Improving Day-ahead Market Efficiency through Advanced Combined Cycle Modeling

FERC TECHNICAL CONFERENCE ON INCREASING REAL-TIME AND DAY-AHEAD MARKET EFFICIENCY THROUGH IMPROVED SOFTWARE
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Outline

• Introduction
• CCP Participation in ERCOT Nodal Market
• Combined Cycle Modeling in SCUC
• Challenges
• Implementation and results
• Summary
Introduction

Typical Combined Cycle Plant
Introduction
ERCOT’s Combined Cycle Fleet

• Combined Cycle Plants (CCPs) provide a significant portion of ERCOT generation capacity (~20%).

• ERCOT system includes more than 60 CCPs in the ERCOT system.

• More than 260 different CCP configurations have been registered.

• The most complex CCP includes:
  • 6 (CTs) X 3 (STs)
  • 17 configurations
ERCOT Nodal Market
Day Ahead Market (DAM)

• DAM is a financial market which co-optimizes
  • Energy offers (3 part offers)
  • Ancillary Services
    o Online: Reg-up, Reg-down, Responsive Reserve, Non-Spin
    o Offline: Non-Spin
  • Both CRR options and PTP obligations
  • Energy-only bids and offers (virtual bids and offers)
  • Block bidding for both generator and AS offers

• Network security constraints with more than
  • 6000 buses
  • 2,000 contingencies

• Dec 1, 2010 ERCOT nodal successfully went live
• 3 Part Offer and online reserves can be submitted separately for each CCP configuration.

• Offline non-spin offer can be submitted only for CCP configurations that are registered as a startup configuration.

• For each time interval:
  • Only one CCP configuration is awarded energy / online reserve
  • Either offline non-spin or energy/online reserve is awarded -- not both
CCP Participation in ERCOT Nodal Market
Reliability Unit Commitment (RUC)

• RUC is a daily or hourly process to commit additional
generation capacity on top of self-committed capacity
to meet the forecast demand.

• The participation in RUC is mandatory for all available
resources.

• All registered CCP configurations are decision
variables.

• If a CCP configuration is already self committed in an
hour, then RUC will not transition the CCP to another
configuration in the same hour.
DAM and RUC Solution Engine

Security Constrained Unit Commitment (SCUC)

- Network security based unit commitment utilizing:
  - Network Security Monitor (NSM)
    - Physical unit-based model
  - Network Constrained Unit Commitment (NCUC)
    - Configuration-based model

- Special Interface between NCUC and NSM
  - NCUC → NSM: Disaggregation of the base point
  - NSM → NCUC: Aggregation of the shift factors
CCP Modeling in SCUC
Configuration-based Model

- Each configuration is treated as a generation resource in the market.
- Each configuration has its own set of data:
  - Generation cost curves (Start up, min gen and incremental cost)
  - Reserve availability and costs
  - Operating Limits
  - Minimum/Maximum up time
  - Minimum down time
  - Maximum number of daily start up
- Different configurations are exclusive at the same time interval
- Using transition matrix to link different configurations.
## CCP Modeling in SCUC

### Configuration Registration

<table>
<thead>
<tr>
<th>Configuration ID</th>
<th>Configuration Type</th>
<th>Primary Unit(s)</th>
<th>Alternative Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1CT</td>
<td>CT1</td>
<td>CT2</td>
</tr>
<tr>
<td>2</td>
<td>2CT</td>
<td>CT1, CT2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1CT+1ST</td>
<td>CT1, ST</td>
<td>CT2</td>
</tr>
<tr>
<td>4</td>
<td>2CT+1ST</td>
<td>CT1, CT2, ST</td>
<td></td>
</tr>
</tbody>
</table>

- For an outaged primary Combined Cycle Unit (CCU) with multiple alternates, DAM/RUC selects
  - Alternative CCU with highest voltage level
  - Alternative CCU with highest capacity
  - Alternative CCU that is first in the database (i.e., random)
Transition matrix defines:

- Allowed transitions between:
  - Different configurations
  - Configurations and off

- Transition directions:
  - “up” and “down” transitions
CCP Modeling in SCUC
Start Up and Transition Modeling

**Startup**
- Considers start up cost
- Considers Min up time; Min down time; Max up time; Max # of daily startups

**Up Transition**
- Considers transition cost
  \[
  \text{Transition cost } [1 \rightarrow 2] = \max(0, \text{StartupCost } [2] - \text{StartupCost } [1])
  \]
- Considers Min up time; Min down time; Max up time; Max # of daily startup

**Down Transition**
- Considers Max on time only
Warmth state determination:

- Startup cost: based on the offline time of the entire CCP
- Transition cost: based on the offline time of the “to” configuration

Assume Hot to Intermediate as 2.5 hrs and Intermediate to Cold as 2 hrs

CC1_1 has been off for 5 hrs → Warmth state is Cold

CCP is offline for 2 hrs → Warmth state is Hot

Down transition → No cost

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• All ERCOT generators can self-schedule at selected times
  • If a generator follows its self-schedule, then no need to satisfy its min up/down time constraints.
  • If a generator deviates from its self-schedule, then resulting schedule has to satisfy min up/down time constraints.
  • If a generator starts at $T$ and is on from $T$ until the time it is self-scheduled, then the generator incurs no startup cost at $T$

• The above rules introduce additional complexity to the CCP modeling in SCUC
Implementation Challenges
A Large Complex Optimization Problem

• Formulated as a Mixed Integer Programming (MIP) Problem
  • Large data volume:
    o For example:
      (transition cost curve) * (transition matrix) * (# of CCPs) * (24 hours)
  • Large decision space:
    o All possible transition paths to be evaluated in the tree

• The Self Scheduling logic adding exceptions to every constraint

• Needed intelligent problem formulation to meet challenging performance requirements

• Infeasibility cause detection:
  • Required a smart way to detect and a user friendly way to report the root cause of infeasibility
Results from the First 6-month of Operations Reported by ERCOT

• “Energy prices in the first six months averaged $30-$35 a megawatt hour (MWh), compared to $55-$60 in the zonal market during the same time last year”

• “Costs for regulation reserves – energy used to regulate grid frequency – were $35.8 million less under nodal compared to the previous year, due to improved congestion management tools in the nodal market…”

• “...using estimated costs for 22.5 hours of unresolved congestion in 2008, the ability to manage that congestion with the nodal tools available today would have reduced the load charges by $90-$180 million had it been in place in 2008.”
Summary

• Market participants including CCPs actively participate in the DAM:
  • Cleared DAM volume is within +/- 3% of the load forecast.

• Market prices have improved and indicate a healthy market
  • Convergence of the day-ahead and real-time prices.

• The system meets its challenging performance requirements

• Advanced combined cycle scheduling works!
  • Behavior matches what market participants anticipated
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