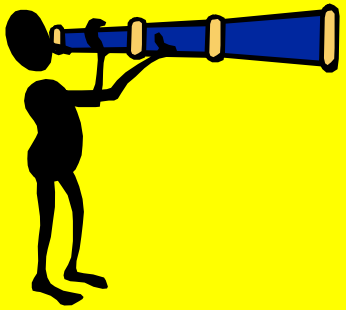
Multi-Period Look Ahead Markets: Price Formation and Dispatch



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What is ARPA-E?

The Advanced Research Projects Agency-Energy (ARPA-E) is an agency within the U.S. Department of Energy that:

- Reduces imports, improve efficiency and reduce emissions
- Provides **Research and Development** funding for high-risk, high-reward, transformational ideas
- Focuses on technologies that could **fundamentally change** the way we get, use and store energy
- Accelerates energy innovations that will create a more secure, affordable, and sustainable **American energy future**

Traditional Pricing Practice under Federal Power Act

⇨FPA requires just and reasonable prices

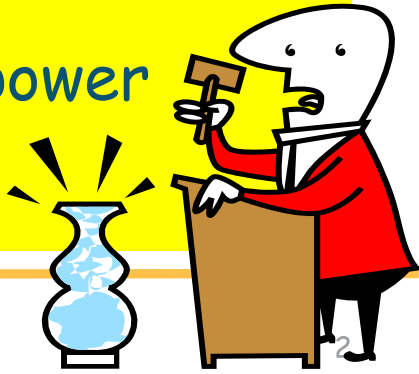
⇨interpreted as efficient (competitive) market pricing

- not lowest price
- but sustainable price (see Hope)
- Not laissez faire

⇨Until 1980s, cost of service regulation sets prices

⇨1980s on, FERC adds

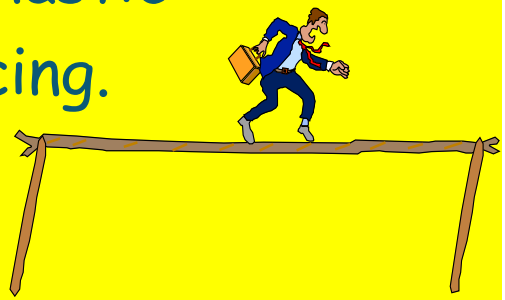
- market-based rates when lacking market power
- auctions with market power mitigation



ISO Real-time Market: Current Practice

⇨Dispatch problem is non-convex and stochastic

- System requires instantaneous balancing.
- Reserves that address contingencies
- Little delivery risk. The risk is price



⇨What is the role of the announced price?

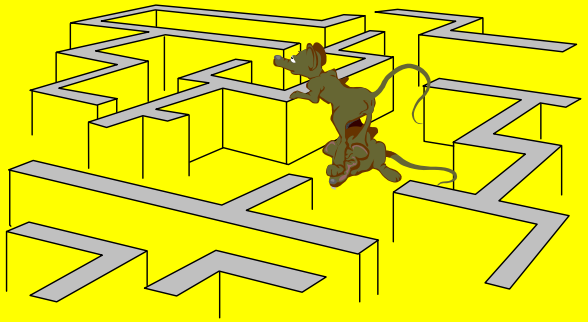
- LMP (alone) has no claim to market clearing
- non-confiscation needs more than the LMP
- LMP is the low-cost entry price for the last period.

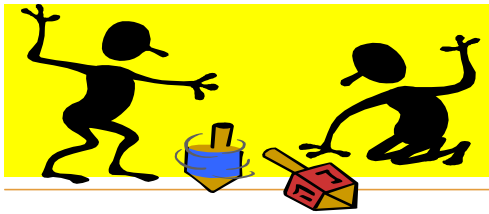
⇨Look-ahead prices and models are not publicly available

⇨Operators are a part of the dispatch decision (Non-AI)

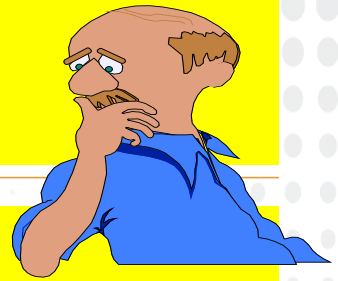
Look-ahead (LA) Variations

- Separate LA model
  - sets reserve constraints in real-time market
- LA part of the real-time market
- LA prices: not available, advisory or settlement prices
- Scenarios: how are they determined?
- market operator
  - looks ahead
  - assisted by scenario generator
- Are ramp rate and N-1 reserves added or reusable?





Stochastics



- Fast-occurring, low-probability, N-1 events
  - Generator contingencies (monetize primary response)
  - Transmission contingencies (thermal and voltage)
  - Solution is capital with the AJ effect
- Slow-developing evolving-probability events:
  - Wind and solar (easy solution: curtail)
  - Temperature and humidity
  - More important as renewables increase
- Better weather forecasts with probability distributions
  - t_0 is the time of the real-time market dispatch.
  - As $t \rightarrow t_0$, var(weather, t) $\rightarrow 0$
  - What is a good horizon?

An 'Ideal' Market Sequence

- ⇨ week ahead advisory scenario based
  - Potential topology reconfigurations
  - for minimum run time (> 24 hr) gens to schedule
- ⇨ day-ahead market with
  - Price-responsive demand (with DER)
  - Forecasted renewables
  - ramp rate reserves for renewable uncertainty
  - Average Incremental Cost (AIC) prices for
    - Settlements without make-whole payments
    - avoidable-cost entry signal
  - LMPs as the marginal-cost entry signal
- ⇨ Rolling horizon real-time market
  - price-responsive demand (with DER)
  - Better renewables forecast
  - Ramp rate and contingency reserves
  - Topology reconfiguration (see SPP)

Price-responsive demand (with DER)

⇨What is the future role of price-responsive demand?

- Follow generation (primary supplier of reserves)
- To avoid spikes and consume in valleys
- Reduce prices in the capacity market
- avoid over-reliance on the ORDC

⇨Participation models for dynamic price-responsive demand and DER (solves principle-agent problem)

- Industrial processes, buildings (storage), heating and cooling, and data centers
- How often does google scholar need to be updated?

⇨price-responsive demand interaction with the ISO

- Aggregation and communication and/or
- Response to frequency/voltage changes

LA Design Questions

⇨Efficient dispatch for energy and reserves? yes

⇨What is the role of selfies?

- self-commits, self-schedules and self-dispatch
- Do they help or hurt efficiency/balancing?
- What should the pricing for selfies be? LMPs?

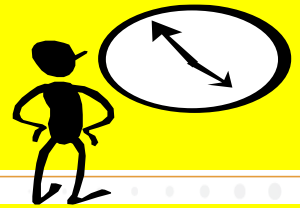
⇨What is the role of prices?

- Entry/exit signals: LMP for marginal entry
- non-confiscatory and transparent settlement: AIC
- AIC for incremental entry (when to calculate)
- Web site map entertainment

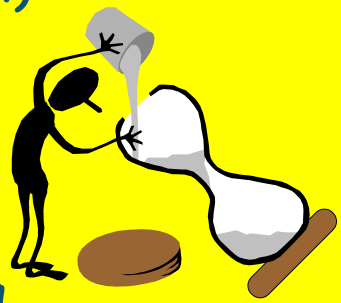
LA design questions

- How will the model be stochastic?
  - Who chooses the scenarios
  - Two-stage stochastic model.
  - Operator decisions on likely events
- Which units will be committable or de-committable?
- What is horizon and interval sizes?
- Will it include minimum run and down times? yes
- Will it have topology optimization? hopefully
- How soft are the soft constraints, for example, thermal
- Should thermal constraints be dynamic?

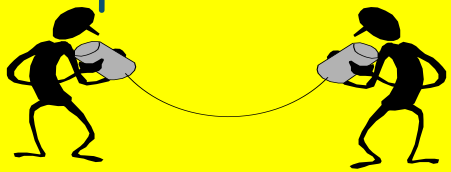
Computation and Communication



- all current models are computationally constrained
  - how much time will be given to solve the LA model?
- Probability distributions need judgement and reduction to a manageable number of events (not an easy problem)
- more detail usually comes with longer run times.
  - CCCT models: configuration dispatch
  - Pumped storage models
  - topology optimization and corrective switching
    - SPP solved wind curtailment (psst improved market surplus)

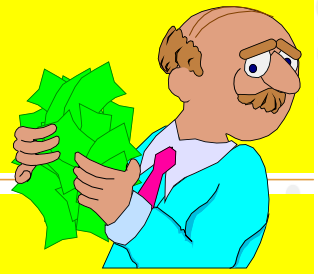


- Can we aggregate and communicate with price-responsive demand?
  - Response to frequency signals



- There is hope. HIPPO/MISO project has 10x improvement

Prices



- What are LA prices telling market participants
  - Advisory for entry/exit bids and offers in the future?
  - LMPs for low cost entry
  - AIC entry at average incremental cost and for settlement
- Short-term entry-exit signal: LMP is the low-cost entry signal
  - available immediately after dispatch
  - For example, for generators running in neighboring markets
- Settlement price: AIC price (says in the optimal neighborhood)
  - Settlement occurs later; not real-time
  - no generator make-whole payments
  - Ramsey-Boiteux pricing for load (more focused than MWP)
- Today's ELMPs are neither fish nor fowl
  - Not entry prices, not transparent (make-whole payments)
  - may not be revenue adequate
- What would CHP be if
  - we penalized self-dispatch (as most ISOs do)
  - Not let non-dispatched units set the price

Thank you