

Look-Ahead Unit Commitment With Robust Optimization

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Summary

- Look-Ahead Unit Commitment Problem Definition
- Look-Ahead RTO/ISO Implementation Examples
- Model Uncertainties in Look-Ahead Unit Commitment
- Robust Look-Ahead Unit Commitment
- Case Study
- Future Work
- Conclusions

Current Processes for Market Operations

- Day-Ahead Market
 - A Financial Market
 - Producing DA unit commitment and DA pricing
- Reliability Unit Commitment
 - Physical unit commitment for reliability purposes
 - Commitment of unit with longer runtime
 - Hourly commitment intervals
 - Initialized from Operating Plan without considering real-time condition
- Real-time Dispatch and Pricing
 - Commitment of fast start units (often via operator manual decision)
 - Real-time load balancing and ancillary services clearing

Operational Challenges

- Real-time Challenges:
 - Increased penetration of intermittent resources
 - Increased frequency of interchange scheduling
 - Increased demand responses participation
 - Real-time offer adjustments
 - Real-time performance of dispatchable resources
- Real-time Commitment/Dispatch
 - Rely on fast start units : Increased Production Cost
 - Emergency procedure: Load Reduction/Shedding
- Is there a better scheduling process to reduce the real-time operational risk?
 - Can commitment decision can be “immunized” to the uncertainties, in particular, in Day Ahead and Look Ahead time frame

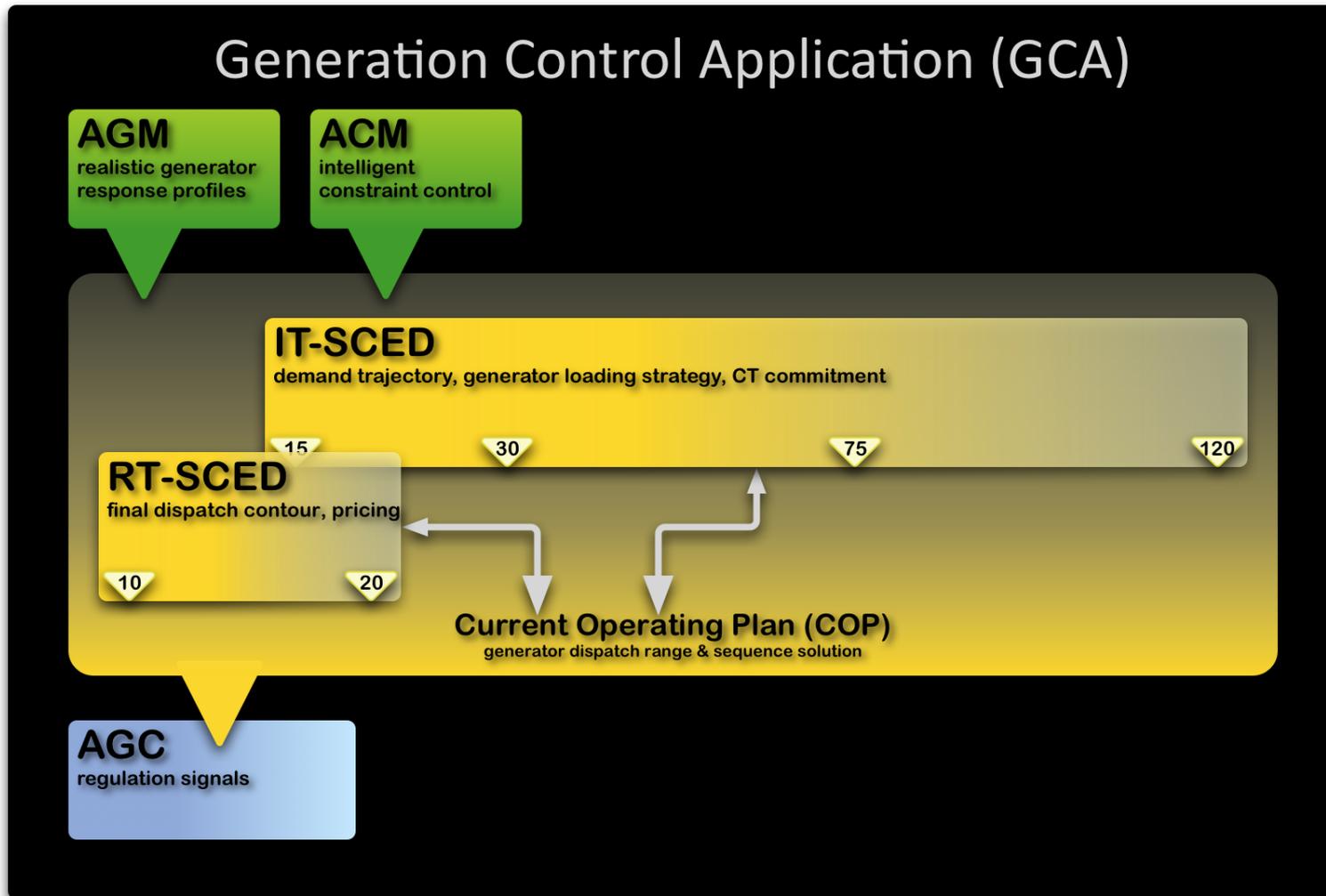
The Goal of Look-Ahead Unit Commitment

- Facilitate operational risk management
 - Trade off between reliability and economics
- Support the operator's decision making process
 - Fast start unit commitment with explicit model of startup/noload costs and resource temporal constraints
 - Reduce make-whole payments
 - Transmission constraint prediction
 - Out-of-Merit dispatch decision including pre-ramping
 - Real-time interchange scheduling
 - Incremental commitment for regulation and reserve
 - Scarcity/Emergency prediction

Look-Ahead Project Implementation Examples

- PJM LA-SCED (GCA) went-live on June 9th 2010
 - LA Commitment: 2 hour look-ahead fast-start unit commitment
 - LA Dispatch: coupled multi-interval SCED replaced 10 year-old RTUDS
- Midwest ISO Look-ahead Commitment (LAC) in production April 2nd, 2012
 - LAC focuses on fast-start unit commitment
 - Look-ahead Dispatch (LAD) will come in next phase
- ISO-NE LA Commitment advisory passed operator testing
 - Commit Fast-start unit, predict emergency conditions, DR activation, and transaction clearing prices
 - Official implementation starts Q2 2012
- SPP LA-SCED for Integrated Marketplace (go-live Q1 2014)
 - Pre-RTBM is a interval coupled LA dispatch to look ahead 2 hours for OOME recommendation

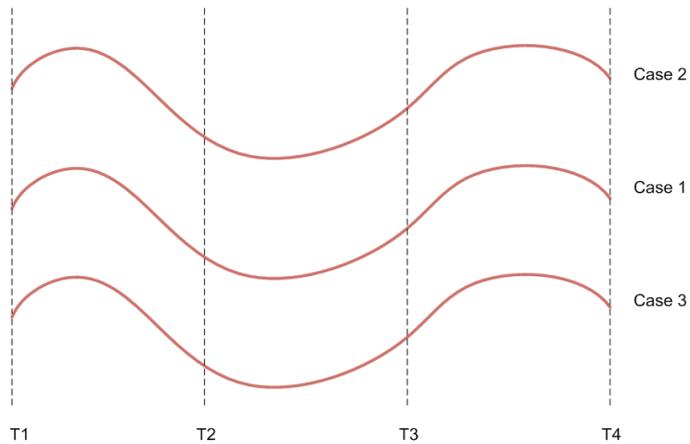
PJM Look-Ahead Commitment and Dispatch



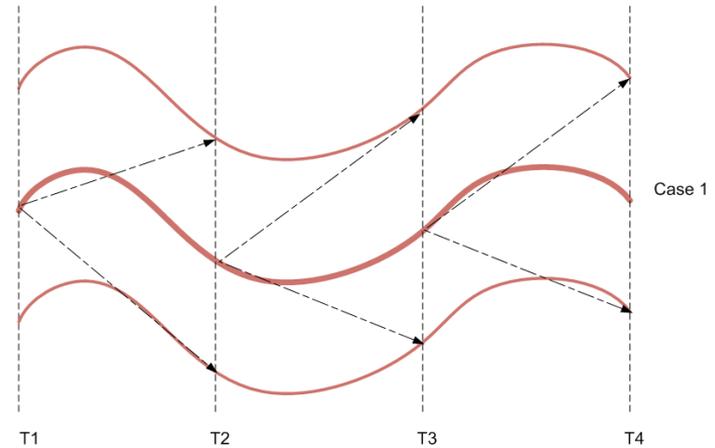
Manage Uncertainties in Look-Ahead Commitment

- Major uncertainties need to be addressed in look-ahead commitment process
 - Demand forecast error
 - Wind forecast error
 - Interchange swing
 - Network topology
 - Dispatchable resource performance
 - Real-time offer adjustments
- Current uncertainty management in practice
 - Simultaneously solving several scenarios
 - Operator picks commitment recommendation from one or more scenarios
 - Consider both reliability and economics
 - Very short time for decision making
 - Computational performance is the key

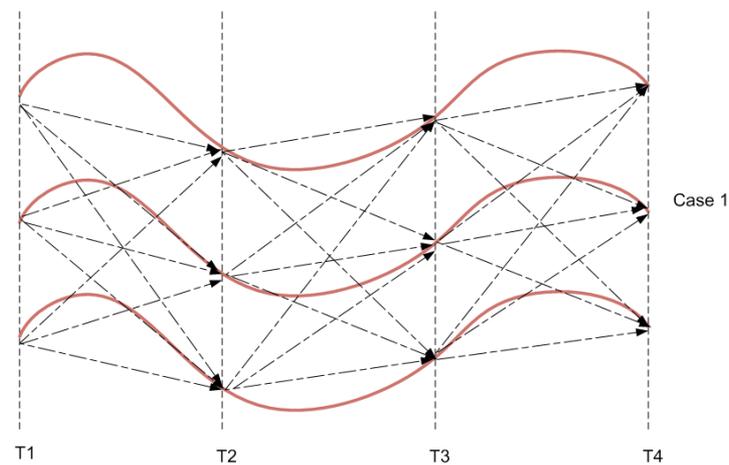
Model Uncertainties in Look-Ahead Commitment



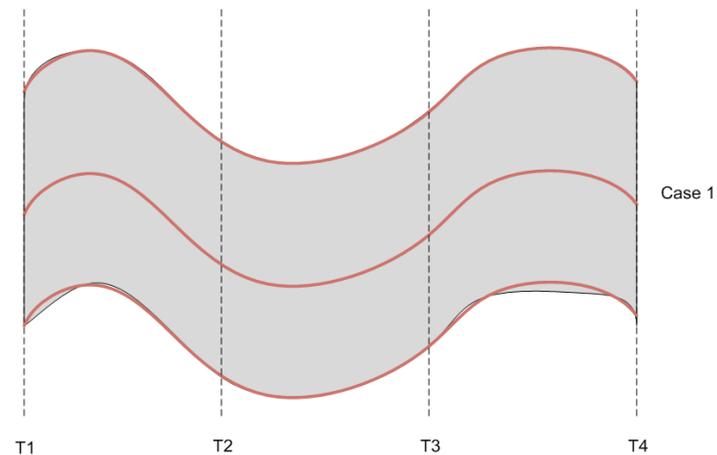
Current three-scenario approach



Single scenario considering worst case ramping



Stochastic programming approach



Robust optimization approach

Robust Look-Ahead Commitment

- Consider the MIP UC problem

$$\begin{aligned} \min \quad & c^T x + b^T y \\ \text{s.t.} \quad & Fx \leq f && x \text{ is integer} \\ & Hy \leq h \\ & Kx + Ly \leq g \\ & \sum_i y_i = \sum_j d_j && \text{system load balancing} \end{aligned}$$

- The constraints $\sum_i y_i = \sum_j d_j$ must be satisfied for **all realizations** of the demand d within **uncertainty set** \mathcal{U}
- The **robust counterpart** is (A. Ben-Tal and A. Nemirovski, 2000):

$$\begin{aligned} \min \quad & c^T x + b^T y \\ \text{s.t.} \quad & Fx \leq f && x \text{ is integer} \\ & Hy \leq h \\ & Kx + Ly \leq g \\ & \sum_i y_i = \sum_j d_j, \forall d_j \in \mathcal{U}_j && \text{system load balancing} \end{aligned}$$

- \mathcal{U}_j is $\text{Box}[d_j^{\min}, d_j^{\max}]$

Adjustable Variables

- The value of y must be a function of d to satisfy the equality constraints $\sum_i y_i = \sum_j d_j$ for all realizations of the demand d within uncertainty set \mathcal{U} ;
- An adjustable variable reflects a decision made after uncertain data has been revealed. In robust optimization it is interpreted as some (explicit or implicit) functions form of the uncertain data on which it depends on;
- The continuous, dispatch related variables are adjustable (function of the demand), while the binary, commitment related variables are nonadjustable;
- The form of the adjustable variable determines the tractability of the solution.

LDR Based Robust Optimization Approach

- Linear Decision Rules (LDR) approach [Ben-Tal et al., 2004] leads to a tractable model:
 - LDR approach makes the assumption that the adjustable decisions depend linearly on the uncertain parameters.
- The Resource Dispatch $y_{t,i}$ depends on uncertain demand $d_{t,j}$, based on LDR we have

$$y_{t,i} = Y_{t,i}^0 + \sum_{[(t', j) | t' \leq t]} Y_{t',i} * d_{t',j}$$

where $Y_{t,i}^0$ and $Y_{t',i}$ are newly introduced intermediate variables, the value of which is determined by solving the robust counterpart. As such, the value of an adjustable variable is not fully determined by the solver. It can be computed afterwards for a given realization of the uncertain parameters

- AIMMS can automatically generate the robust counterpart with LDR adjustable variables and their uncertainty dependency defined.

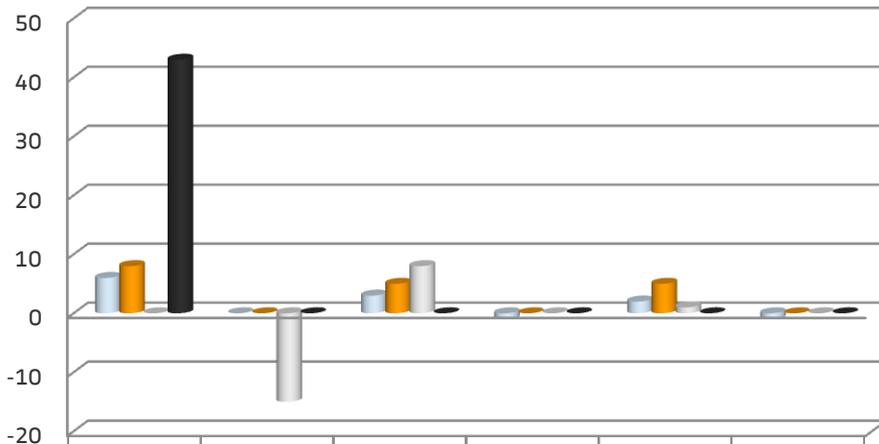
Case Study

- Identify the value of a robust Look-ahead commitment
- Performance benchmark
- Based on a RTO system look-ahead commitment case
 - 12000+ buses
 - 200+ committable resources
 - 4 look-ahead intervals (15min, 15min, 45min, 45min)
- 3 deterministic scenarios:
 - Nominal Load – system demand forecast
 - High Load – system demand forecast plus a negative offset
 - Low Load – system demand forecast plus a positive offset
- Robust look-ahead commitment
 - System demand with uncertainty bounds between negative offsets and positive offsets

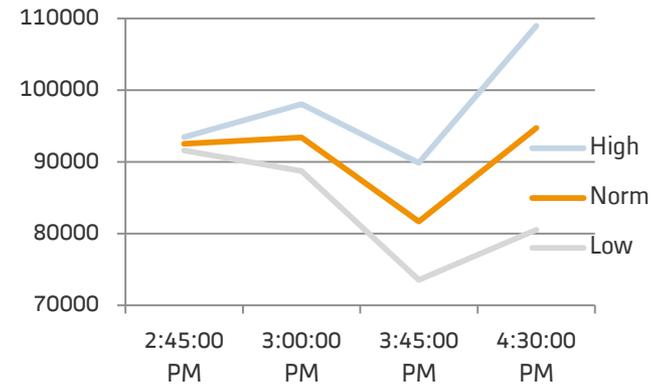
Robust Solution v.s. Deterministic Solutions

- Set the positive/negative deviation bounds of system demand to be 1%, 5%, 10% and 15% for 4 commitment intervals
- Robust model commits more flexible resources to handle the worst scenario.

number of startup and shutdown



	RO Startup	RO Shutdo wn	HL Startup	HL Shutdo wn	LL Startup	LL Shutdo wn
11/22/2011 14:45	6	0	3	-1	2	-1
11/22/2011 15:00	8	0	5	0	5	0
11/22/2011 15:45	0	-15	8	0	1	0
11/22/2011 16:30	43	0	0	0	0	0



Model Type	Total Cost (\$)
Deterministic Model (Nominal Demand)	7,110,998.91
Deterministic Model (High Demand)	8,115,738.09
Deterministic Model (Low Demand)	6,363,717.40
Robust Model	8,311,788.86

Performance Analysis

Testing HW: Intel(R) Xeon(R) CPU x5680 @ 3.33GHz

Testing SW: AIMMS 3.11 and CPLEX 12.2

- Comparison between different uncertainty deviations

Uncertainty Deviations	CPU Time
1%, 2%, 3%, 5%	160.35s
1%, 5%, 8%, 10%	323.80s
1%, 5%, 10%, 15%	386.01s

- Comparison between different number of uncertainty parameters

Number of Uncertainty	CPU Time
4	386.01s
6	1400s
8	MIP timed out after 3600s

Case Study Remarks

- Severe system load fluctuation (may be caused by wind drop and interchange swing) is simulated. System is at edge of ramping shortage.
- Robust Model commits/decommits more flexible units (faster ramping and shorter startup/notification time) and more frequently in order to find feasible solution for the worst scenario.
- Robust Model has slightly higher cost than the high demand scenario but avoid more expensive manual emergency dispatch if the worst scenario occurs
- Acceptable performance of Robust Model with system load uncertainties in 4 intervals

Future Work

- Performance tuning when
 - Number of demand uncertainties increases
 - A non-linear uncertainty budget constraint is introduced
- Compare LDR approach with two-stage approach
- Identify more scheduling problems that Robust Optimization could add value

Conclusion

- Increasing uncertainties need to be managed in real-time look-ahead commitment process
- Robust Optimization can produce a more robust fast-start commitment solution that is “immunized” to the uncertainties
- A LDR based approach is used to implement a Robust Look-ahead Commitment
- Case study with large system data
- Potential value of Robust Look-ahead Commitment is demonstrated
- Performance needs improvement for modeling more uncertainties and uncertainty budget constraint
- Plan to compare the results between LDR and two stage



Questions?