Course notes for EE394V
Restructured Electricity Markets:
Locational Marginal Pricing

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Hedging

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(ii) Forward markets,
(iii) Contract for differences.
(iv) Relationship to capital formation,
(v) Transmission prices,
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(vii) Revenue adequacy.

11.1 Volatility of energy prices

- LMPs vary over time as supply and demand conditions vary:
  - the prices are said to be **volatile**.
- Consider a generator and demand that are co-located at the same bus.
- More precisely, consider a generator and demand that are exposed to the same LMPs.
- Each might prefer to be exposed to a less varying price over time.
- That is, they may want to **hedge** (or remove) their exposure to LMP volatility.

11.2 Forward markets

- In the previous discussion of offer-based markets, we did not discuss in the detail the differences between **forward markets** and **real-time markets**, except briefly in Sections 8.11.3 and 10.10.
- Real-time markets match physical supply and physical demand over short time intervals.
- The price outcome on any given day will depend on the supply and demand conditions on that day:
  - prices will tend to fluctuate considerably, or be highly volatile.
- The day-ahead market provides a mechanism to reduce exposure to this volatility.
- Other forward markets provide a way for a generator and a (representative of) demand to agree to a price for a specific quantity of energy in advance of the day-ahead market.
- In the context of an offer-based economic dispatch market, the most natural forward contract is called a **contract for differences**:
  - this is a forward financial commitment,
  - other types of forward agreements are possible.

11.3 Contract for differences

- If a generator and demand are exposed to the same LMP, then a **contract for differences** removes both their exposures to variation in that LMP for a given contract quantity over a given contract period.
- A contract for differences is an agreement between a generator and demand that entails a payment by the demand to the generator equal to:

$$(\text{contract quantity}) \times ((\text{contract price}) - \text{LMP}),$$

- for each pricing interval in the contract period.
- The contract quantity is in MW, while the contract price is in \$/MWh.
- Since the demand will also be required to pay the ISO for its energy based on the LMP then, if it consumes at a power level equal to the contract quantity in each pricing interval, its total payment will be:

$$\begin{aligned}(\text{contract quantity}) \times ((\text{contract price}) - \text{LMP}) &+ (\text{contract quantity}) \times \text{LMP} \\ &= (\text{contract quantity}) \times (\text{contract price}).\end{aligned}$$

- Similarly, the net payment to the generator will be:

$$(\text{contract quantity}) \times (\text{contract price}).$$

Contract for differences, continued

- If the demand consumes more or less than the contract quantity, then it will pay for or (effectively) be refunded for the deviation at the LMP:
  - as in the case of the deviation of real-time quantity from day-ahead quantity.
- If the generator produces more or less than the contract quantity, then it will be paid paid or (effectively) pay back the deviation at the LMP:
  - as in the case of the deviation of real-time quantity from day-ahead quantity.
- This means that the previous results about incentives will still apply even in the presence of forward contracts:
  - first-order necessary conditions for profit maximization of consumption and production decision will be based on the LMPs, not the contract price.

11.4 Relationship to capital formation

- **Bilateral contracts**, such as contracts for differences, between generators and demand have an important role in the financing of new generation.
- If a developer builds a generator, and does not have a bilateral contract, then it is taking the risk that LMPs are high enough to cover its capital and operating costs.
- With a bilateral contract, a developer can assure a less volatile revenue stream.
- Bilateral contracts typically allows for easier financing of construction compared to speculative development.

11.5 Transmission prices

- If the generator and demand are not co-located, they are effectively exposed to the *difference* in LMPs between their buses.
- Although they could hedge exposure to either the generator LMP or the demand LMP with a contract for differences, they will be exposed to variation in the price difference between the two LMPs.

11.6 Financial transmission rights

- A **financial transmission right** (**FTR**) or **congestion revenue right** (**CRR**) is the right to receive the product of:

  (contract quantity) $\times$
  (the difference in LMPs between a notional point of withdrawal and a point of injection),

- for each pricing interval in the contract period.
- The CRR hedges the exposure to volatile LMP differences:
  - if a generator and a demand have signed a contract for differences and also possess a CRR then the net payment by the demand to the generator is:

$$(\text{contract quantity}) \times (\text{contract price}),$$

  - as in the case of the generator and demand being exposed to the same LMP.

11.6.1 Issuing CRRs

- Since prices are typically higher at demand than generation, CRRs will typically pay out positive amounts of money in expectation.
- That is, the expected payout over a contract duration will be positive.
- It can therefore be expected that a typical CRR will cost money to acquire!
- A speculator might offer to sell a CRR based on the expected payout over the contract duration (plus a **risk premium** for taking on the risk).
- Is there any other source of money to fund CRRs not involving speculation?

11.6.2 CRRs funded out of congestion rent

- Congestion rent accrues to the ISO.
- It can be used to fund (non-speculative) CRRs.
- The ISO can sell CRRs.
- How "much" CRRs can be sold?
- Consider a collection of CRRs that have been sold.

  Model each injection as a generation and each withdrawal as a demand, with power level equal to the CRR contract quantity.

  Let the total vectors of **implied dispatch** be P' and D', respectively.
- By (9.7) in Corollary 9.3, if P' and D' are feasible for the transmission system (so that the implied dispatch due to all CRRs is **simultaneously feasible**) then we have:

$$[\lambda^\star]^\dagger(D' - P') \leq [\lambda^\star]^\dagger(\overline{D} - P^\star),$$

- where $\lambda^\star$ are the LMPs corresponding to the actual dispatch $P^\star$ and $\overline{D}$.
- Note that the term on the left is payout from the CRRs.
- The term on the right is the congestion rent.

11.6.3 Revenue adequacy

- That is, we have shown that the revenue to the ISO from the congestion rent is **revenue adequate** to fund the CRRs so long as the implied dispatch is simultaneously feasible.
- In issuing CRRs to market participants, the ISO only needs to make sure that the implied dispatch of the CRRs is simultaneously feasible.

11.6.4 Test system

- CRRs are typically issued for extended periods such as a month or longer.
- A **test system** is used for testing that the CRRs are simultaneously feasible.
- If the system used in the actual market has smaller line capacities (or there is a constraint represented in the market that was not in the test system) then the revenue adequacy result no longer applies.
- A **derating policy** is needed for the case of revenue shortfall.

11.7 Summary

- In this chapter we have considered volatility of energy and transmission prices and hedging.
- We defined FTRs/CRRs and considered conditions for revenue adequacy.

References

- William W. Hogan "Contract Networks for Electric Power Transmission," *Journal of Regulatory Economics*, 4(3):211–242, 1992.
- Felix Wu, Pravin Varaiya, Pablo Spiller, and Shmuel Oren, "Folk Theorems on Transmission Access: Proofs and Counterexamples," *Journal of Regulatory Economics*, 10(1):5–23, 1996.