Wholesale Market Design: Lessons from the United States

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Outline of Presentation

- History of US market design process
  - The trouble with zonal market designs
- Market design principles from US experience
  - Match between market model and network model
  - Multi-settlement market
  - Local market power mitigation mechanism
  - Co-optimize energy and ancillary services procurement
  - Reliability externality and need for Long-Term Resource Adequacy (LT-RA) mechanism
  - Regulatory oversight and market monitoring
- Over-arching theme of presentation
  - Restructuring can yield economic benefits if it sets efficient prices and allows customers to be exposed to these prices
    - Don't re-structure if you're unwilling to do this

Match Between Network Model Used to Operate Market Model and Network Model Used to Operate Transmission Network

Lesson from US Zonal Markets

- **Market model must accurately capture reality of how transmission network and generation units operate**
- Differences between market model and operating reality requires re-dispatch of generation units
  - Generation unit owners require compensation to increase and decrease output relative to what cleared market model
- Payment for re-dispatch creates incentives for generation unit owners to take actions to cause it to occur
  - Unnecessarily increases cost of serving final demand
  - Creates incentive for suppliers to degrade, rather than improve system reliability

Lesson from US Zonal Markets

- The “DEC game” in single zone or zonal market
  - Generation unit owner sells energy in zonal day-ahead market that cannot be delivered because of intra-zonal constraints
    - Unit owner sells energy at market-clearing price in day-ahead market and buys it back at lower offer price
    - Make money by selling little or no actual energy
- The “INC game” in single zone or zonal market
  - Generation unit owner knows that energy will be required from unit in real-time because of intra-zonal constraints
    - Unit owner offers a high price day-ahead market, but sells no energy
    - Unit supplies necessary energy at offer price in real-time
- In real-time, physics always wins
  - Realities of how grid is actually operated must be respected
  - Market participants use this knowledge it to maximize profits
    - Graf, Quaglia, and Wolak (2020) “Simplified Electricity Market Models with Significant Intermittent Renewable Capacity: Evidence from Italy,” on web-site

US Solution

- All US markets have adopted locational marginal pricing (LMP) which explicitly prices all transmission constraints and generation unit operating constraints
  - Limits difference between market model used for pricing and actual operation of transmission network
  - *No infeasible schedules accepted in day-ahead market*
- LMPs are computed in day-ahead and real-time markets by minimizing the as-offered cost of meeting demand at all locations subject to configuration of transmission network and operating constraints on generation units
  - LMP at a location is increase in objective function value associated with a one unit increase in withdrawals at that location

Multi-Settlement Locational Marginal Pricing Market

Multi-Settlement Market

- Advance planning should produce more efficient real-time dispatch of generation units
  - Particularly true for systems with thermal generation units that have significant start-up costs
  - Running only an hourly real-time market makes it more difficult for these units to operate in most efficient manner possible
- All US wholesale electricity markets operate a day-ahead forward market and real-time imbalance market employing locational marginal pricing (LMP)
  - Suppliers submit multi-part offers to day-ahead market for all 24 hours of following day
    - Start-up and minimum load costs and energy offer curve for each hour of the day
  - ISO minimizes as-offered costs to meet demand at all locations in grid for all 24 hours of following day to compute market prices and day-ahead schedules for withdrawals and injections for all 24 hours of the day
    - Day-ahead schedules are firm financial commitments

IMPORTANT WARNING

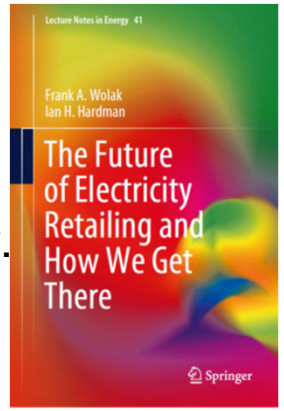
- A multi-settlement zonal market design creates opportunities for the INC/DEC game described earlier
- Sell physically infeasible energy or operating reserves in day-ahead market
- These schedules must be made physically feasible in real-time using INCs and DECs
  - Many examples from zonal markets around the world
- Important Point: Efficiency of multi-settlement market design requires all markets—day-ahead, intra-day, and real-time to employ locational marginal pricing (LMP)

Wholesale Market Lessons from US

- For same level of output produced by thermal units in California, both total BTUs of fossil fuel energy used and total operating costs of thermal generation units fell after transition to multi-settlement LMP market from multi-settlement zonal market
  - Total fossil fuel energy used each hour to dispatch system fell by 2.5 %
  - Daily variable cost of operating system fell by 2.1%
    - Wolak, F.A. (2011) "Measuring the Benefits of Greater Spatial Granularity in Short-Term Pricing in Wholesale Electricity Markets," *American Economic Review, also on web-site.*
  - Estimated reduction in annual total cost of operating thermal units of more than $100 million from transition to multi-settlement LMP market
- Even larger costs savings from transition to multi-settlement LMP market design from multi-settlement zonal design in Electricity Reliability Council of Texas (ERCOT) market
  - Daily variable cost of operating system fell by 3.9%
    - Triolo, R. and Wolak, F.A. (2020) "Measuring the Market Efficiency Benefits of the Transition to a Multi-settlement LMP market in ERCOT," available on web-site
  - Estimated reduction in annual total cost of operating thermal units of more than $300 million from transition to LMP market

Multi-Settlement and Demand

- Facilitates active participation of final demand with interval meters in wholesale electricity market
- Avoids need to pay for demand reductions relative to administratively determined baseline MWh as is the case with traditional demand response products
  - Traditional demand response products have created significant regulatory controversy and reliability challenges in many markets
    - Bushnell, James, Benjamin F. Hobbs, and Frank A. Wolak. "When it comes to demand response, is FERC its own worst enemy?." The Electricity Journal 22, no. 8 (2009): 9-18, also on web-site
- In multi-settlement market, loads simply buy their baseline consumption in previous forward market
  - Day-ahead market purchase allows sale in real-time market
  - Important for developing active demand-side participation in wholesale market
- For more information of retail market reform and dynamic pricing see
  - Wolak, Frank A. and Hardman, Ian M., *The Future of Electricity Retailing and How We Get There*. Springer.



Local Market Power Mitigation Mechanism

Local Market Power Mitigation

- All US LMP markets have some form of ex ante automatic mitigation procedure (AMP) for local market power built into market software
  - Operates every hour before market-clearing occurs
- All AMP procedures follow three-step process
  - Determine system conditions when supplier is worthy of mitigation
  - Mitigate offer of supplier to some reference level
  - Determine payment to mitigated and unmitigated suppliers
- Survey of existing US LMPM mechanism
  - Conduct and impact
    - NY-ISO, ISO-NE
  - Market Structure-Based
    - CAISO, PJM, ERCOT

Local Market Power Mitigation

- As share of energy from intermittent renewables increases, need for explicit local market power mitigation mechanism increases
  - When wind or solar energy is unavailable, remaining suppliers can have a substantial ability to exercise unilateral market power at their location in transmission network
- Survey of existing US LMPM mechanisms with recommendations for different wholesale market designs
  - Graf, Christoph, Emilio La Pera, Federico Quaglia, and Frank A. Wolak. "Market Power Mitigation Mechanisms for Wholesale Electricity Markets: Status Quo and Challenges." (2021).

Co-optimization of Energy and Ancillary Services Procurement

What is Co-Optimization?

- System operator minimizes as-offered cost to meet demand for energy and all operating reserves in day-ahead market for all *24 hours of the day simultaneously*
  - Co-optimize procurement of energy and four ancillary services in day-ahead market
  - Can specify locational demands and prices for operating reserves, just like for energy
- Day-ahead market respects all transmission network and all relevant generation unit and transmission network operating constraints
  - Energy and operating reserves schedules that result from day-ahead market are physically feasible
- Price of each operating reserve is increase in optimized value of the objective function associated with increasing demand for that service by 1 MW

Why Co-Optimization?

- Sequential energy and operating reserve markets are unnecessarily expensive procurement mechanism
  - Sequential market uses a "stale" or "wrong" opportunity cost of energy when computing an operating reserve price
    - Supplier with $1/MW offer price could be taken for 10 MW of operating reserves at $5/MWh, because implied day-ahead price of energy was $23/MWh and its marginal cost is $20/MWh
    - In real-time, supplier could regret this operating reserves sale because price of energy is $30/MWh, which implies $10/MWh opportunity cost of energy
- Early in California, the ancillary services market cleared before real-time energy market and after day-ahead energy market (not co-optimized with day-ahead market)
  - During this time period ancillary services costs were 13% of annual energy costs in 1998, 5.7% in 1999 and 6.8% in 2000
  - During last three years of co-optimized market in California with approximately 30% renewables, ancillary services costs were 1.6% of annual energy costs in 2017, 2% in 2018 and 1.7% in 2019
- With co-optimized energy and ancillary services market, generation unit is always taken for highest margin product
  - Supplier that sells energy has no regret doing so given energy and ancillary services prices
  - Supplier that sells ancillary services has no regret doing so given energy and ancillary services prices

Outstanding Topics

- Reliability externality and need for Long-Term Resource Adequacy (LT-RA) mechanism
  - Wolak, F.A., 2021. Market design in an intermittent renewable future: cost recovery With zero-marginal-cost resources. *IEEE Power and Energy Magazine*, 19(1), pp.29-40.
  - Wolak, F.A. 2021. Long-Term Resource Adequacy in Wholesale Electricity Markets with Significant Intermittent Renewables, on web-site
- Regulatory oversight and market monitoring
  - Wolak, F.A., 2014. 4. Regulating Competition in Wholesale Electricity Supply. In *Economic regulation and Its reform* (pp. 195-290). University of Chicago Press.

Thank you

Questions/Comments

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