# Production Cost Models

Sourabh Dalvi

# Production Cost Models (PCM)

- Unit Commitment + Economic Dispatch models
- Scheduling problem to meet demand while minimizing cost
- Scheduling horizon - 24- 48 hr Look ahead - 24 hr
- Various formulations:
  - UC + DC OPF (B-$\theta$)
  - UC + Contingency Constraint
  - Stochastic UC
  - UC + Startup/ Shutdown trajectory
  - Linearized UC

## Main Components of PCM

- Modeling Startup/ Shutdown
- Satisfying operating constraints
  - Min up/down-time
  - Ramping
- Calculating non-linear cost (quadratic)
- Meeting forecasted Demand on an hourly /sub-hourly time scale

## Drawbacks

- Deal with at least one binary variable for each unit
- Cost function could be piecewise linear or quadratic
- Assumption of basic models
  - Instantaneous Start/Stop
  - Simplified operation of Plants
  - Perfect foresight
  - Ignore system inertia
  - Ignore complex AC power flow dynamics

# Commonly used hack

- Model Piecewise Linear Cost without using binary variables, as total variable cost (generation cost) is always increasing
- Using last day's commitment for mipstart reduces solution time by more than 50%
- Fixing commitment of large units (Nuclear and Coal)
- Provide Branching hierarchy
    a. Cheapest unit first ( Add small noise to cost, if there are multiply similar units)
    b. Time
- Decomposing the problem according to balancing areas where transmission constraints can be relaxed and impose constraints on the power transmitted between balancing regions
- Solve only specific hours of the day with a representative scenarios set.

# Reformulation of the problem

- Compact
  - Increases the searching speed
  - Fewer constraints
  - Compact formulation may be less tight
- Tight
  - Reduces the search space
  - Fewer binary variables or more restricted variables
  - Tighter formulation may be less compact

Addition Components :

- Compact formulation for different types of Start-up (hot, warm, cold)
- Tight Start/Shutdown constraints (no need for binary variables for start/shutdown)
- Initial Condition constraints for Minimum Up/Down - time, ramping & commitment

# Flexibility Analysis of CC units

**100%**

Increase in Ramp rate

50% Faster Start-up Ramp

- How does the unit operate after the upgrades ?
- Does O&M Cost Change ?

**20%**

Increase in Maximum Generation Level

15 % Decrease in Minimum Generation Level

- Is it Committed more often ?
- How much of the upgrades does it use ?

**30%**

Decrease in Min-up and Min-down time

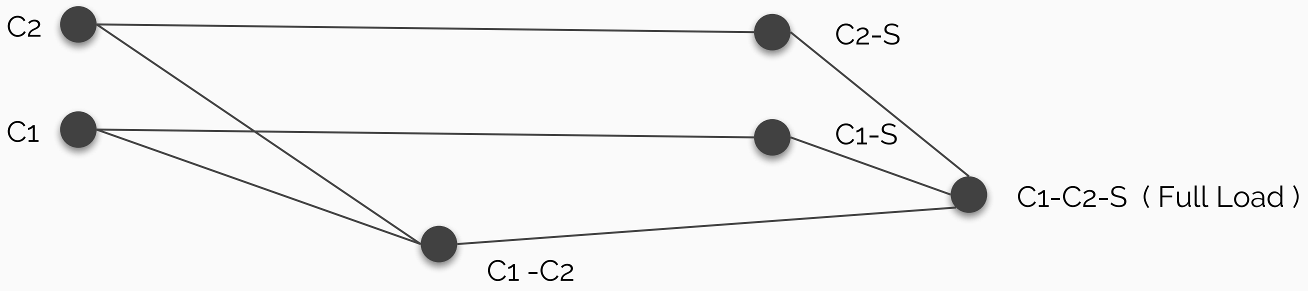
20 % Efficient Start-up (Hot Start only)

- How does its revenue change ?
- Are there any cost savings for ISO ?

# Combined Cycle Units

- Most models either consider them as one combined unit or n separate units
- Generally, CC units have multiple modes of operation depending on the type of the unit
  - Running only the CT's
  - Running some combination of available CT's and ST
- So the Steam is units always need to be turned on after at least one CT is online
- Modeling these operation modes needs
  - All units should be separate
  - Adding constraints to mimic the modes of operation

C1 , C2 - Combustion turbines
S - Steam Turbine




Operation of Traditional 2-on-1 Combined Cycle Unit

# Combined Cycle Modeling

- If we use the current set of binary variables we can model this behaviour

$$u^S \le u^{C1} + u^{C2}$$

  - Here variable 'u' is binary variable that indicates the status of the unit

- This still insufficient to represent the time lag to bring the ST online

$$v^S \le u^{C1} + u^{C2}$$

$$w^S \le u^{C1} + u^{C2} + w^{C1} + w^{C2}$$

  - $v^S$ - binary variable that indicates the start-up decision for ST
  - $w^S$ - binary variable that indicates the shutdown decision for ST
- Model CC as one unit and not have accurate representation of the start/shutdowns