Overview of Power Market Organization

**Important Acknowledgement:**

These notes are based on lecture slides by Daniel Kirschen for Kirschen/Strbac Chapter 1, with edits by Leigh Tesfatsion

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Wholesale and Retail Power System Operations

U.S. High-Voltage Transmission Network
Classification of Competition Models by Hunt & Shuttleworth (1996):
Fig. 1.1(a): Traditional Vertically-Integrated Electric Utility

- **Generation**
- **Transmission**
- **Distribution**
- **Consumers**

Monopolistic control of generation, transmission, & distribution

Retail buyers of electrical energy who “use up” (consume) their energy purchases
Figure 1.3: Wholesale Competition Only (IPP=Independent Power Producer, DisCo=Distribution Company)
North American energy regions that have restructured their wholesale operations to permit more competition

Source: www.ferc.gov/industries/electric/indus-act/rto/rto-map.asp
MISO Extended Market Footprint: August 2011

Entergy Electric Territory to join MISO!
Figure 1.4: Both Wholesale and Retail Competition

Wholesale Market and Transmission Wires

Retail Market and Distribution Wires

IPP

Retailer

Large Consumers

Consumer
Integrated Retail/Wholesale Power Market Operations in the ERCOT (Texas) Energy Region with Retail Competition
Consumer-Owned Distributed Energy Resource Possibilities

Source: Slide by Prof. Dionysios Aliprantis (ECpE, ISU)
Why introduce competitive electricity markets?

• Vertically integrated utilities operating under regulated rates ensuring costs & “normal” profit tend to be inefficient
  ✓ No incentive to operate efficiently
    • Operation costs are higher than they could be
  ✓ No penalty for planning mistakes
    • Costs of unnecessary or poorly considered investments are passed along to consumers

• Potential benefits of introducing competition
  ✓ Increased efficiency in generation and distribution of electric power
  ✓ Lower electric power prices for consumers
  ✓ Promotion of economic growth through appropriate investment in new generation and new transmission
Restructuring Movement: Structural Goals

- **Privatization/Unbundling**
  - As far as possible, generation and distribution should be separately carried out by multiple private for-profit companies that have to compete with each other for business.
  - Vertically integrated utilities should be broken up by “divestiture” into separate companies

- **Competition**
  - **Wholesale level**: Generators compete to sell electrical energy
  - **Retail level**: Consumers choose their electrical energy suppliers
  - **Grid**: Regulated to ensure open access for all potential users
Is Unbundling (Divestiture) Really Needed?

• Competitive market will work only if it is fair

• Market participants should not be able to prevent others from competing

• Should management of the transmission/distribution *networks* be independent from electrical energy trading?
  ✷ A company should not be able to keep others from competing for energy trades by inducing congestion that prevents power inflow
  ✷ “Open access” to transmission and distribution networks is needed

• More generally, should “wires businesses” be separated from “energy businesses”?
  ✷ Energy businesses can become part of a competitive market
  ✷ Wire businesses must remain regulated (public goods)
Fundamental underlying assumption:

- Electrical energy should be treated as an ordinary commodity as far as possible.

- Examples of commodities:
  - A bushel of wheat
  - A metric barrel of crude oil
  - A cubic meter of natural gas
How should we define the “unit” for electrical energy as a commodity?

- Volt V (unit of voltage = “electrical pressure”)
- Amp A (unit of electrical current flow I)
- Watt W (unit of power = rate of flow of energy)
- Watt-Hour Wh (unit of energy = accumulation of power)

- For direct current (DC) systems, Power = V * I:

  120 Volts

  **One amp of current I forced through M**

  120 Watts

Appliance M
Important characteristics of electrical energy:

• Electrical energy is difficult to store economically

• Electrical energy injections and withdrawals/losses on the HV transmission grid must be balanced at all times

• The demand for electrical energy varies over time

• Cost of producing electrical energy changes with demand

» Value of a megawatt-hour (MWh) varies over the course of a day, e.g., a MWh corresponding to a peak demand hour doesn’t have same value as a MWh for an off-peak hour.

• Value of a MWh can vary depending on the location of its injection into or withdrawal from the transmission grid.
Effects of daily variations in demand:

- **Light demand period**
  - Need only the most efficient generators
  - Marginal cost is low

- **High demand period**
  - Need to run less efficient generators
  - Marginal cost is high
Effects of binding transmission constraints:

- Price of electrical energy at A = marginal cost at A = 50$/MWh
- Price of electrical energy at B = marginal cost at B = 100$/MWh
- Different prices persist at buses A and B because not enough power can flow from A to B to fully service the 200MW demand at B

Binding transmission constraints can segment the market (different energy prices at different buses)
Effects of laws of physics in presence of binding transmission & capacity constraints:

Power flows from high price to low price! (Kirschen, Fig. 6.24, p.170)
Effect of the laws of physics

Exporting oranges from Norway to Spain?
Given these characteristics of electrical energy....

• The “unit” for electrical energy as a commodity should be conditioned on both time and location.

• The basic unit for electrical energy as a commodity is often taken to be the average power (flow of energy) during a particular interval of time at a particular location on the transmission grid.

  **Example:** 4 MW (= 4 MWh/per h) at bus K during hour H

• Sometimes, however, it is taken to be the energy (accumulation of power) during a particular time interval at a particular location on the transmission grid.

  **Example:** 6 MWh of energy withdrawn at bus K during the course of an hour H.
However, security of supply can also affect value:

- Consumers expect a continuous supply of electrical energy.
- Electrical energy commodity should be conditioned on security of supply (risk) as well as on time and location.
- Operational risk management through imposition of “security constraints” is an important topic, to be addressed later in the course.
Challenges Posed by Restructuring

- Traditional Organization (Vertically-Integrated Utilities)
  - Each VIU has operational control over gen, trans, & dist in its franchised area, subject to regulatory oversight
  - Regulatory focus on reliability of system operations, not efficiency

- Restructured (Unbundled) Competitive Electricity System
  - Many actors, each controlling one aspect
  - Different perspectives, different objectives
  - Participants include private trading companies (GenCos, DisCos, Retailers), market and transmission operators (ISOs, RTOs), private transmission companies (TransCos), regulators (e.g., FERC, NERC), and consumers

- How to make the system work so that all participants are satisfied (i.e. objectives achieved to satisfactory degree)?
Generating Company (GenCo):

- Produces and sells electrical energy in bulk
- Owns and operates generating plants
  - Single plant
  - Or a portfolio of plants with possibly different technologies
- Often called an Independent Power Producer (IPP) when coexisting with a vertically integrated utility

Objective:

- Maximize the long-run profits it makes from the sale of electrical energy and other services
- *Note:* As will be clarified later in the course,
  \[ \text{Profits} = [ \text{Revenues} - \text{Total Costs} ] \]
Distribution Company (DisCo):

- Owns and operates distribution network
- Traditional environment:
  - Monopoly for the retail sale of electrical energy to consumers in a given geographical area
- Competitive environment:
  - Operation and development of distribution network separated from the retail sale of electrical energy to consumers
  - Operation of distribution network remains a regulated monopoly

Objective:
- Maximize long-run profits
Retailer (or “Load-Serving Entity” = LSE):

- Buys electrical energy on wholesale market
- Resells this energy “downstream” to retail consumers
- The consumers contracting with any one retailer can be spread over multiple buses & multiple distribution networks
- Typically does not own large physical assets
- Occasionally a subsidiary of a GenCo or a DisCo

Objective:
- Maximize long-run profits by “buying low and selling high”
Market Operator (MO):

- Manages the computer system that matches demand bids and supply offers submitted by buyers and sellers of electrical energy in the **day-ahead market (DAM)**

- Manages the market settlement system
  - Monitors delivery of energy
  - Transmits payments from buyers to sellers

Objective:

- Ensure market efficiency (i.e., avoid wastage of resources)
Independent System Operator (ISO):

- Maintains the security of the system
- Should be independent from other participants to ensure the fairness of the market
- Usually runs the market of last resort ("real-time market")
  - Ensures generation and load balanced in real time (adequacy)
- In U.S., an ISO typically also acts as a market operator, managing the operation and settlement of a day-ahead market (DAM)
- Owns only computing and communication assets

Objective:

- Ensure system reliability (security and adequacy)
- Ensure efficient market operation (if also an MO)
Transmission Company (TransCo):

- Owns transmission assets such as lines, cables, transformers, and reactive power compensation devices
- Operates these assets according to instructions of an ISO
- TransCos are sometimes subsidiaries of companies that also own generating plants.
- An **Independent Transmission Company (ITC)** is a TransCo that does not own generating plants and that operates its own assets (acts as its own ISO)

**Objective:**
- Maximization of long-run profits
Regulators:

• Government bodies
• Determine or approve market rules
• Investigate suspected “market power” abuses (manipulation of prices for one’s own gain)
• Set or constrain the prices for products and services provided by monopolies

Objectives:

- Make sure that the overall electrical energy sector operates in a *fair and economically efficient* manner
- Make sure the overall electrical energy sector operates in a *reliable* manner (security and adequacy)
- Ensure quality of supply
Small Retail Consumer (Typically Residential):

- Buys electrical energy from a retailer
- Leases wire connection from the local DisCo
- Market participation is usually limited to choice of retailer

Objectives:

- Maximize net benefits (i.e., benefits minus costs) from use of electrical energy
- Obtain a satisfactory quality of supply
Large Retail Consumer (Commercial, Industrial):

• Often participates actively in electrical energy markets
• Buys electrical energy directly from wholesale market
• Sometimes connected directly to the transmission grid
• May act as a “demand response” resource for the ISO to help control the system (e.g., agree to have its demand curtailed under certain stated conditions)

Objectives:

- Maximize long-run profits
- Obtain a satisfactory quality of supply