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

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

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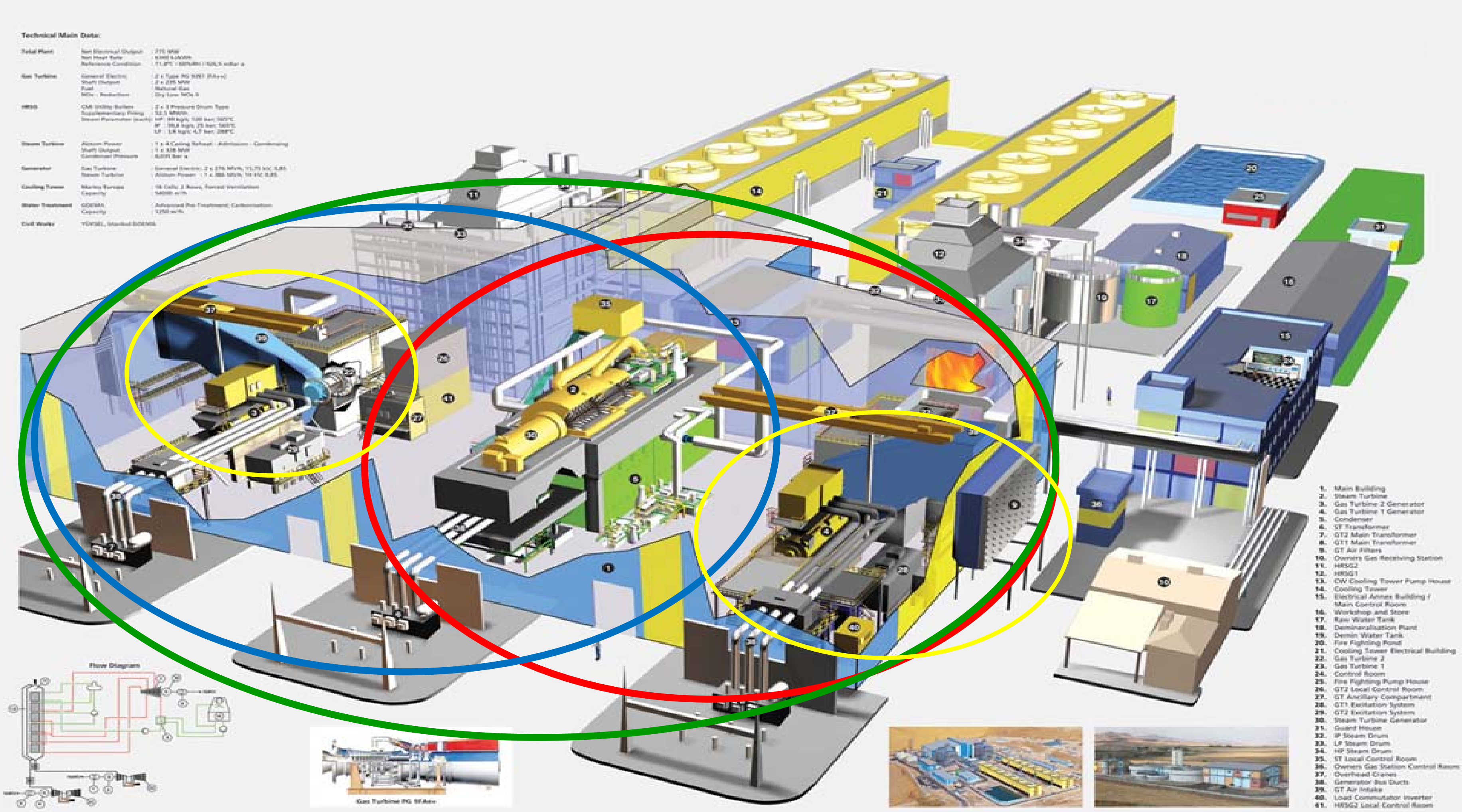
Introduction

Typical Combined Cycle Plant



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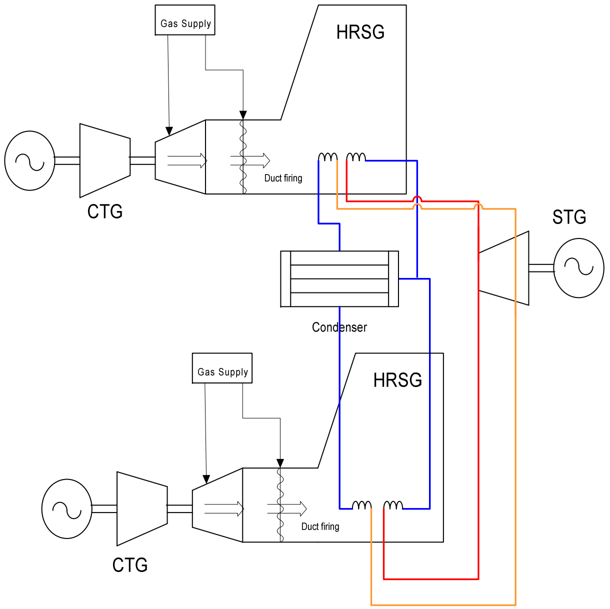
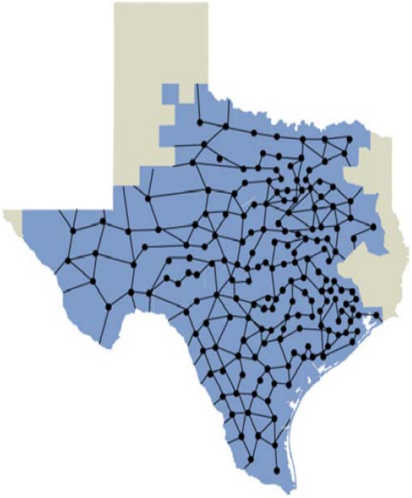
Introduction
ERCOT's Combined Cycle Fleet

- **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**

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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

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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.**

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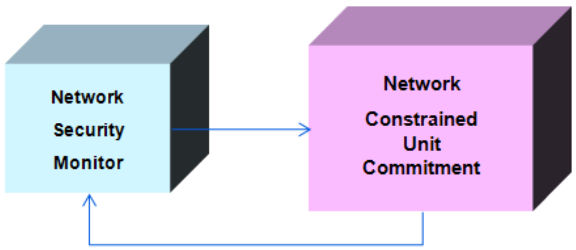
DAM and RUC Solution Engine
Security Constrained Unit Commitment (SCUC)

- **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

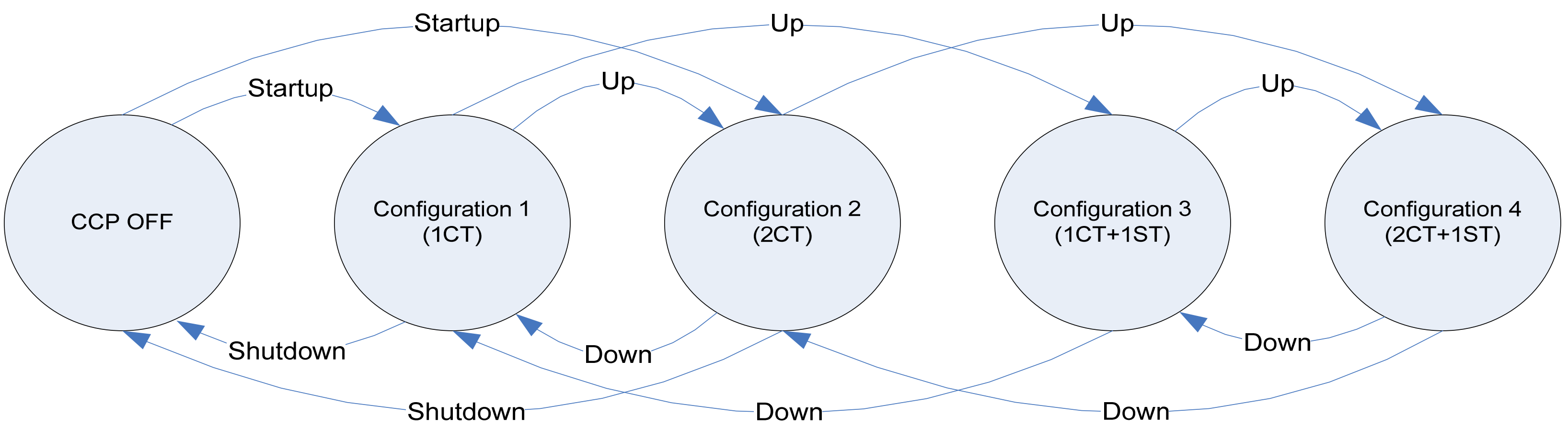
- **Each configuration is treated as a generation resource in the market.**
- **Each configuration has its own set of data:**
  - Generation cost curves (Start up, min gen and incremental cost)
  - Reserve availability and costs
  - Operating Limits
  - Minimum/Maximum up time
  - Minimum down time
  - 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:
  - o Different configurations
  - o Configurations and off
- Transition directions:
  - o “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→2] = max(0, StartupCost [2]– StartupCost [1])

- Considers Min up time; Min down time; Max up time; Max # of daily startup

Down Transition

- Considers Max on time only

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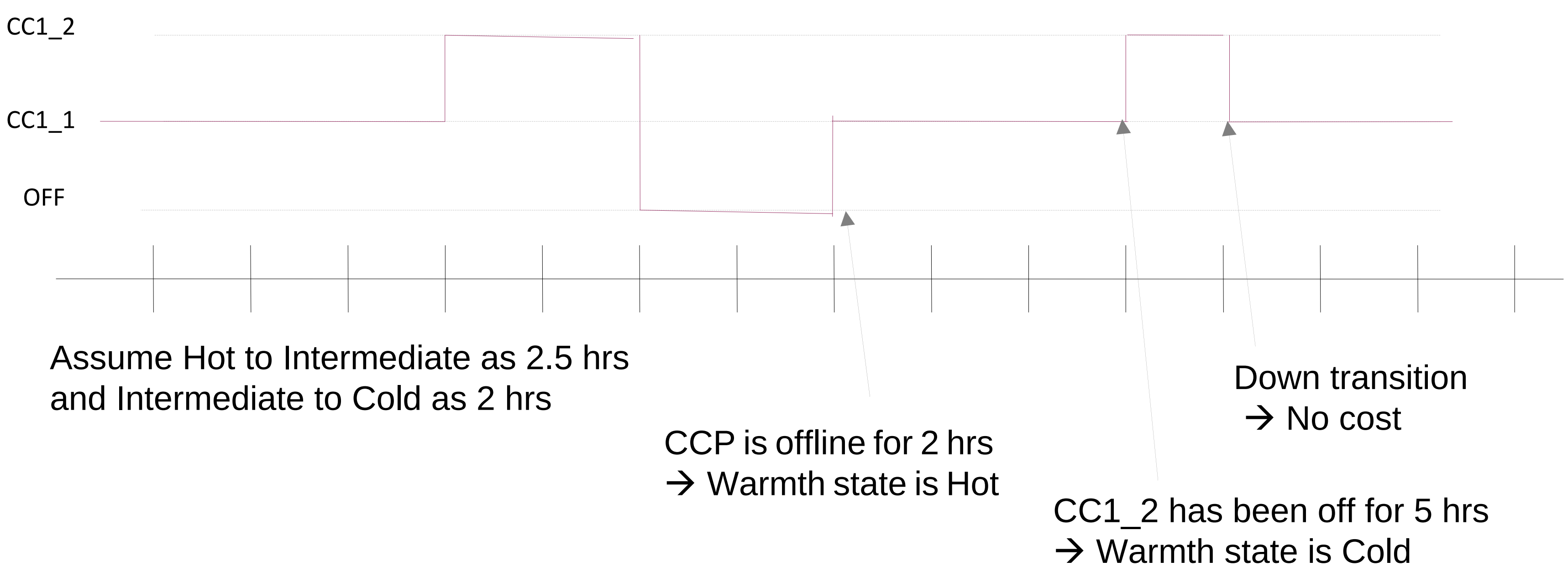
CCP Modeling in SCUC
Start Up and Transition Modeling

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**

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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

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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."

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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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