of penalty functions to enforce scheduling priorities (i.e. ETC, RMR, TOR, Self-Schedules....)
- Multi-Day Optimization
  - Improve cross-day unit commitment decision making and avoid unnecessary cycling