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What Is the Value of Alternative Methods for Estimating Ramping Needs?

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Contents

- Background: Ramping products in wholesale markets
- Ramping product estimation methodologies
- System performance under different ramping product estimation methodologies
- Conclusions and future research

Ramping products in wholesale markets (1/2)

Ramping products can help independent system operators manage:

a) Uncertainty of net load [1], [2]

b) Variability of net load [1], [3].

Example for uncertainty: CAISO data, May 15, 2019, 8:00 a.m.

		Renewable forecast
14–37 hours ahead	Day-ahead market	6,227 MW
45 min ahead	Real-time unit commitment (RTPD)	5,637 MW
10 min ahead	Real-time dispatch (RTD)	4,331 MW

Within ~30 minutes, CAISO *forecast* **“lost” 1,306 MW** > 1,122 MW (largest unit in CA)

[1] B. Wang and B. F. Hobbs, “Real-Time Markets for Flexiramp: A Stochastic Unit Commitment-Based Analysis,” *IEEE Trans. Power Syst.*, vol. 31, no. 2, pp. 846–860, 2016.

[2] K. H. Abdul-Rahman, H. Alarian, M. Rothleder, P. Ristanovic, B. Vesovic, and B. Lu, “Enhanced system reliability using flexible ramp constraint in CAISO market,” in *Proceedings of the 2012 IEEE Power and Energy Society General Meeting*.

[3] E. Ela and M. O’Malley, “Scheduling and Pricing for Expected Ramp Capability in Real-Time Power Markets,” *IEEE Trans. Power Syst.*, vol. 31, no. 3, pp. 1681–1691, 2016.

Ramping products in wholesale markets (2/2)

The introduction of a ramping product or constraint can reduce the number of intervals with insufficient ramping capability, thereby mitigating undesirable outcomes of ramp shortages [1]:

- Infeasible real-time dispatch and prices at administrative penalties
- Leaning on regulation
- Leaning on interconnection.

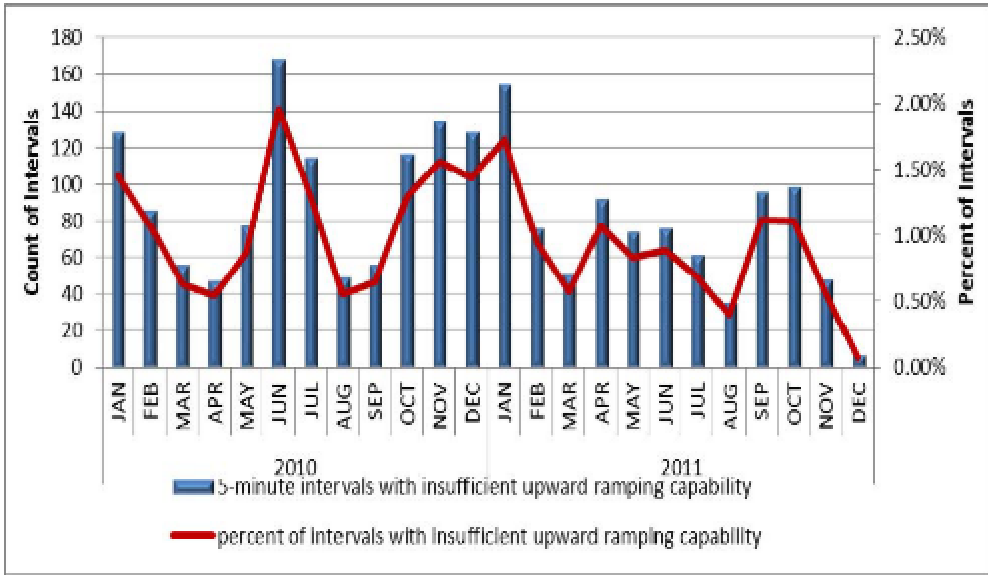
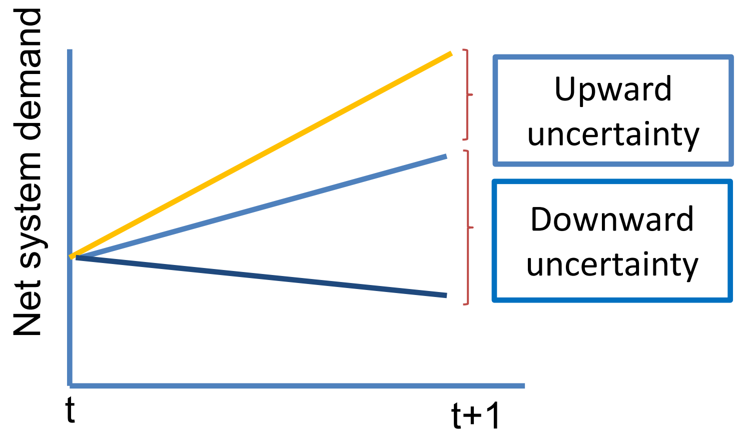


Figure taken from [1]: illustrates how the number of 5-min intervals with insufficient upward ramping capability reduced after enforcement of ramping constraint on Dec. 13, 2011

[1] K. H. Abdul-Rahman, H. Alarian, M. Rothleder, P. Ristanovic, B. Vesovic, and B. Lu, “Enhanced system reliability using flexible ramp constraint in CAISO market,” in *Proceedings of the 2012 IEEE Power and Energy Society General Meeting*.

Flexible ramping product: CAISO conceptual design



$FRUR_{Ut}$

$FRDR_{Ut}$

Not exhaustive

System-wide constraints

Flex ramp-down procurement	$3 * \sum_g frd_{g,t} + frds_t \geq FRDR_{Ut}$
Flex ramp-up procurement	$3 * \sum_g fru_{g,t} + frus_t \geq FRUR_{Ut}$

Resource-specific constraints (valid if unit online at both t and t+1)

Lower operating limit	$gen_{g,t} - 3 * frd_{g,t} - rs_{g,RD,t+1} \geq PMIN_g * u_{g,t+1}$
Capacity constraint	$gen_{g,t} + 3 * fru_{g,t} + \sum_{res \neq RD} rs_{g,res,t+1} \leq PMAX_g * u_{g,t+1}$
Ramping up capability	$3 * fru_{g,t} + 0.75 * \left(rs_{g,RU,t} + rs_{g,RU,t+1}\right) \leq RR_g * 15$
Ramping down capability	$3 * frd_{g,t} + 0.75 * \left(rs_{g,RD,t} + rs_{g,RD,t+1}\right) \leq RR_g * 15$

Slightly different constraints are enforced during startup, shutdown of units

Source: L. Xu, "Discussion on flexible ramping product," CAISO, Market Surveillance Committee Meeting General Session, September 8, 2017.

Ramping product estimation methodologies: Industry practice and state-of-the-art research

Existing ramping sizing methods are calendar-based [1], [2]:

- Collect sample of past forecast errors
- Estimate parametric or empirical probability distribution of net load
- Determine requirements using moments of parametric distributions or percentiles.

State-of-the-art research on sizing methodologies for balancing needs investigates if:

- Real-time weather forecasts
- Real-time renewable forecasts
- Measurements

could be leveraged to estimate balancing needs [3], [4], [5].

[1] N. Navid and G. Rosenwald, "Ramp Capability Product Design for MISO Markets," MISO, DRAFT, 2013.
[2] California ISO, "Flexible Ramping Product Draft Final Technical Appendix," CAISO, 2016.
[3] P. Etingov et al., "Balancing needs assessment using advanced probabilistic forecasts," in *Proceedings of the 2018 International Conference on PMAPS*, pp. 1–6.
[4] K. De Vos, N. Stevens, O. Devolder, A. Papavasiliou, B. Hebb, and J. Matthys-Donnadieu, "Dynamic dimensioning approach for operating reserves: Proof of concept in Belgium," *Energy Policy*, vol. 124, no. June 2018, pp. 272–285, 2019.
[5] CAISO, Flexible ramping product refinements, Stakeholder call, March 23,2020. http://www.caiso.com/InitiativeDocuments/Presentation-FlexibleRampingProductRefinements-RevisedStrawProposal.pdf.

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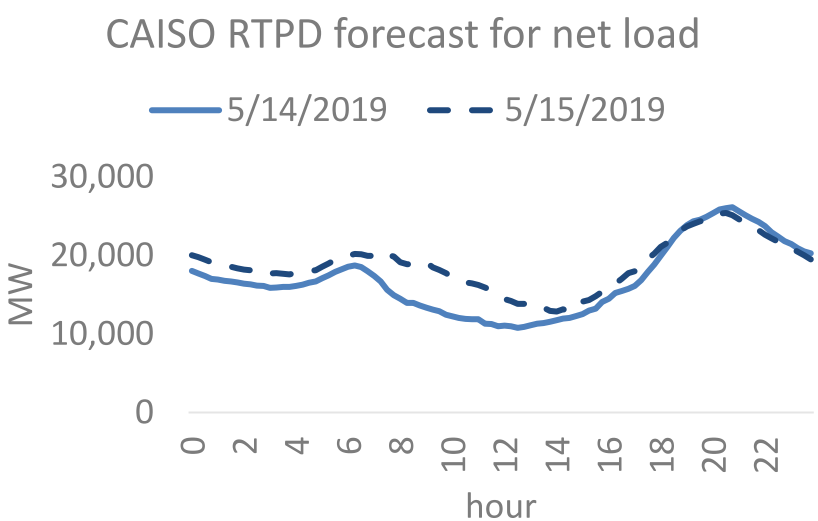
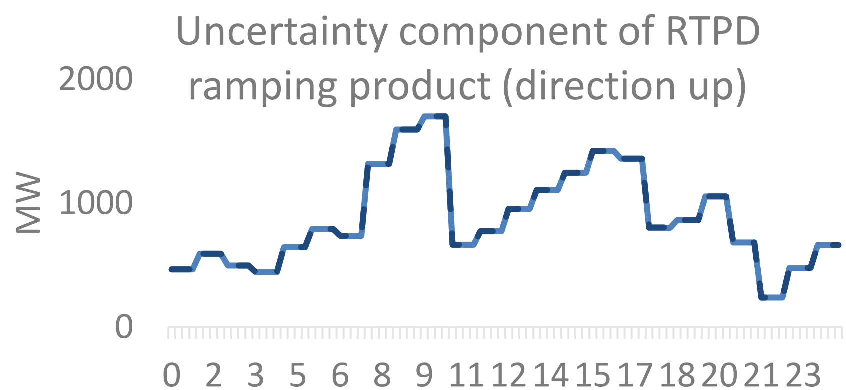
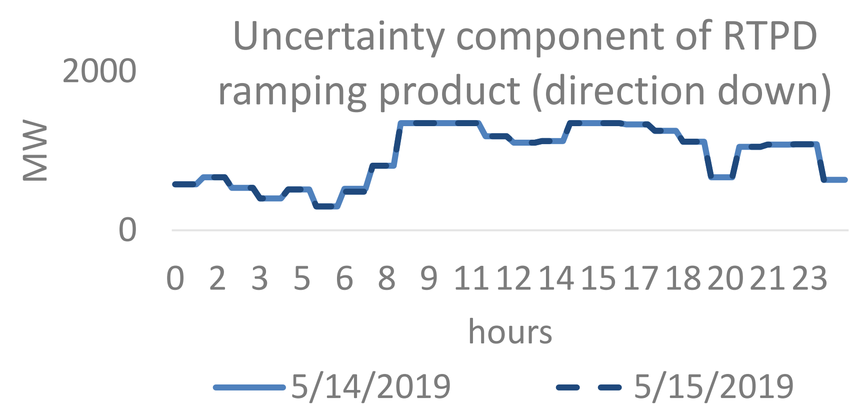
Ramping product estimation methodologies: Weather omitted in analysis of past errors

Two-day **example**: CAISO data







Two days with **different** net load profiles estimate **the same** uncertainty component for all intervals.

Source: CAISO Open Access Same-time Information System (http://oasis.caiso.com)

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The value of alternative ramping estimation methodologies

Research question:

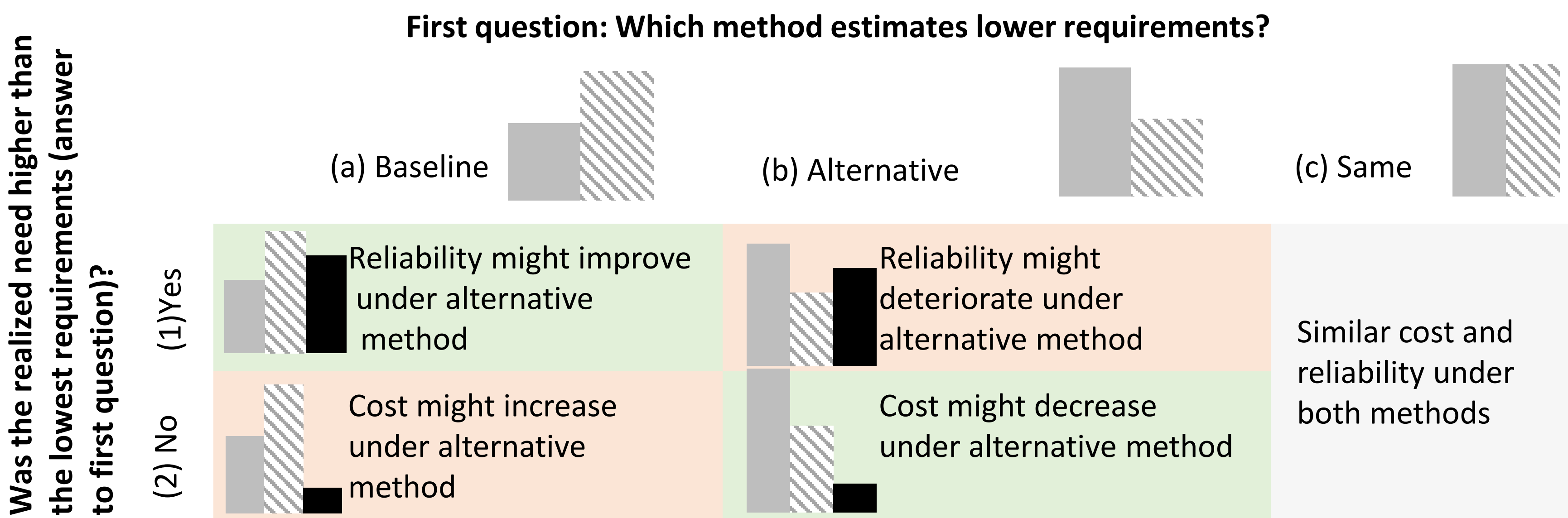
How would system costs and reliability change under alternative *weather-informed* ramping product requirements?

Illustration through:

- A theoretical framework
- Numerical example via a case study on a modified 118-bus system.

Theoretical framework: The value of alternative ramping estimation methodologies

- Five cases arise by comparing requirements from two methods (baseline and alternative) to each other and to actual needs.
  - The higher the ramping requirements, the higher the reliability and cost.
  - The actual ramping need realized affects the value realized.



Framework classifying market intervals by comparing ramping requirements from two methods (baseline/alternative illustrated with solid/pattern gray bars) and the realized ramping needs (illustrated with solid black bars). Green, red, and gray boxes indicate potentially improved, deteriorated, and similar system performance, respectively, under the alternative ramping requirements.

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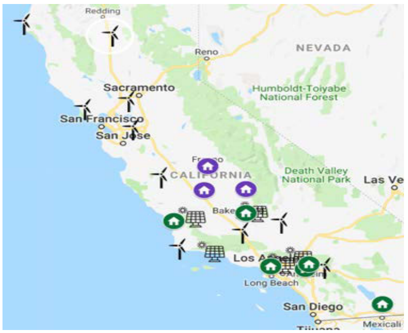
Case study: The value of alternative ramping estimation methodologies



Probabilistic approach: weather-informed

Bottom-up approach (tentative); ongoing research on top-down approaches

Global horizontal irradiance quantiles forecast → Site-specific solar power forecast → System-level solar power forecast → System net load probabilistic forecast

Sandia PV tool kit

Convolution across sites (assumed independency in this paper)

Convolution with other uncertainties (wind, load): assumed perfect knowledge for wind and load in this paper

Test system:

- Modified CAISO-like, 118-bus, mimicking : 1/10th CAISO system [1]
- Uncertainty: Solar generation in day-ahead and RTPD
- Simulation software: Flexible Energy Scheduling Tool for Integrating Variable Generation (FESTIV) [2]

Baseline approach (for demonstration):

- Assume probabilistic distribution of net load (above) is correct.
- Estimate a likely requirement based on PDF of the third largest number over a sample of 30 days.

[1] B.-M. Hodge, C. Brancucci Martinez-Anido, Q. Wang, E. Chartan, A. Florita, and J. Kiviluoma, The combined value of wind and solar power forecasting improvements and electricity storage, *Applied Energy*, 214 (March 2018), 1–15.
[2] E. Ela, M. Milligan, and M. O'Malley, "A flexible power system operations simulation model for assessing wind integration," in *Proceedings of the 2011 IEEE Power and Energy Society General Meeting*.

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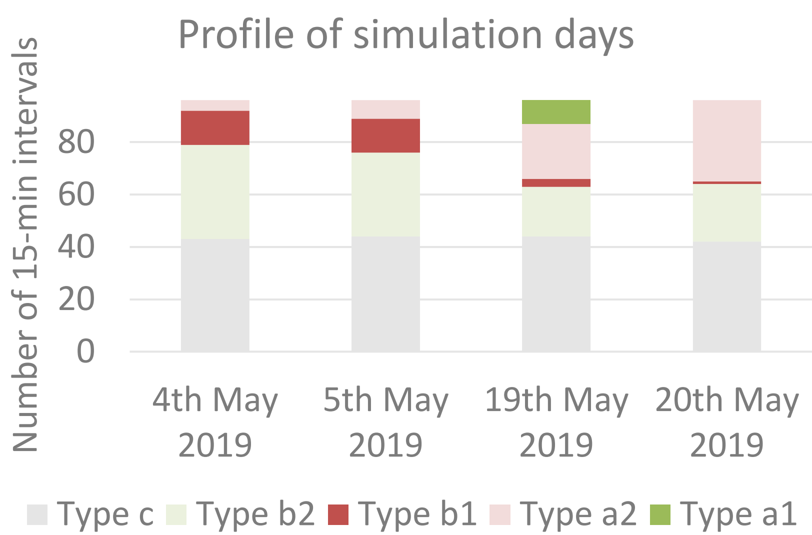
Case study: Experimental design

We choose four simulation days that have different profiles, i.e., frequency of different types of intervals according to the framework in Slide 9.



The alternative method estimates:

- Lower requirements than the baseline most of the time (type: (b)) on May 4 and May 5.
- Higher requirements than the baseline for most daylight hours (type: (a)) on May 19 and May 20.

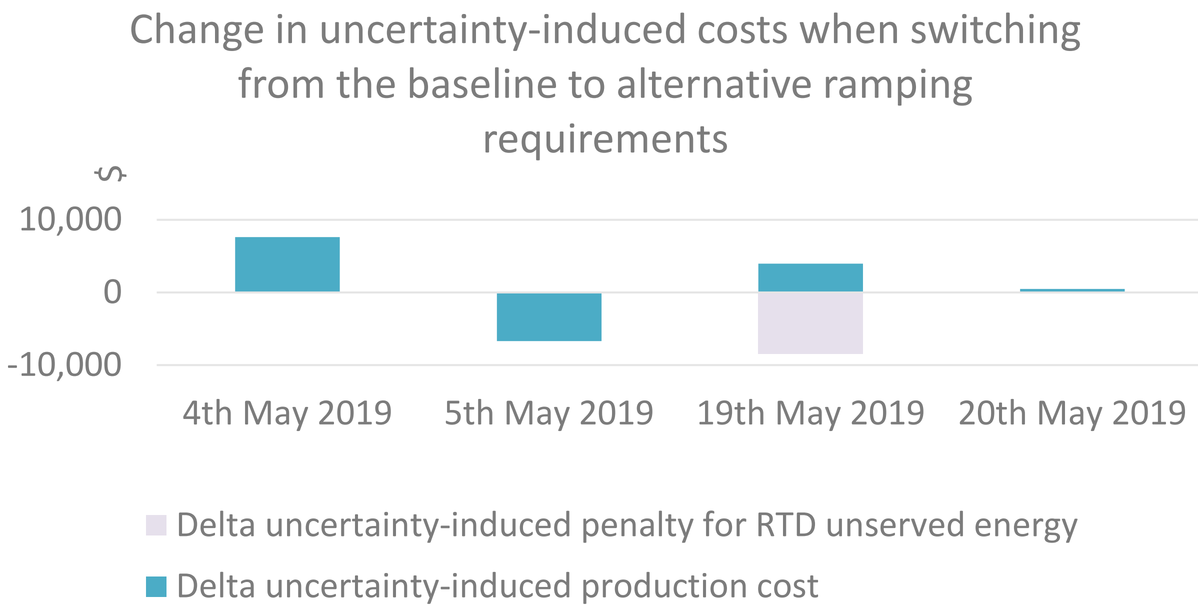
Bold colors indicate that we anticipate differences in reliability; softer colors indicate that we anticipate differences in costs. Green/orange indicate that we anticipate the alternative method to perform better/worse than the baseline.

Case study results: Alternative ramping requirements reduce uncertainty-induced costs during some days

Performance metric:

Uncertainty-induced production cost and penalties for power balance violations

$$Uncertainty - induced\ cost = Cost_{run\ with\ ramping\ product\ and\ uncertainty} - Cost_{run\ with\ perfect\ forecast}$$



The value of alternative ramping requirements varies significantly in a sample of 4 days in May 2019: from a $6,702 cost savings to a $7,633 cost increase.*

*83% cost savings to 150% cost increase in relative terms.

Case study: Results per type of interval

Delta in production costs for 4 simulation days in May 2019 per type of interval (Slide 9)

Day in May 2019	a1	a2	b1	b2	c
4	5	28,329	-3,674	-20,370	3,344
5	-276	-18,208	6,289	7,103	-1,609
19	548	-649	-2,076	6,079	41
20	304	-1,818	0	3,266	-1,254

The performance per type of interval (table above) sometimes contradicts the hypotheses presented in Slide 9:

- Higher costs (positive deltas) are expected for (a1) but are not observed on May 5.
- Higher costs are expected for (a2), but on May 5, 19, and 20, lower costs are recorded.
- Lower costs are expected under type (b) but are not observed on May 5, 19, and 20.

Two possible explanations:

- Inter-temporal effects due to the multiple interval horizon of RTPD scheduling engine
- Allocating costs to a specific interval is challenging (approximate) because of nonconvexity of commitment costs (startups and min-run).

Conclusions and future work

- Existing methodologies that estimate net load uncertainty to size ramping products overlook weather variables/forecasts.

- **Improved estimates of net load uncertainty that could leverage weather-informed probabilistic forecasts** might lead to:
  - **Increased** ramping requirements and **reliability benefits**
  - **Reduced** ramping requirements and **production cost savings.**

- Preliminary results for the value of **alternative estimation methods for ramping requirements** suggest:
  - **A wide range of system benefits** when switching from the baseline to an alternative method (-$7,633 to $6,702). Our future work will investigate system benefits during periods longer than 4 sample days.
  - **Quantification of benefits is affected by system conditions.** We plan to conduct simulations using larger and more realistic systems employed in previous studies.

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Thank you

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