Flexibility Management in Day-Ahead Unit Commitment

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Net Load

–

=

actual load – uncontrolled renewable generation

= net load

= controllable generation

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What is Flexibility?

- Ability of the power system to follow the changes in the net load

- Controllable resources must provide:
  - Reserve capacity (MW)
  - Ramping ability (MW/min)
  - Ability to sustain the ramps (min)

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Optimizing flexibility

- Providing flexibility costs money
- Optimize the flexibility requirements
  - How much?
- Optimize the provision of flexibility
  - Where from?
- Day-ahead perspective
- Use available information:
  - Forecasts
  - Historical data

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Forecasts

- Load
- Wind generation
- Central forecast
- Uncertainty
- Use to schedule resources
- 1-hour resolution

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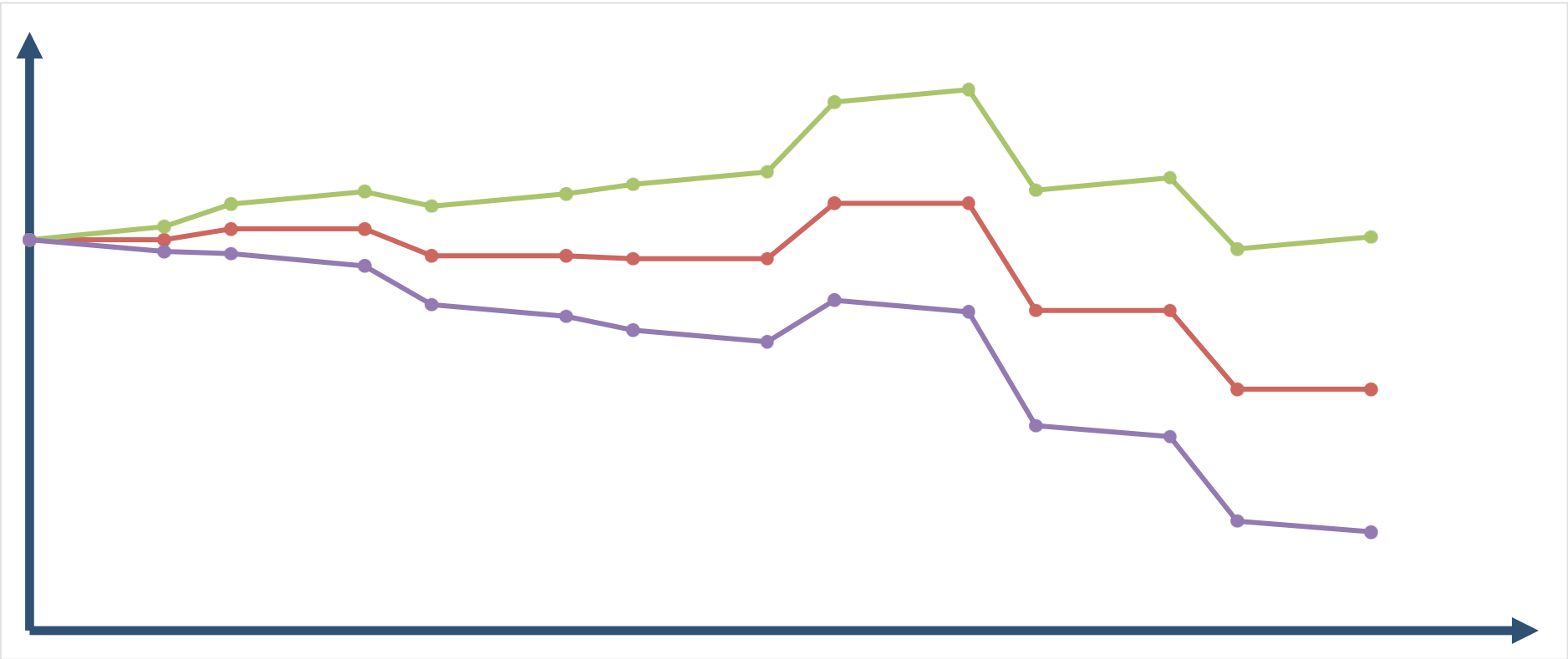
Forecasts

Schedule deployment of resources to meet forecast changes and uncertainty on the forecast values



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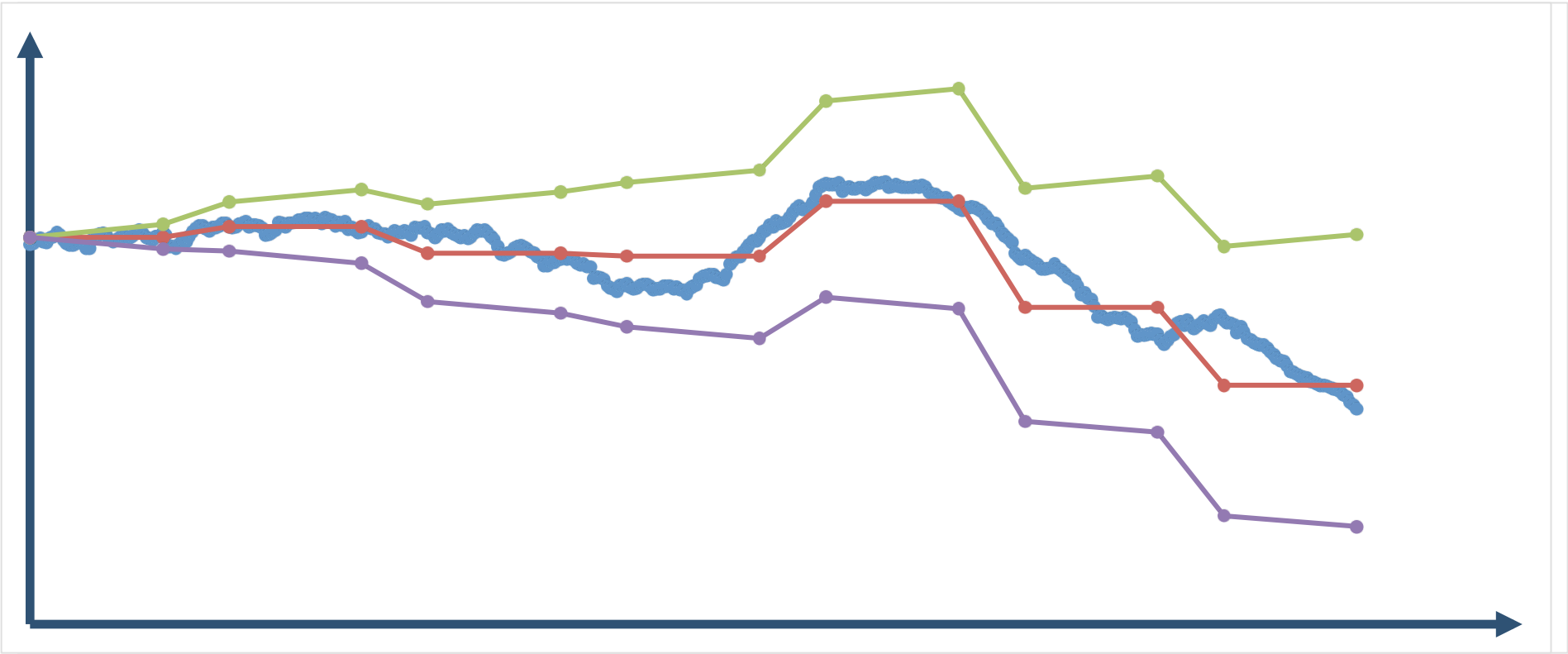
Limitation of forecasts

Because of their limited time resolution, forecasts do not help with deployment sub-hourly flexibility needs



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Historical data

- Actual load
- Actual generation
- 1 minute resolution

- Process this data to obtain a statistical description of the needs for intra-hour flexibility

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Managing day-ahead flexibility

- Inter-hour flexibility:
  - Based on forecasts
  - Stochastic/Interval/Robust Unit Commitment
  - Can we do better using a combination?

- Intra-hour flexibility:
  - Based on historic data
  - Requirements for capacity, ramp rate, and duration
  - How can we optimize the requirements?

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Stochastic, Interval, Robust UC

- Stochastic UC (SUC)
  - Minimizes expected cost over a set of scenarios
  - Less than optimal dispatch for extreme scenarios
- Interval UC (IUC)
  - Minimizes cost of central forecast scenario
  - Guarantees feasibility of worst-case scenarios
- Robust UC (RUC)
  - Minimizes cost of most expensive worst case scenario

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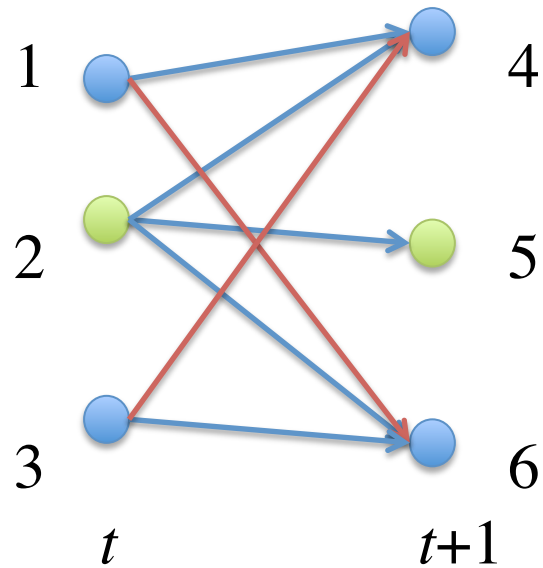
Interval Unit Commitment



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Conflicting objectives

Security → IUC or RUC

HYBRID?

Cost

→ SCUC

CPU time

→ IUC or RUC

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Observations

- Day-ahead commitment cost:

$$C^{SUC} < C^{IUC}$$

- Expected cost of corrective dispatch:

$$\Delta C^{SUC} > \Delta C^{IUC}$$

  – Stochastic commitment is less adaptive

- Need for corrective dispatch increases with time horizon for SUC because uncertainty increases
- IUC carries a "security premium" because it always considers the worst case

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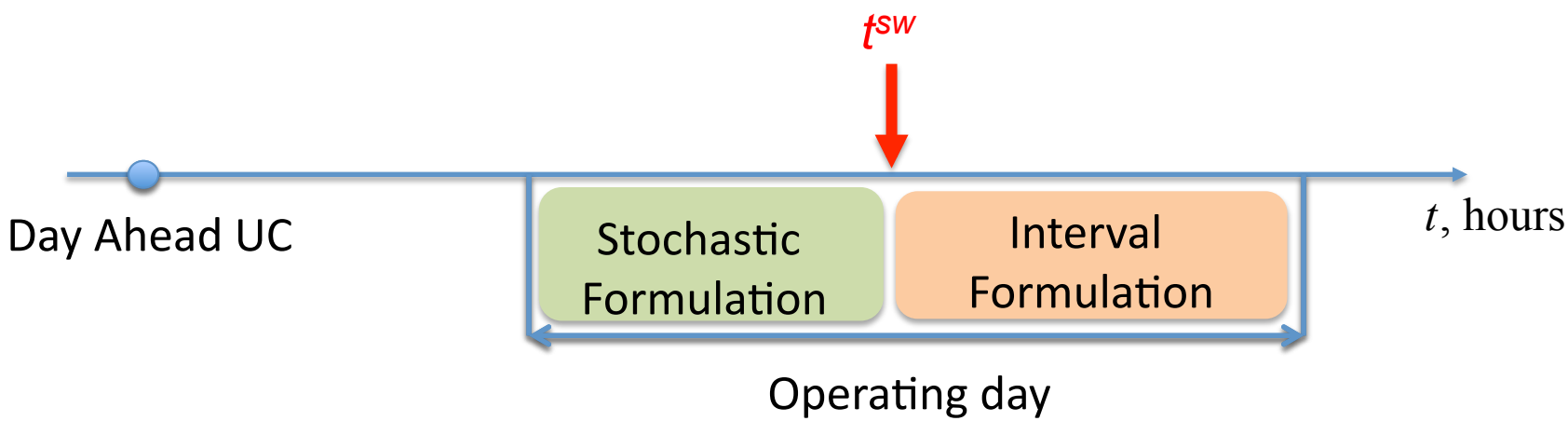
Hybrid UC formulation



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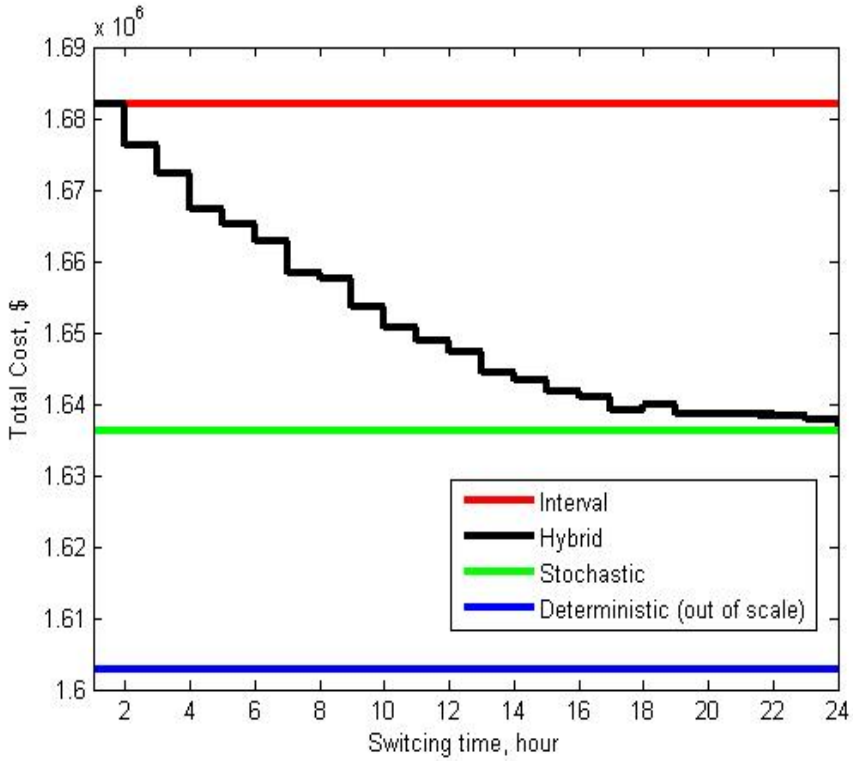
Hybrid UC formulation (HUC)



The day-ahead cost of the HUC decreases with t^{sw}

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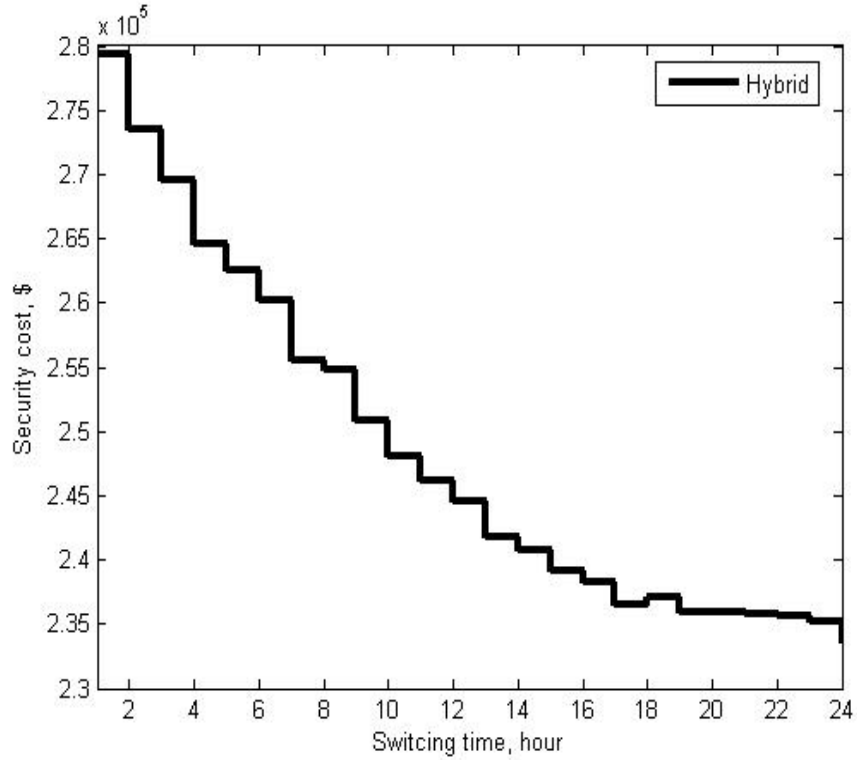
Hybrid UC



The security premium of the HUC decreases with t^{SW}

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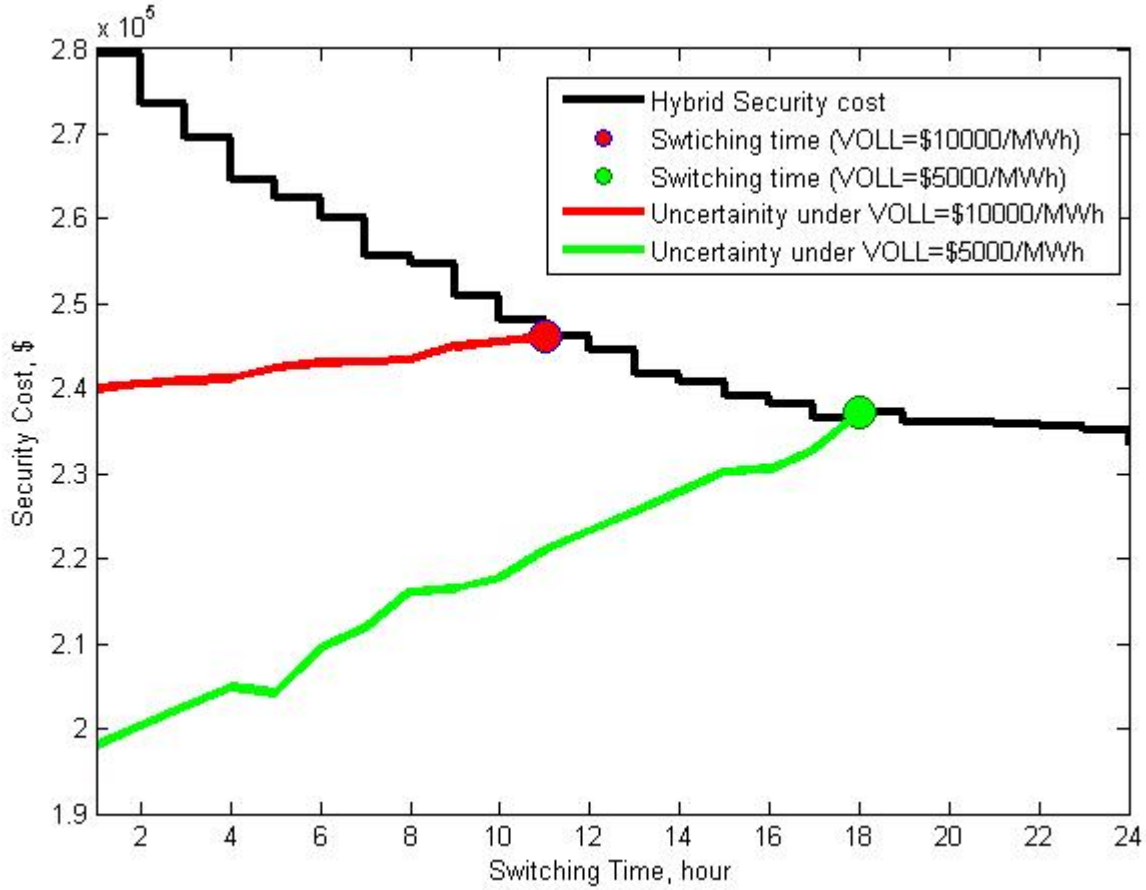
Hybrid UC: Optimal Switching Time



The expected cost of load shedding increases with t^{sw} for the SUC

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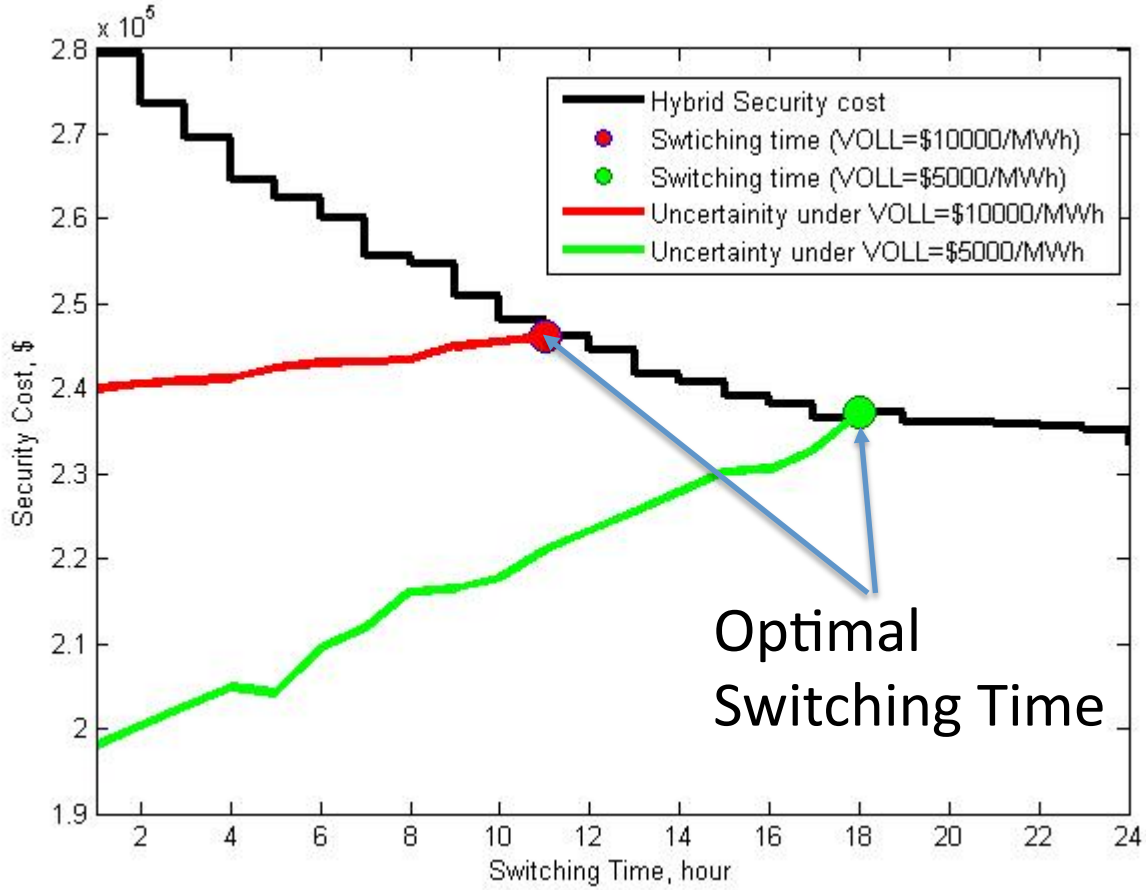
Hybrid UC: Optimal Switching Time



The optimal t^{sw} depends on *VOLL*

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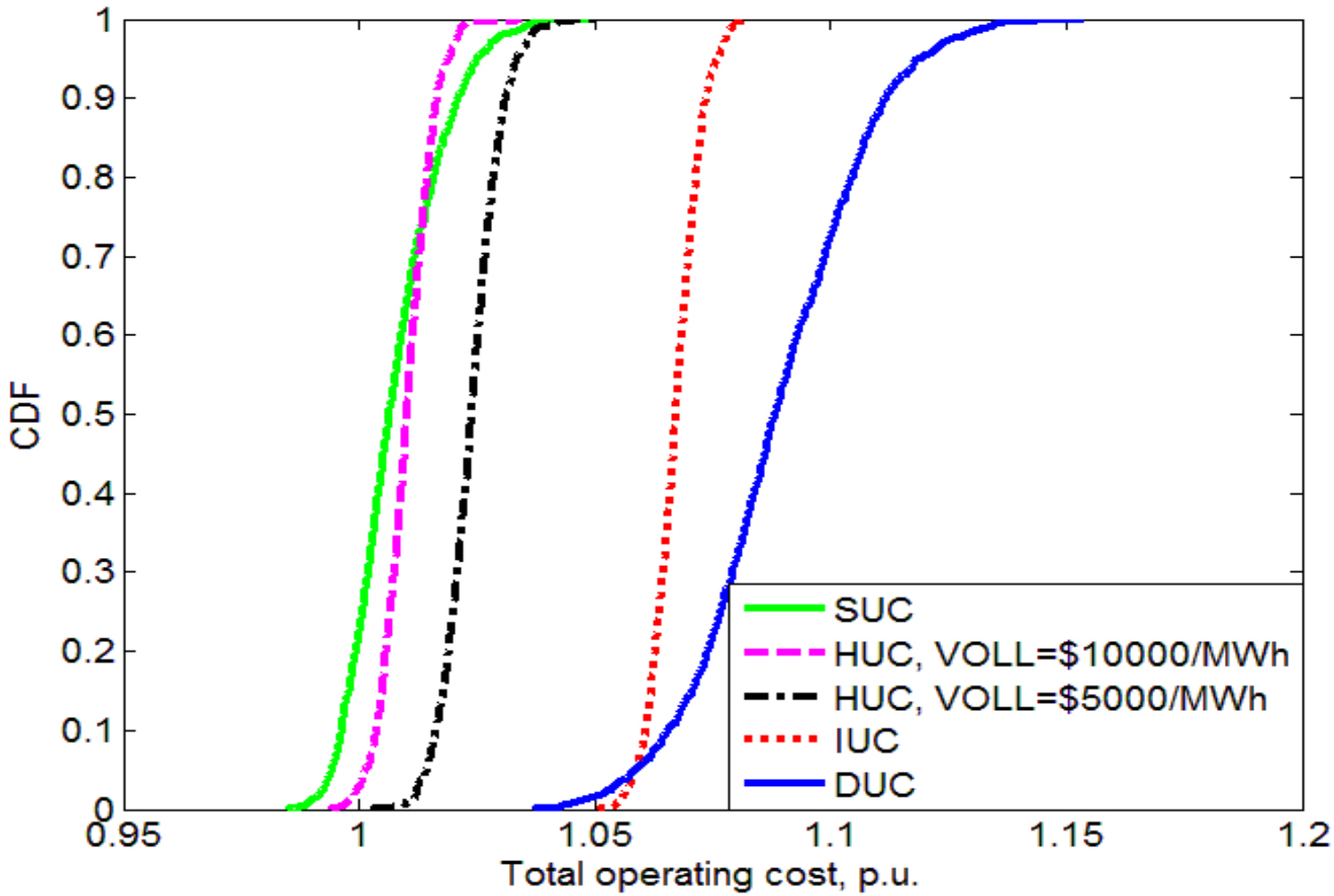
Monte–Carlo simulation



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Monte–Carlo simulation

	Deterministic	Stochastic	Interval	Hybrid 10000 $/MWh	Hybrid 5000 $/MWh
Expected cost	1.09	1.01	1.07	1.02	1.01
Minimum cost	1.04	0.98	1.05	0.98	1.007
Maximum cost	1.15	1.04	1.08	1.03	1.06
95% cost	1.12	1.03	1.07	1.02	1.05
RT unit startups (min/mean/max)	6/12/23	1/2/5	0	0/2/3	1/2/5
EENS, MWh	13.6	0.4	0	0	0.1

(All costs normalized on the basis of the day-ahead SUC cost)

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Intra-hour Flexibility

- Optimize flexibility requirements based on historical data
- Identify deviations between forecast and actual net load
  - Capacity, ramp rate, duration
- Balance cost and benefit of flexibility based on this data

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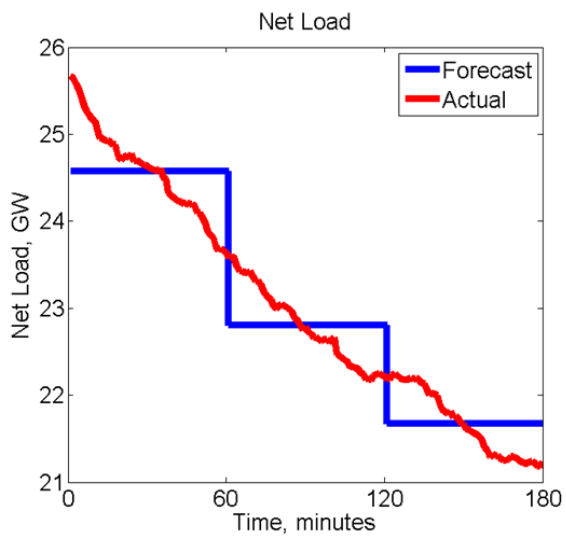
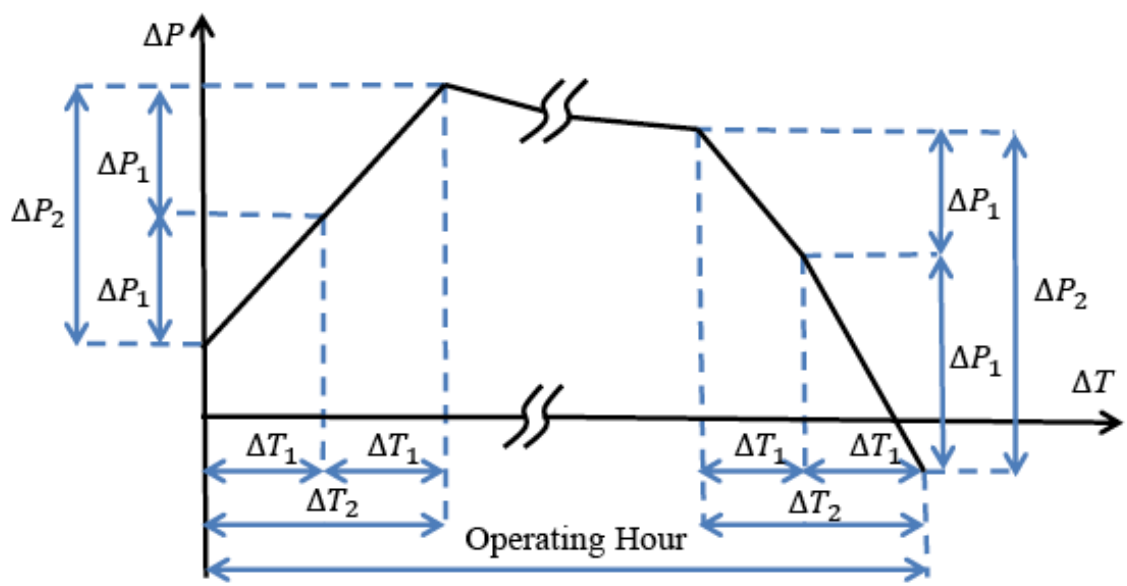
Deviations between actual and forecast





$$\zeta_k = \{\Delta P_k, \Delta R_k, \Delta T_k\}$$

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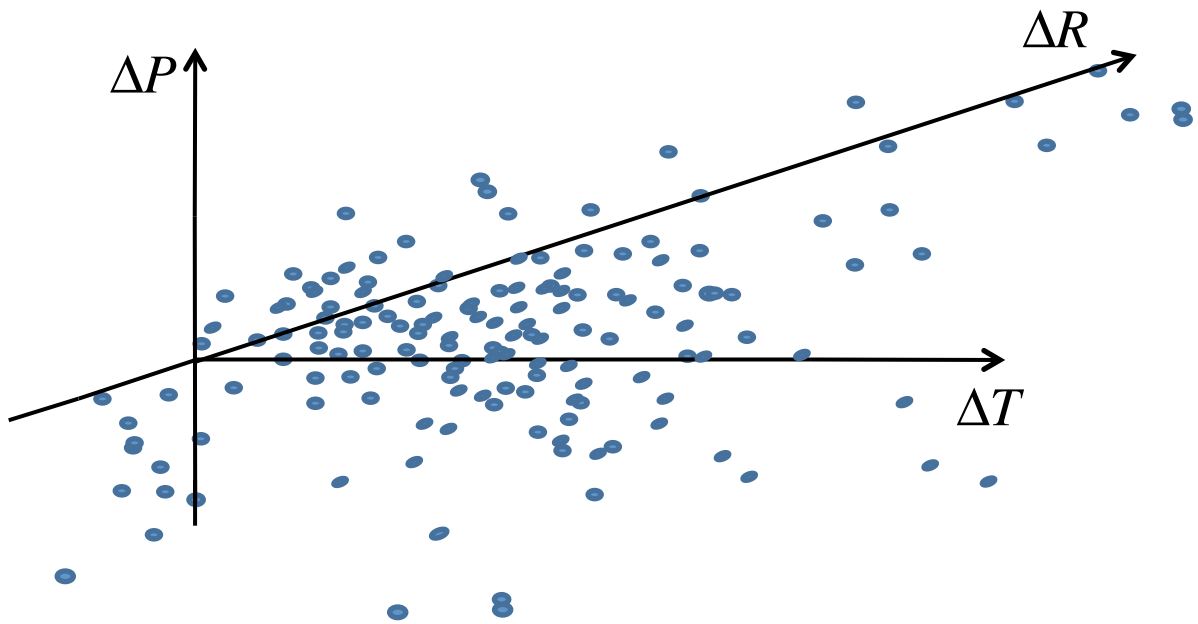
Triplets of net load deviations



$$\zeta_k = \{\Delta P_k, \Delta R_k, \Delta T_k\}$$

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Cost/Benefit analysis

$$\min\left[\sum_{S}\sum_{T}\pi_s\cdot\left[\underbrace{C^{g}_{t,s}+C^{UP\ FLEXIBILITY}_{t,s}+C^{DOWN\ FLEXIBILITY}_{t,s}}_{\text{Cost of providing flexibility}}+\underbrace{EENS_{t,s}\cdot\mathrm{VOLL}}_{\text{Cost of energy not served}}+\underbrace{EWES_{t,s}\cdot\mathrm{WSC}_t}_{\text{Cost of spilling wind}}\right]\right]$$

Progressively expand the requirements until we find the data point that minimizes this objective

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Tailored flexibility requirements

- Secondary control
- Tertiary control
- Time of day
- Day of week
- Season

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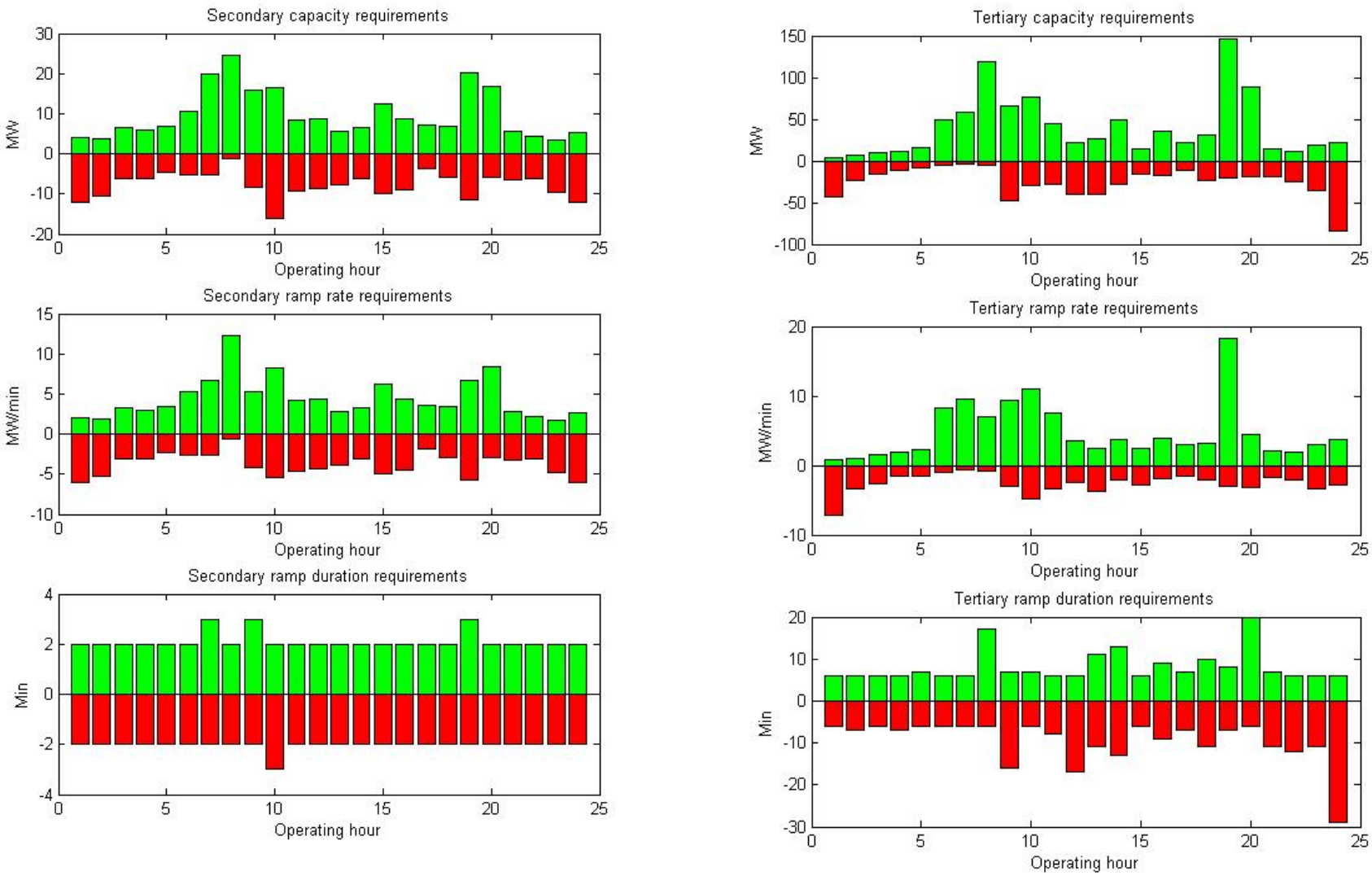
Flexibility requirements for each hour



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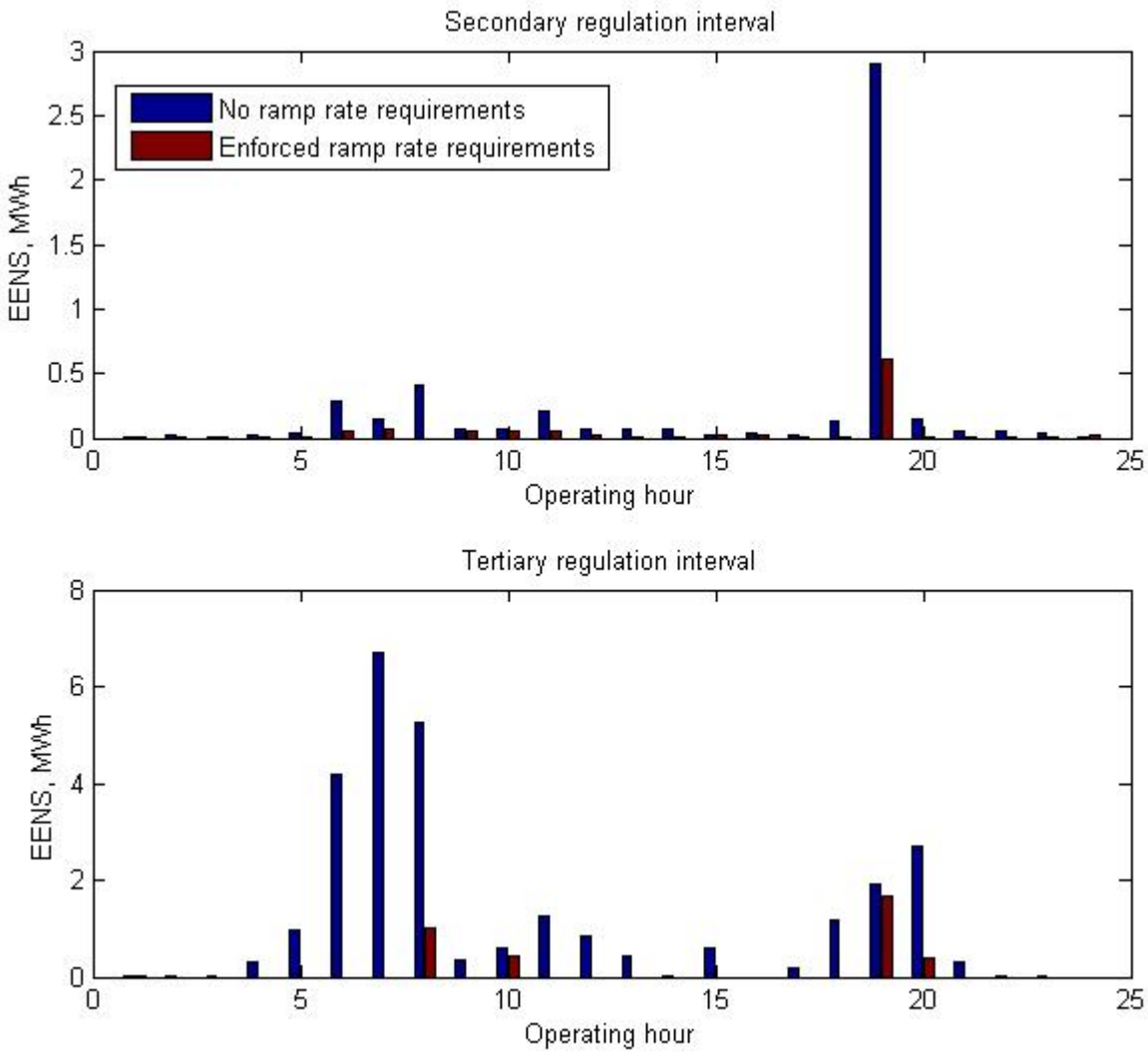
Effect on Expected Energy Not Served



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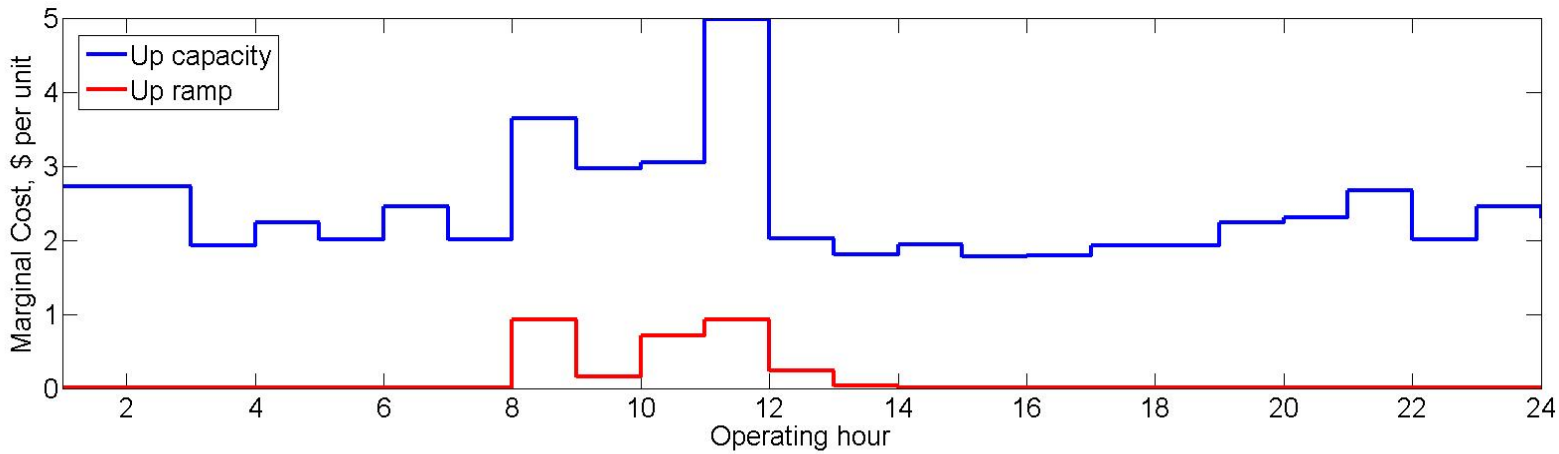
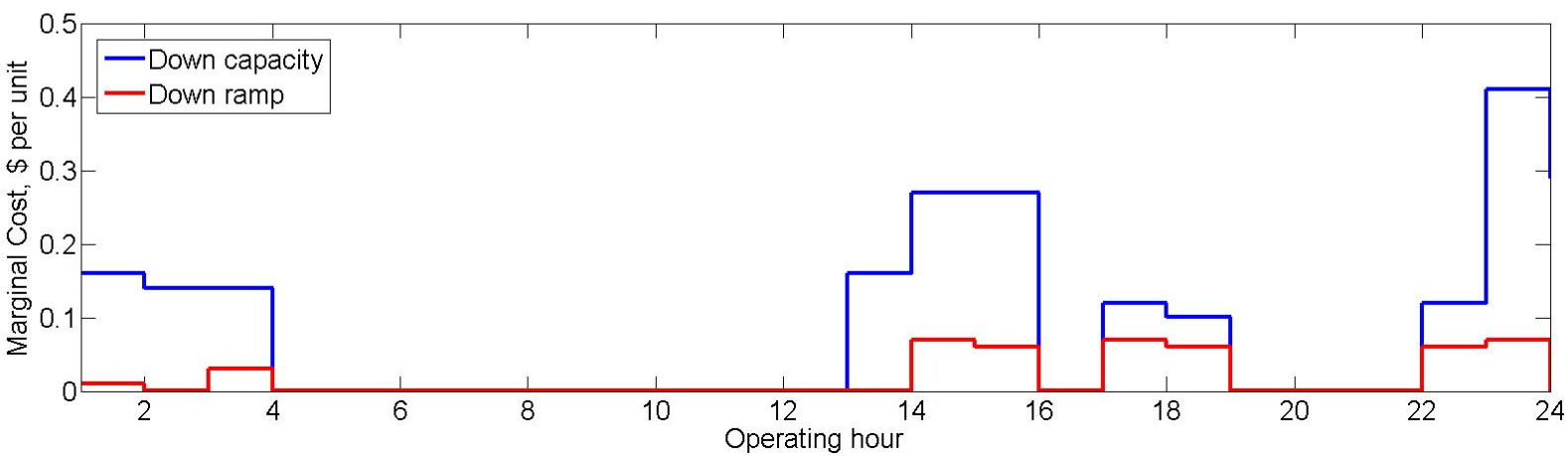
Marginal cost of flexibility requirements





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Summary

- Inter-hour flexibility
  - Use forecasts
  - Various formulations of unit commitment
- Intra-hour flexibility
  - Capacity, ramp rate, ramp duration
  - Use historical data
  - Optimize requirements using cost/benefit analysis
- Optimize procurement of inter- and intra-hour flexibility simultaneously within UC

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