



ELMP Redux: Improved approximations to convex hull prices.

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Outline

- Inter-related policy goals,
- Theory and computation related to convex hull pricing,
- Improve performance of unit commitment algorithms.



Inter-related policy goals.

- Avoid LMP “pricing paradox” of price not increasing, or even decreasing, with increasing demand when, for example, block loaded units are committed:
 - Seek clearer incentives to both supply and demand side to respond to supply-demand balance,
- Reduce out-of-market uplift payments for commitment:
 - Make energy prices better indicators of supply-demand balance and of need for new investment.



LMP pricing paradox example.

- Two units, offers based on marginal costs:
 1. \$10/MWh, generate from 0 to 50MW,
 2. \$50/MWh, block loaded either off or 50MW.
- As demand increases from 0 to 50MW:
 - LMP is \$10/MWh, reflecting marginal unit 1 offer.
- For demand above 50MW:
 - Unit 2 operated at 50MW,
 - Marginal unit is still unit 1,
 - LMP is still \$10/MWh, despite needing unit 2.



LMP pricing paradox.

- When demand is below 50MW in example, LMP recovers operating costs,
- For demand above 50MW, LMP falls short of recovering operating costs for unit 2:
 - Uplift payment based on \$40/MWh shortfall.
- LMP of \$10/MWh does not reflect cost of operating unit 2:
 - Most of unit 2 operating costs are recovered out-of-market, so muted signal for new entry.
 - If unit 1 has increasing marginal costs, then LMP can even decrease when demand increases.



Reduce out of market side payments.

- LMP of \$10/MWh does not reflect unit 2 costs.
- Consider modifying (increasing) energy price to reduce out of market payments.
- Prices based on solving so-called “Lagrangian dual” of unit commitment problem minimize out-of-market payments:
 - Assuming out-of-market payments cover all make-whole, lost opportunity costs, and FTR uplift.
 - “Old-fashioned” approach to approximately solving unit commitment.



Theory and computation.

- “Sub-gradient” algorithm and other related approaches to solving Lagrangian dual is cumbersome:
 - Contributed to abandonment by ISOs and adoption of MIP-based unit commitment.
- Classical theory shows that Lagrangian dual can also be solved more easily as “integer relaxation” of unit commitment under particular conditions:
 - If so-called “convex hull” and “convex envelope” of problem can be characterized,
 - Resulting prices called “convex hull prices.”



Theory and computation.

- In general, it is difficult to characterize convex hull and convex envelope exactly:
 - Exact characterization may result in large number of constraints.
- *Approximation* to convex hull and convex envelope can allow tractable *approximation* to convex hull prices:
 - Current MISO ELMP implementation is simplified single-period approximation that ignores inter-temporal issues, but will be updated to include single-period convex envelope enhancement.



Theory and computation.

- Recent advances have helped to better characterize convex hull and convex envelope representing inter-temporal issues:
 - Minimum up- and down- times, and
 - Ramp-rate constraints.
- In absence of ramp-rate constraints, have tractable and exact characterization of convex hull prices:
 - Hua and Baldick, 2017.



Improve performance of unit commitment algorithms.

- Convex hull and convex envelope approximations also help MIP algorithms to solve unit commitment faster!
 - Relatively easy to implement.
- Currently working on convex hull representation for combined-cycle:
 - Goal is modeling operating configurations in combined cycle plant,
 - Improve unit commitment,
 - Improve convex hull pricing for combined cycle.



Conclusion

- Convex hull pricing supports policy goal of better pricing to reflect supply-demand balance.
- Theoretical improvements can enhance both the single-period approximation and the more general case with inter-temporal constraints.
- Also can be included in unit commitment to improve performance.