



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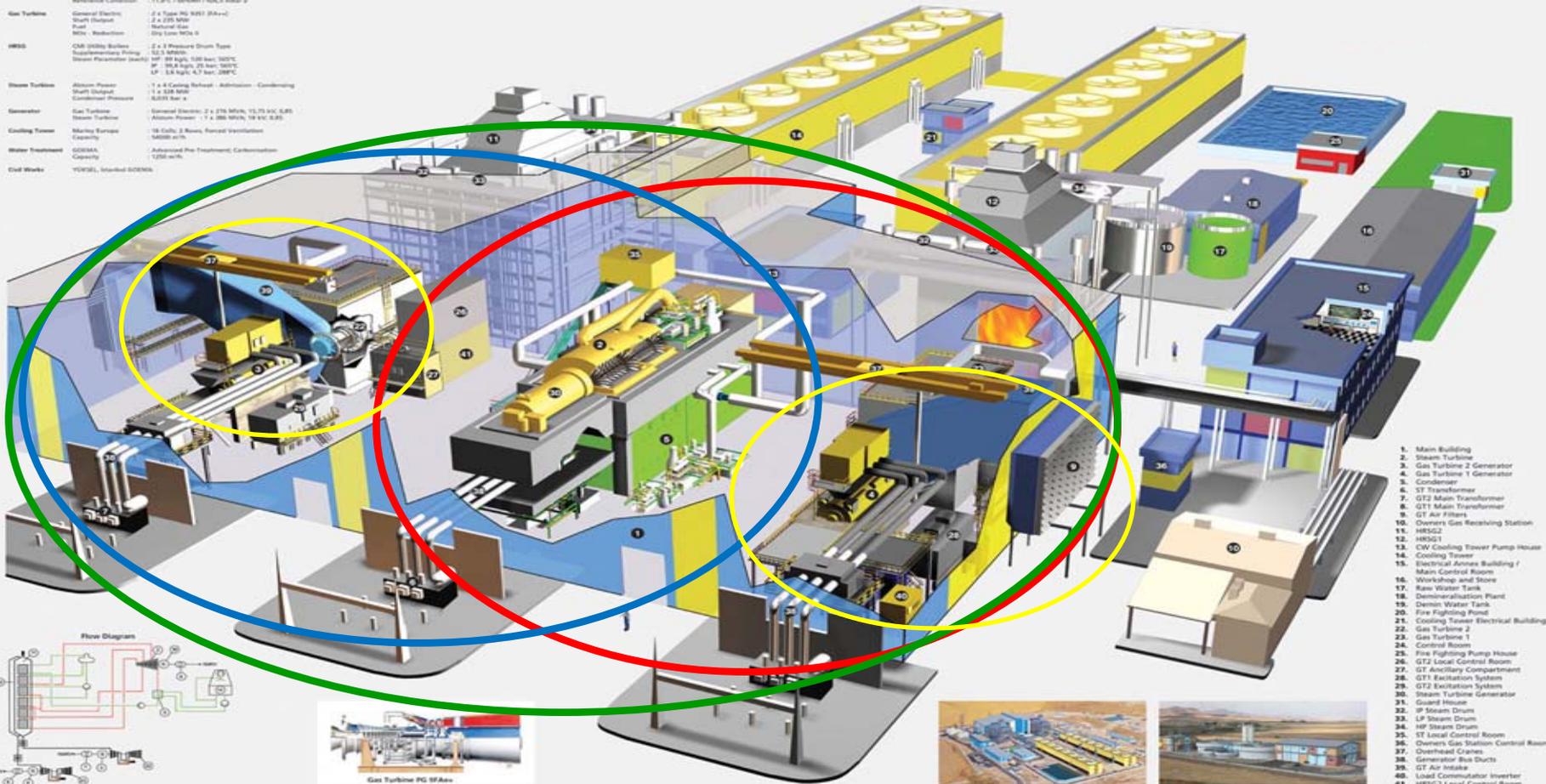
- **Introduction**
- **CCP Participation in ERCOT Nodal Market**
- **Combined Cycle Modeling in SCUC**
- **Challenges**
- **Implementation and results**
- **Summary**

Introduction

Typical Combined Cycle Plant

Technical Main Data:

Total Plant	Net Electrical Output: 2,275 MW Net Heat Rate: 8,000 kJ/kWh Reference Condition: 1.01325 bar(a), 15°C, 60% RH
Gas Turbine	General Electric: 2 x 2 x 9FA 93 (30+3) Shaft Output: 2 x 2,275 MW Fuel: Natural Gas MFC - Reduction: Dry Low NOx II
HRSG	CM 10000 Boiler: 2 x 3 Pressure Drum Type Supplementary Firing: 2 x 2,275 MW MF: 90 kg/s, 530 bar, 522°C MF: 100 kg/s, 530 bar, 522°C LP: 1.8 kg/s, 4.7 bar, 280°C
Steam Turbine	Alstom Power: 1 x 4 Cooling Reheat - Admission - Condensing Shaft Output: 8,000 MW Condenser Pressure: 0.075 bar a
Generator	Gas Turbine: General Electric: 2 x 2,275 MW, 15,75 kV, 5,000 A Steam Turbine: Alstom Power: 1 x 8,000 MW, 18 kV, 8,000 A
Cooling Tower	Marley Surpass: 10 Cells, 2 Rows, Forced Circulation Capacity: 5,000 m ³ /h
Water Treatment	CGEMA: Advanced Pre Treatment, Carbonation Capacity: 1,500 m ³ /h
Civil Works	YOKES, Incelec SOGESA



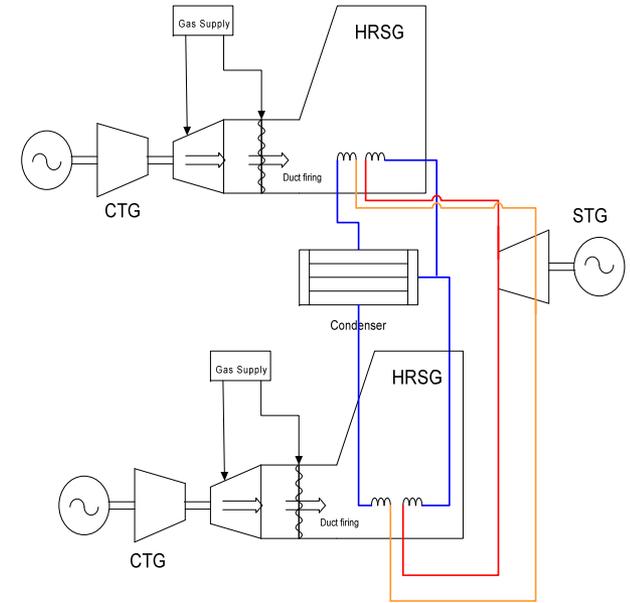
1. Main Building
2. Steam Turbine
3. Gas Turbine 2 Generator
4. Gas Turbine 1 Generator
5. Condenser
6. ST Transformer
7. GT2 Main Transformer
8. GT1 Main Transformer
9. GT Air Filters
10. Owners Gas Receiving Station
11. HRSG2
12. HRSG1
13. CW Cooling Tower Pump House
14. Cooling Tower
15. Electrical Annex Building / Main Control Room
16. Workshop and Store
17. Raw Water Tank
18. Demineralisation Plant
19. Demin Water Tank
20. Fire Fighting Pond
21. Cooling Tower Electrical Building
22. Gas Turbine 2
23. Gas Turbine 1
24. Control Rooms
25. Fire Fighting Pump House
26. GT2 Local Control Room
27. GT Ancillary Compartment
28. GT1 Excitation System
29. GT2 Excitation System
30. Steam Turbine Generator
31. Guard House
32. HP Steam Drum
33. LP Steam Drum
34. HP Steam Drum
35. ST Local Control Room
36. Owners Gas Station Control Room
37. Overhead Cranes
38. Generator Bus Ducts
39. GT Air Intake
40. Local Commutator Inverter
41. HRSG2 Local Control Room

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Introduction

ERCOT's Combined Cycle Fleet

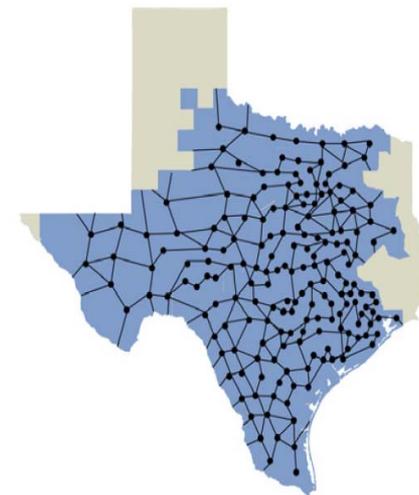
- **Combined Cycle Plants (CCPs)** provide a significant portion of ERCOT generation capacity (~20%).
- ERCOT system includes more than 60 CCPs in the ERCOT system.
- More than 260 different CCP configurations have been registered
- The most complex CCP includes:
 - 6 (CTs) X 3 (STs)
 - 17 configurations



ERCOT Nodal Market

Day Ahead Market (DAM)

- **DAM is a financial market which co-optimizes**
 - Energy offers (3 part offers)
 - Ancillary Services
 - Online: Reg-up, Reg-down, Responsive Reserve, Non-Spin
 - 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**



CCP Participation in ERCOT Nodal Market Day Ahead Market (DAM)

- **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)

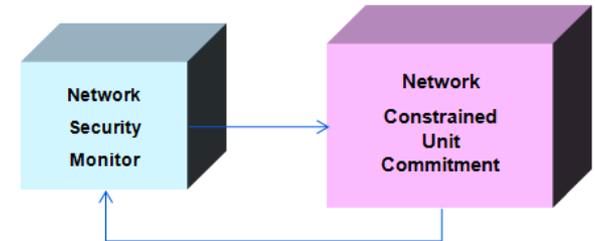
- **Network security based unit commitment utilizing:**

- **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

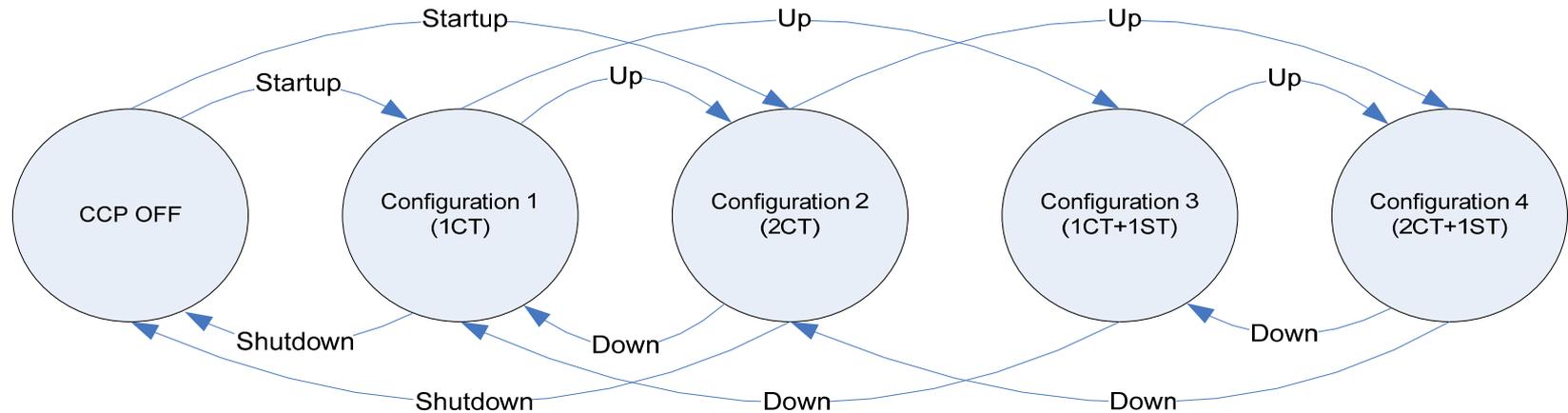
Configuration Registration

Configuration ID	Configuration Type	Primary Unit(s)	Alternative Unit
1	1CT	CT1	CT2
2	2CT	CT1, CT2	
3	1CT+1ST	CT1, ST	CT2
4	2CT+1ST	CT1, CT2, ST	

- 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)

CCP Modeling in SCUC

Transition Matrix



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
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

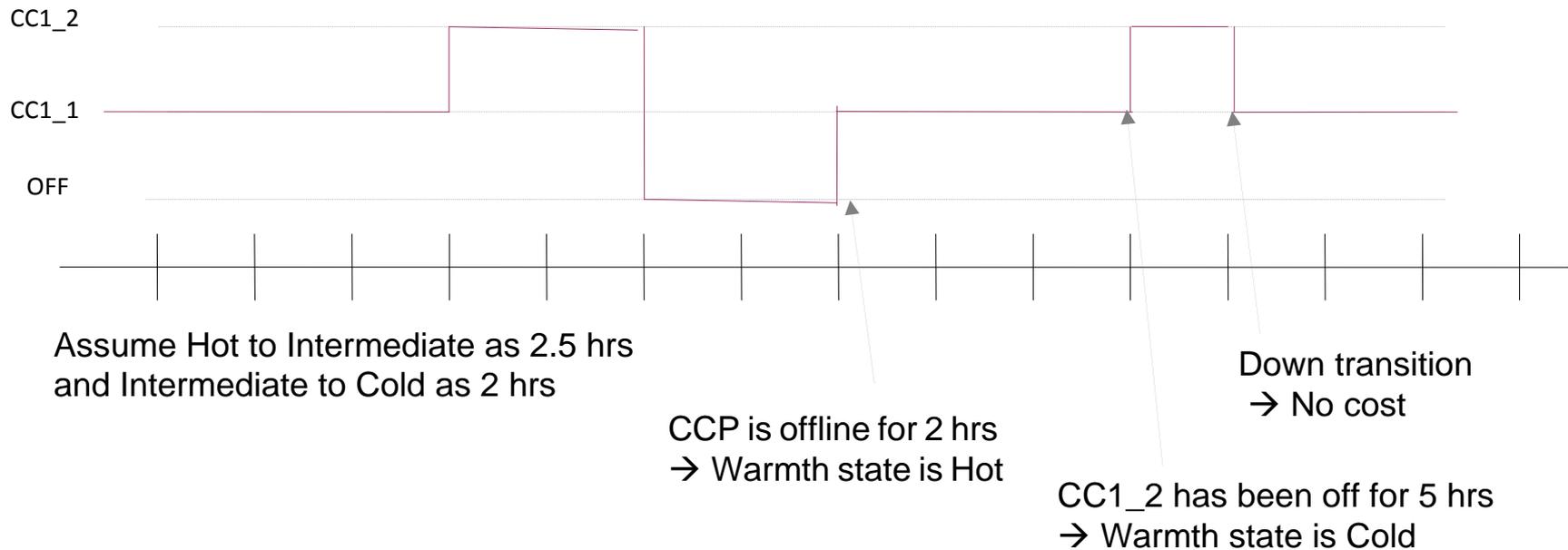
- Considers Max on time only

CCP Modeling in SCUC

Start Up and Transition Modeling

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



CCP Modeling in SCUC

RUC Self Scheduling

- **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:**
 - For example:
 $(\text{transition cost curve}) * (\text{transition matrix}) * (\# \text{ of CCPs}) * (24 \text{ hours})$
 - **Large decision space:**
 - 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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