ECEN 615
Methods of Electric Power Systems Analysis

Lecture 23: Electricity Markets

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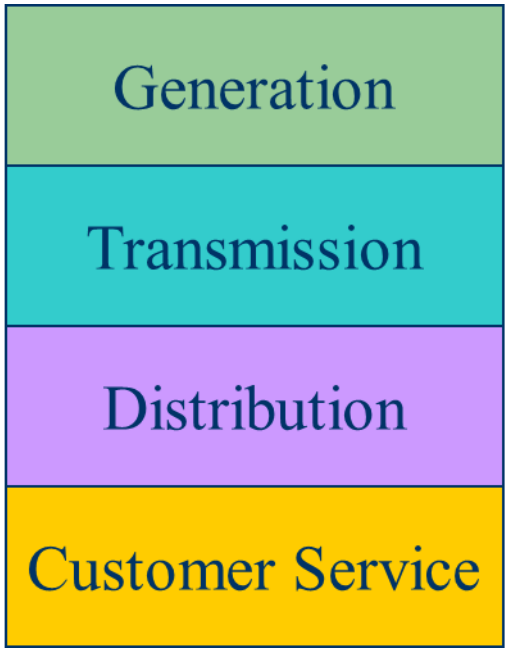
Announcements

- Read Chapter 8 and Appendices 3B and 3E of Chapter 3
- Homeworks 6 and 7 are assigned today, with Homework 6 due on Nov 12 and Homework 7 by Nov 24
- The second exam will be in class on Nov 17
  - Distance learners will be able to take the exam from Nov 16 to Nov 18
- Associated with Homework 7 will be student presentations; these will be about 15 minutes during class on Nov 19 or Nov 24
  - Other times can be arranged for the distance learners

Electricity Markets History

- For decades electric utilities operated as vertical monopolies, with their rates set by state regulators
- Utilities had an obligation to serve and customers had no choice
  - There was little third party generation
- Major change in US occurred in 1992 with the National Energy Policy Act that mandated utilities provide "nondiscriminatory" access to the high voltage grid
- Goal was to setup true competition in generation



Markets Versus Centralized Planning

- With the vertically integrated utility, a small number of entities (typically utilities) did most of the planning
  - For example, which new generators and/or lines to build
  - Planning was coordinated and governed by regulators
  - Regulators needed to know the utilities actual costs so they could provide them with a fixed rate of return
- With markets the larger number of participants often make individual decisions in reaction to prices
  - For example, whether to build new generation
  - Generator owners in general to not need to reveal their true costs; rather they make offers into the market

Overall Goal

- Goal is to maximize the economic surplus (or total welfare), which is the sum of the consumer surplus and the producer surplus (i.e., their profit)
- Generation owners have to decide their offer prices
- If their price is too high, they are not selected to generate
- At the wholesale level, the consumers often just see a price, though there can be price responsive load bids

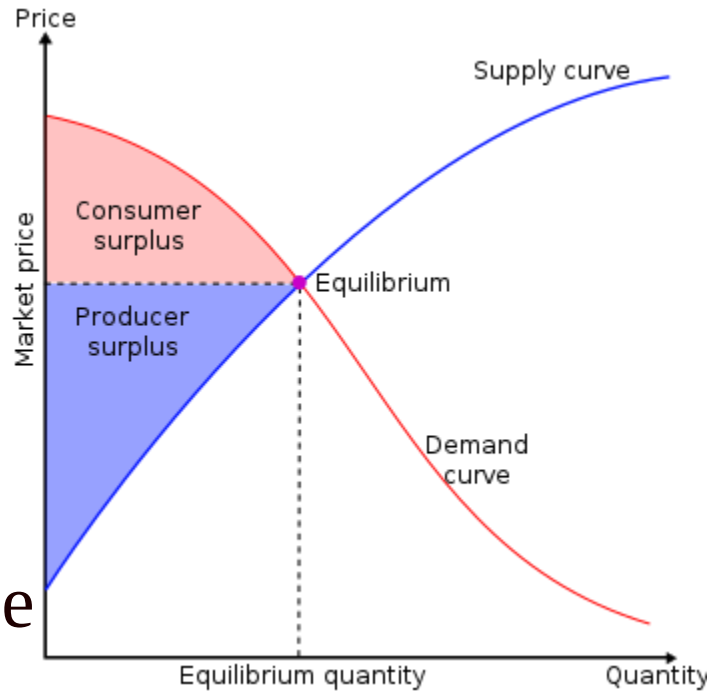
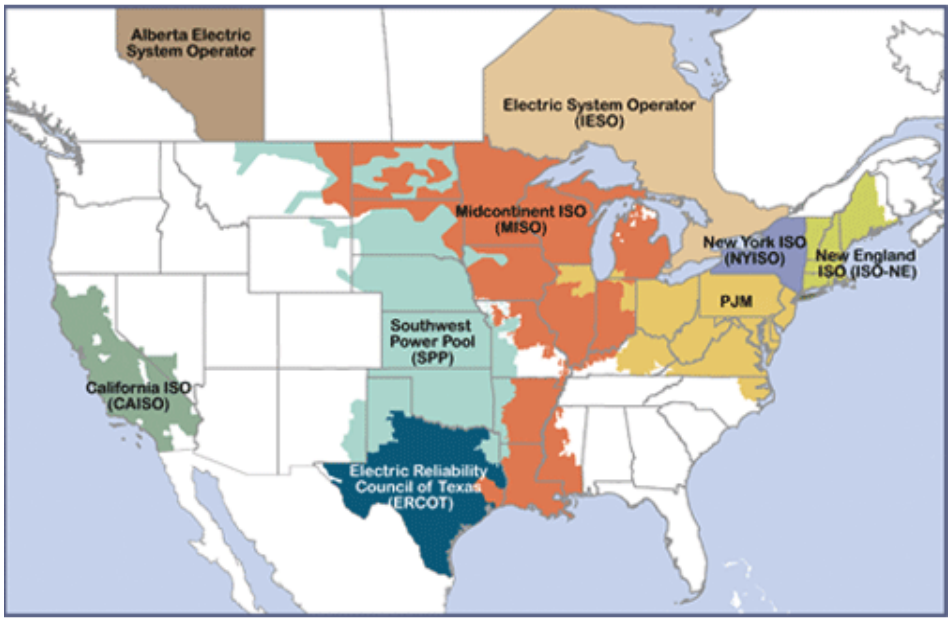


Image Source: en.wikipedia.org/wiki/Economic_surplus#/media/File:Economic-surpluses.svg

Electricity Markets Today

- Starting in about 1995 electricity markets gradually started to develop, both in the US and elsewhere
- In North America more than 60% of the load is supplied via wholesale electricity markets; markets differ but they all have certain common features



  - The terms regional transmission organizations (RTOs) and independent system operators (ISOs) are used (RTOs are more functionality and most are actually RTOs

Image source: www.ferc.gov/industries-data/electric/power-sales-and-markets/rtos-and-isos

Aside: NERC Reliability Coordinators (RCs)

As noted in NERC IRO-001-1, "Reliability Coordinators must have the authority, plans and agreements in place to immediately direct reliability entities within the Reliability Coordinator Areas to re-dispatch generation, reconfigure transmission, or reduce load to mitigate critical conditions to return the system to a reliable state."

Electricity Markets Common Features

- Day ahead market – this is needed because time is required to make decisions about committing generators
  - Generation owners submit offers for how much generation they can supply and at what price; accepted offers are binding
- Real-time energy market – needed because day ahead forecasts are never perfect, and unexpected events can occur
- Co-optimization with other "ancillary services" such as reserves

The source for much of this material "Analytic Research Foundations for the Next-Generation Electric Grid" (Chapter 2), The National Academies Press, 2016 (free download available)

Electricity Markets Common Features

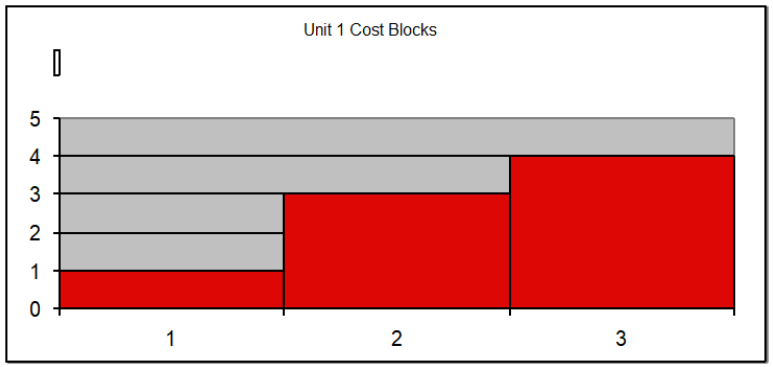
- Pricing is done using locational marginal prices, determined by an SCOPF
  - Most markets include a marginal losses component
- LMP markets are designed to send transparent price signals so people can make short and long-term decisions
  - Generators are free to offer their electricity at whatever price they desire; they do not have to reveal their "true" costs
  - Most of the times markets work as planned (competitive prices)
  - During times of shortages (scarcity) there are limits on LMPs; ERCOT's is $9000/MWh
  - Markets are run by independent system operators (ISOs)

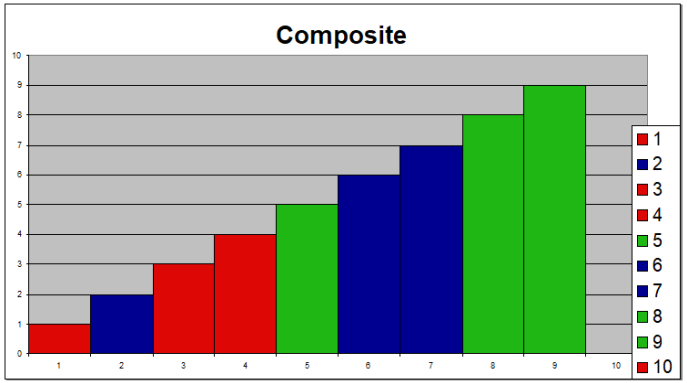
LMP Energy Markets

- In an LMP energy market the generation is paid the LMP at the bus, and the loads pay the LMP at the bus
  - This is done in both the day ahead market and in the real-time market (which makes up the differences between actual and the day ahead)
- The generator surplus (profit) is the difference between the LMP and the actual cost of generation
- Generators that offer too high are not selected to run, and hence make no profit
- A key decision for the generation owners is what values to offer

Generator Offers

- Generator offers are given in piecewise linear curves; that is, a fixed $/MWh for so much power for a time period
- In the absence of constraints (congestion) the ISO would just select the lowest offers to meet the anticipated load
- Actual dispatch is determined using an SCOPF





General Guidelines

- Generators with high fixed costs and low operating costs (e.g., wind, solar, nuclear) benefit from running many hours
  - Usually they should submit offers close to their marginal costs
  - Wind (and some others) receive a production tax credit for their first ten years of operation
    - $23/MWh for systems starting construction before 1/1/2017
    - $18/MWh 2017, $14/MWh in 2018, $10/MWh in 2019
    - It was suppose to end in 2019, but was extended in 12/2019 through 2020 at $15MWh (stay tuned for future changes!)
- Generators with low fixed costs and high operating cost can do fine operating fewer hours (at higher prices)

Auctions

- In its simplest form, an auction is a mechanism of allocating scarce goods based upon competition
  - a seller wishes to obtain as much money as possible, and a buyer wants to pay as little as necessary.
- An auction is usually considered efficient if resources accrue to those who value them most highly
- Auctions can be either one-sided with a single monopolist seller/buyer or a double auction with multiple parties in each category
  - bid to buy, offer to sell
- Most people's experience is with one-side auctions with one seller and multiple buyers

Auctions, cont.

- Electricity markets can be one-sided, with the ISO functioning as a monopolist buyer, while multiple generating companies make offers to sell their generation, or two-sided with load participation
- Auctions provide mechanisms for participants to reveal their true costs while satisfying their desires to buy low and/or sell high.
- Auctions differ on the price participants receive and the information they see along the way

Types of Single-Sided Auctions with Multiple Buyers, One Seller

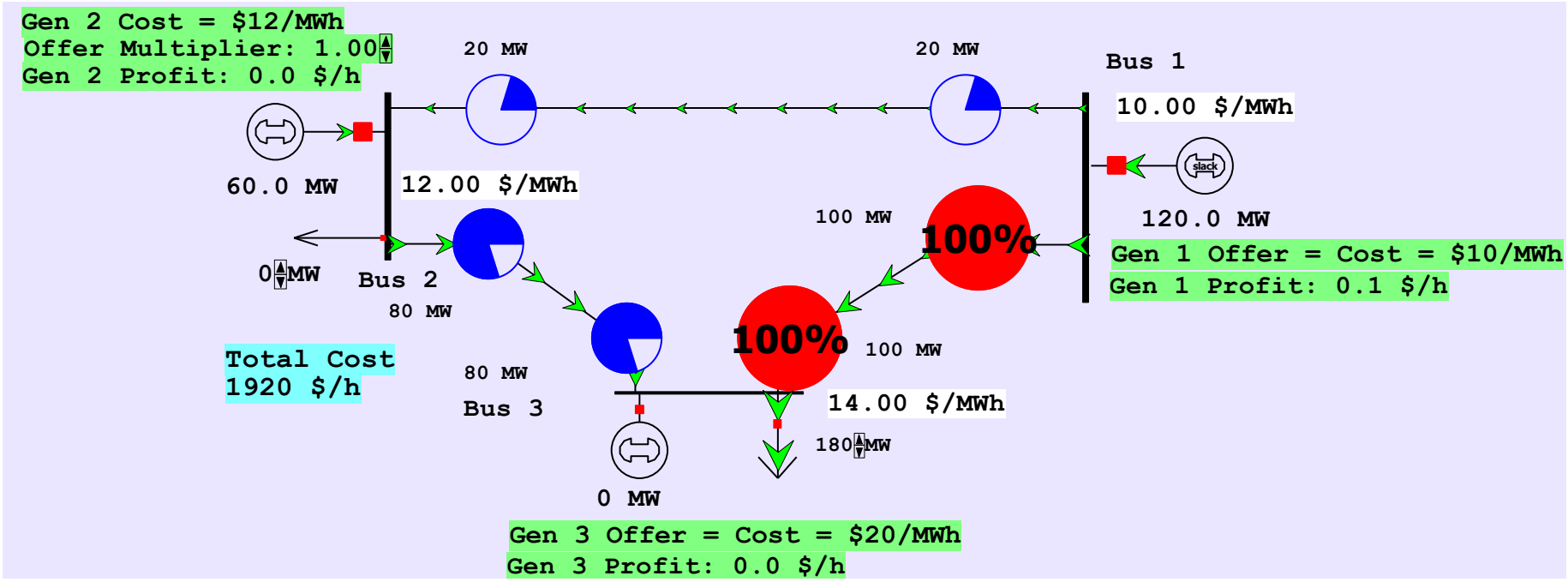
- Simultaneous auctions
  - English (ascending price to buy)
  - Dutch (descending price to buy)
- Sealed-bid auctions (all participants submit offers simultaneously)
  - First price sealed bid (pay highest price if one, discriminatory prices if multiple)
  - Vickrey (uniform second price) (pay the second highest price if one, all pay highest losing price if many); this approach gives people incentive to bid their true value

Uniform Price Auctions: Multiple Sellers, One Buyer

- Uniform price auctions are sealed offer auctions in which sellers make simultaneous decisions (done when submitting offers).
- Generators are paid the last accepted offer
- Provides incentive to offer at marginal cost since higher values cause offers to be rejected
  - reigning price should match marginal cost
- Price caps are needed to prevent prices from rising up to infinity during shortages
- Some generators offering above their marginal costs are needed to cover their fixed costs

What to Offer Example

- Below example shows 3 generator case, in which the bus 2 generator can vary its offer to maximize profit



Note, this example makes the unrealistic assumption that the other generators do not vary their offers in response

Horizontal Market Power

- One issue is whether a particular group of generators has market power
- Market power is the antithesis of competition
  - It is the ability of a particular group of sellers to maintain prices above competitive levels, usually by withholding supply
- The extreme case is a single supplier of a product (i.e., a monopoly)
- In the short run what a monopolistic producer can charge depends upon the price elasticity of the demand
- Sometimes market power can result in decreased prices in the long-term by quickening the entry of new players or new innovation

Market Power and Scarcity Rents

- A generator owner exercises market power when it is unwilling to make energy available at a price that is equal to that unit's variable cost of production, even thought there is currently unloaded generation capacity (i.e., there is no scarcity).
- Scarcity rents occur when the level of electric demand is such that there is little, if any, unused capacity
- Scarcity rents are used to recover fixed costs