Siemens Implementation CAISO Experience

ERCOT – METF Meeting for LA-SCED

April 26, 2012

Smart Grid Division

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Siemens Implementation sub-items:

- Real Time Unit Commitment
- Real Time Interval Dispatch
- Full Network Model Implementation
- Challenges
- Wind Power Management
- Future Needs at Review at CAISO

Siemens Framework for RT Market Applications

ERCOT SIEMENS California ISO Your Link to Power

Real Time Unit Commitment (RTUC)

- Configurable periodicity, no. of intervals, and interval duration for Security Constrained Unit Commitment (SCUC)
- CAISO configuration: Periodicity = 15m, Length of Interval=15m
- RTUC run types: Hour Ahead Scheduling Process (7 interval HASP), Short Term Unit Commitment (18 interval STUC), and Real Time Pre Dispatch (5 and 4 interval)
- Co-optimization of Energy and AS in a single process
- Detailed Resource Models: Highlights are combined cycle plants, start up and shut down profiles, storage models and demand response
- Up to 2500 binding constraints
- Full Network Model (FNM) representation - Full AC Power Flow and Contingency Analysis - 150 contingencies

Siemens Framework for RT Market Applications.. *(cont.)*

Real Time Interval Dispatch

- Configurable periodicity, no. of intervals, and interval duration
- Same SCUC engine used to meet the Security Constrained Dynamic Dispatch (SCDD) needs of Interval Dispatch
- CAISO configuration: every 5 minutes with uniform 5 minute long intervals covering a horizon up to 13 intervals (1 hour and 5 minute horizon)
- Network constraints from RTUC
- Topology Changes trigger Power Flow/Contingency Analysis in case of events
- Detailed Resource Models for Combined Cycle Plants, Start up and Shut down profiles, Storage Models, and Demand Response

Configuration of Market Software at CAISO

1 Security Constrained Unit Commitment (SCUC) pass:

- 3-4 MIP-PF/CA iterations
- Each MIP iteration with. scheduling and pricing runs

1 Security Constrained Dynamic Dispatch (SCDD) pass:

- 1 MIP iteration with scheduling and pricing runs
- Multiple interval dynamic ramping and forbidden operating region constraint enforced

DAM 24 hour simultaneous intervals run ~ under 1 hour computing time for 3 SCUC Passes

- 1 SCUC pass – Market Power Mitigation / Reliability Requirements (MPM)
- 1 SCUC pass – Integrated Forward Market (Energy and A/S) (IFM)
- 1 SCUC pass – Residual Unit Commitment (RUC)
- MIP Gap ~ 0.02% for 24 hour DA - IFM runs in about 10-20'

RT Unit Commitment (RTUC) executed every 15' up to 18 15' intervals ahead ~ 10' computing time for 2 SCUC passes

- 1 SCUC pass – MPM
- 1 SCUC pass, RTUC and A/S procurement

RT Dispatch executed every 5' up to 13 5' intervals ahead ~ 1' computing time

- 1 SCDD pass

CAISO Experience

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1. What other goals are the ISO's striving to address or has addressed …?

- Reduce Bid Cost Recovery uplift.
- Model physical resources inter-temporal constraints such as start-up time, min up and down time, ramping, and other inter-temporal constraints
- Schedule wheeling, and hourly flat inter-ties in HASP
- Capture cross hour ramping behavior
- Model multi-stage (combined cycle plants) generation
- Model resource's dynamic ramp rate based on the MW output
- Enforce daily Energy Use limited resources
- Ensure appropriate online flexible ramping capacity
- Plan for forecasted load including on/off peak and other cycles in between.

1. What other goals are the ISO's striving to address or have addressed …? *(cont.)*

- Protect DA awards terminal conditions
- Avoid over-generation or under-generation conditions
- Ensure deliverability of AS
- Model ramp sharing between energy and AS
- Improve forecasting and management of network congestion
- Co-optimize energy, AS, and fixed commitment costs.
- Model pump-storage resources
- Model group of resources constraints such as order of startups, delays between startups, minimum online commitment constraints

2. Is there any make whole due to commitment and is there any statistics that demonstrate that overall costs (including make whole) have reduced in comparison to not having a look-ahead commitment?

- CAISO uses the term "Bid Cost Recovery" (BCR)
- CAISO includes in BCR:
  - Startup and transition costs
  - Minimum load costs
  - Energy costs
  - AS cost
- CAISO nets out above costs with market revenues from energy and AS markets over each Trading Day
- CAISO then pays out any shortfalls
- Special provisions rule out costs accrued due to self-schedules or self-commitments in the markets
- Look-ahead and grid reliable operation

3. How is the make whole charge allocated?

- For day-ahead bid cost payment, it will be allocated based on two tiers,
  - Tier 1: in proportion to a market participant's Day-ahead scheduled Demand minus Day-ahead schedule generation (net demand including virtual demand).
  - Tier 2: Any cost left from Tier 1 will then be allocated to a market participant's measured demand.

3. How is the make whole charge allocated?

- For RUC bid cost payment, it will be allocated based on two tiers,
  - Tier 1: in proportion to a market participant's net negative demand deviation plus virtual supply.
  - Tier 2: Any cost left from Tier 1 will then be allocated to a market participant's metered demand.

3. How is the make whole charge allocated?

- For real-time bid cost payment,
  - allocated in proportion to a market participant’s measured demand
  - plus inter-tie import schedules reduced from the day-ahead value
  - plus inter-tie export schedules increased from the day-ahead value in real-time.
- CAISO pays up to the bid price if price correction is performed for exports (DA&HASP) and bid –in demand (DA)

4. What makes up the make whole – startup and min-gen only or is there a make whole for the energy component too?

- CAISO bid cost recovery includes eligible:
  - Start-up cost,
  - minimum load cost,
  - energy bid cost,
  - RUC bid cost,
  - AS bid cost,
  - transition cost for MSG resources.
- Cost versus Revenue per day per resource
- End of 2012, DA costs and revenue will be separate from real-time cost and revenue for BCR purposes

5. Is the make whole charge a separate line item or bundled with other? If bundled, what is the reason?

- Different components have different charge codes but we sum them up for BCR purposes.

6. What problems/challenges have they experienced with look-ahead commitment? How did they resolve them?

- Uncertainties increase as the multi-interval unit commitment and dispatch pushes further into the future. The impact of the future intervals on the dispatch and cost of the first interval become harder to justify as that uncertainty increases.
- There is a tradeoff between the benefits of the look-ahead capability and the contamination from the high uncertainty in far-off intervals.

6. What problems/challenges have they experienced with look-ahead commitment? How did they resolve them? …. (Cont.)

- Anticipated high prices in future intervals may not materialize when the future interval becomes the binding one, which may result in over-generation conditions with –ve prices, or resources dispatched inefficiently at their min load MW (mingen).
- Financially binding real-time bids for future hours (past the second hour) are not usually available because the real time market is still open for these hours. Bids for these hours should be constructed from any available pending bids, historical bids, or bids from the Day-Ahead Market, based on rules and policy.

7. How are the interactions of self-commitments with the commitments from Look-Ahead Commitment impacting the market and make whole payments? How does the ISO manage this?

- CAISO evaluates the inter-temporal constraints such as minimum up time and minimum down time.
- Self committed units are required to stay on line for their minimum up time
- Bid cost recovery is not paid for these remaining hours
- Physical constraints are observed while preventing opportunities for potential gaming

Siemens Implementation

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Real Time Unit Commitment

- Application executes every 15 min –different roles
- HASP (Hour Ahead Scheduling Process 7 interval in 15 min step)
- STUC (Short Term Unit Commitment 18 interval in 15 min step)
- RTPD (Real Time Pre-Dispatch 5 interval in 15 min step)
- RTPD (Real Time Pre-Dispatch 4 interval in 15 min step)
- HASP, STUC, RTPD5, RTPD4 run sequentially in the hour
- The Optimization Horizons are different
- Closed Loop execution with Real Time Interval Dispatch

HASP (Hour Ahead Scheduling Process)

Definition

- Executes at the top of the Hour
- Look Ahead of two hour in 15 min step
- Integral SCUC-NA iteration process
- Performs Market Power Mitigation
- Schedules Hourly Ties in blocks
- Procures Ancillary Service (Regulation Up, Down, Spin and Non-Spin : RU, RD, SR, NR)
- Provides Advisory Schedules and Prices in 15 min time Increments
- Commits Fast Start units and issues Binding Commitment Instruction for all Commitments

STUC (Short Term Unit Commitment)

Definition

- Looks Ahead 5 hours (T+30 to T+300) 18 intervals
- Integral SCUC-NA iteration process
- Commits Short Start and Medium Start units
- Procures Ancillary Service (RU, RD, SR,NR)
- Issues Binding Commitment Instruction
- Capable to run De-Coupled mode using configuration flags

RTPD 5 and 4

Definition

- Look Ahead of 5 to 4 intervals of 15 min segment
- Commits and De-Commits Short Start Units
- Procures additional AS (RU, RD, SR, NR)
- Issues Binding Commitment Instruction

Real Time Unit Commitment

Functional Capabilities

- Co-Optimization of Energy and AS
- Based on Mixed Integer Linear Programming
- Generators, System Resources, Pumps, Pump Storage, Multi-Stage Generators, Demand Response, Storage etc.
- System Energy Balance and Regional AS balance constraints
- Transmission Network Constraints (AC power flow)
- Nomogram Constraints
- Inter-Tie Scheduling Constraints
- Resource Capacity Constraints
- Ramping Constraints (Static and Dynamic)
- Minimum Up and Down Time
- Maximum Number of Start-ups
- Maximum Number of transition for Plant and Configuration
- Maximum Number of transition per transition
- Multi-Segment Startup Time function (hot-intermediate-cold)
- Multi-Segment Startup Cost

Real Time Unit Commitment… (contd.)

Functional Capabilities

- Regulation Ramping Rule
- AS Cascading (Regulation to Spin)
- AS Cascading (Regulation to NSpin)
- AS Cascading (Spin to NSpin)
- AS Ramping Limits
- Daily Energy Limits
- System Requirement Infeasibility Screening
- AS Scarcity Pricing
- Online Upward ramping capacity
- Minimum Regional Online Capacity
- Load Following Capacity and Instruction
- Constraints Relaxation

Real Time Interval Dispatch

Definition

- Runs every 5-minute to meet Imbalance Energy Requirement
- Configurable look ahead capacity up to two hour in 5 min steps
- Based on Mixed Integer Linear Programming
- Configurable Co-Optimization Energy and AS
- Generators, System Resources, Dynamic Ties, DR, Storage etc
- Configurable Commitment capability for demand response units
- Configurable Commitment capability for very fast start units
- Closed loop execution with Real Time Unit Commitment
- Binding Dispatch Operating Target and Point Calculation
- Symmetrical Energy ramping profile
- Start-up and Shutdown ramping Profile
- AS awards dispatch and system reserve requirements
- On Demand and On Event Network Constraint update

Real Time Interval Dispatch … (contd.)

Functional Capabilities

- Capacity Constraints
- Daily Energy Limit Management
- Static and Dynamic Ramping
- Forbidden Region Operation
- Combined Cycle plant dispatch
- Hourly Resource AS management
- Operating Reserve Management
- Regulating Resource Management
- Dynamic Load Following
- Exceptional Dispatch (Operator Entered Constraints)
- Flexible Ramping
- Binding Nodal LMP calculation
- Intra interval ramping profile (Dispatch Operating Point)

Challenges

Modeling Challenges
- As close to physical conditions (Ex: Multi-stage, Start-Up, Shutdown, Full Network Model)

Feasible Schedule
- One that can be implemented physically (Ex: Realizable Ancillary Service, Protection of DAM Terminal Conditions)

Co-Existence of Operator directives and Optimization
- Use of practical knowledge (Ex: Operational need for exception to solution)

Data Consistency
- Adaptive correction of invalid data (Ex: infeasible de-rate of operating limits)
- Idiosyncrasies warranting Modeling improvements (Start-Up, Shutdown Process)

Challenges *(Cont)*

Infeasible Scenarios detection and handling

- Proactive counter measures (Proper Messaging)

Real Time conflict resolution

- Reliable and Robust Operation (Ex: loss of renewable, generators, operational errors)

Explanation of Results

- Impact of future on present (uncertainty of the future interval on present)

Purpose of FNM in RTUC

- Examine the impact of market clearing awards on the MW flows of the electrical grid
  - Base case impact
  - Post-contingency impact
- Formulate linear inequality flow constraints for enforcement in the market clearing process
- Formulate linear loss model for use in the market clearing process
- Include the effect of scheduled outages on the topology for future time intervals
- Provide linear flow and loss models for the LA SCED time intervals

Reasons for SCUC-NA Iterations in RTUC

- Identify any new violations resulting from scheduling decisions
- Accounts for the non-linearity of the System PF equations and the losses
- Calculate MW flow limits from MVA limits utilizing current MVAR flows

FNM in Interval Dispatch

Determine the impact of scheduling decisions on the electrical grid (base case and post-contingency)

- Utilize linear models developed in the RTUC analysis during the LA SCED processing
- Future intervals respect scheduled outages
- In case of an event on the physical system run PF/CA for the first interval
- Determine a new binding constraint set (reflecting the new topology)
- RTUC catches up w/ Event in next execution

Wind Power Management

Consideration for reliability for system operation

- Siemens implementation in progress jointly with REE, Spain for Wind Power Management (20% - 40% of generation provided by Wind Generation at REE)
- Wind Generation forecast – by location and amount - in (5m, 15m) needed for RTID and RTUC
- RTID to consider commitment of fast resources in dispatch problem to manage variability of renewables
- Accelerate dispatch to run more frequently for closer load-following
- System Ramping (Flex Ramp) to be allocated for managing uncertainty of demand and variability of supply.

Future Needs at Review at CAISO

Smart Grid Division

Increase efficiency in existing grid utilization

- Critical line rating calculation
- Dynamic thermal line ratings
- On-Line and Look Ahead Voltage stability analysis
- On-Line and Look Ahead Dynamic stability analysis
- Voltage control and accurate active losses modeling
- Dynamic Nomogram constraints as functions of equipment connectivity statuses
- Co-optimization of energy, AS, and active power losses i.e. integrated active/reactive optimization
- Integrated preventive/corrective control in handling contingency cases
- Transmission equipment switching as controls

Enhanced real-time control

- Improved AGC and tighter coupling between AGC and real-time market dispatch
- Adaptive control algorithms including interaction with micro-grids
- Built-in management of traditional resources wear and tear
  - Automatic deployment of regulation and non-contingent operating reserves
  - Compliance incentives with following dispatch instructions

Improvements in market applications

Improved modeling of Ancillary Services (AS)

- Locational AS
- Co-optimization of energy and AS in 5 minute Interval Dispatch
- Extended real-time dispatch time horizon
- New market products for firming up intermittent resources
- Improved optimization algorithms to handle uncertainties
- Modeling and managing contingencies in fuel supply (gas, hydro, wind, solar) within market software