

Deterministic Optimization

Linear Optimization Modeling
Electricity Markets

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How Electricity Markets Work

Modeling using Linear Programs

Learning Objectives for this Module

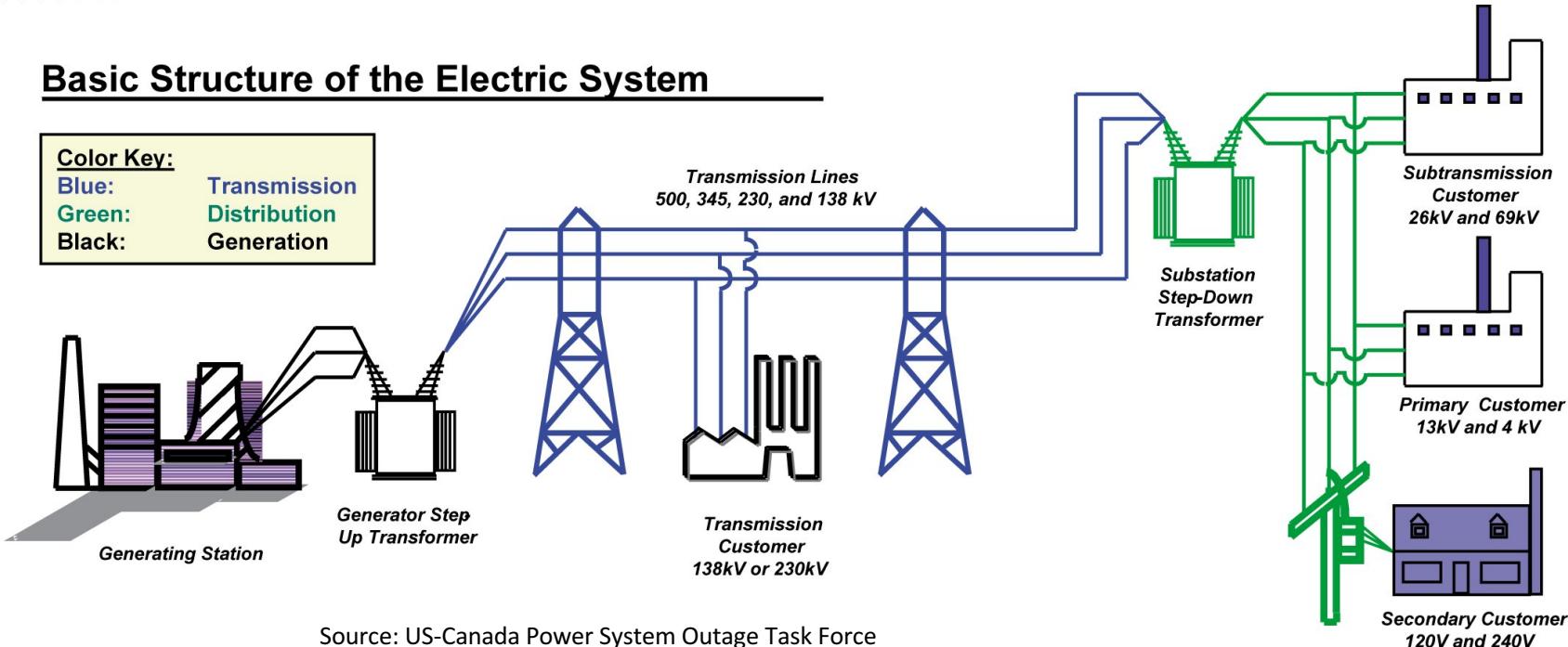
- Discover electricity markets
- Create LP models for scheduling generation in power systems
- Discover how electricity markets are operated
- Discover how electricity prices are created using LP theory

Electric Power Systems

- According to United States National Academy of Engineering, electric power system is the most complicated engineering system that humans have ever built.
- Electric power systems also have a complicated economic and financial aspect – the electricity markets
 - Annual sales of electricity in US ~ \$400 billion
- Operating the power system and the electricity markets involves A LOT of optimization.

Composition of PS: Generation, Transmission, and Distribution

Basic Structure of the Electric System



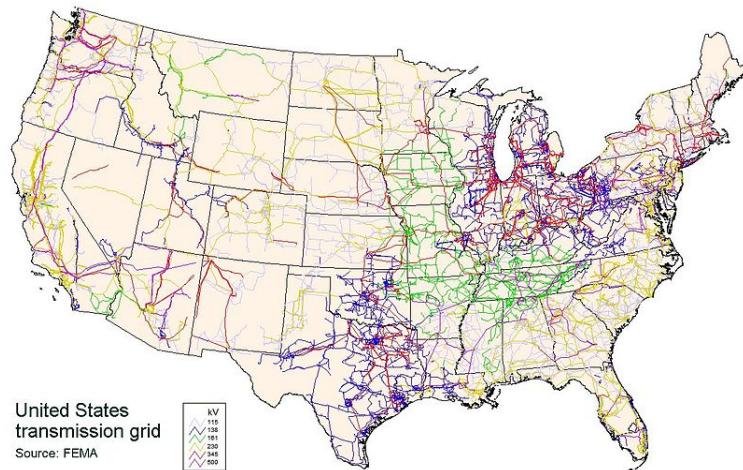
Various Equipment



Brief History of Power Systems

- **1882** – Thomas Edison introduced Pearl Street DC system in Manhattan supplying 59 customers within a one mile radius
- **Mid 1880's** – Westinghouse/Tesla introduce rival AC system
- **1893** – First 3-phase transmission line operating at 2.3 kV, 12 km in Southern California
- **1896** – AC lines deliver electricity from hydro generation at Niagara Falls to Buffalo, 20 miles away
- **Early 1900's** – Private utilities supply all customers in a city
- **1935/6** – Rural Electrification Act brought electricity to rural areas
- **By 1970's** – Utilities gradually interconnected their systems in North America, with voltages up to 765 kV

Current Power System in U.S.



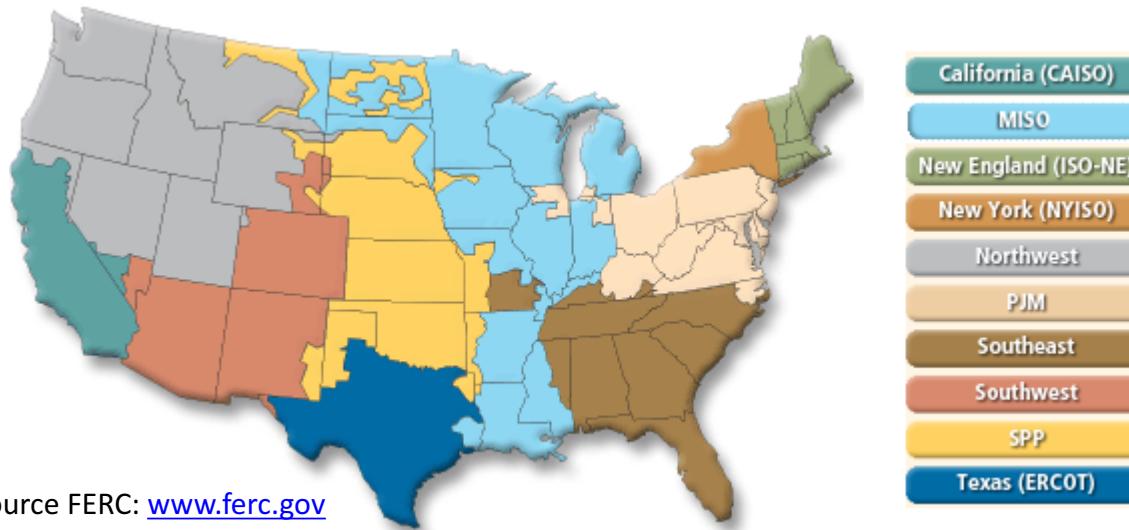
Source NASA: <https://earthdata.nasa.gov/nighttime-lights-over-the-us>

Development of Electricity Markets

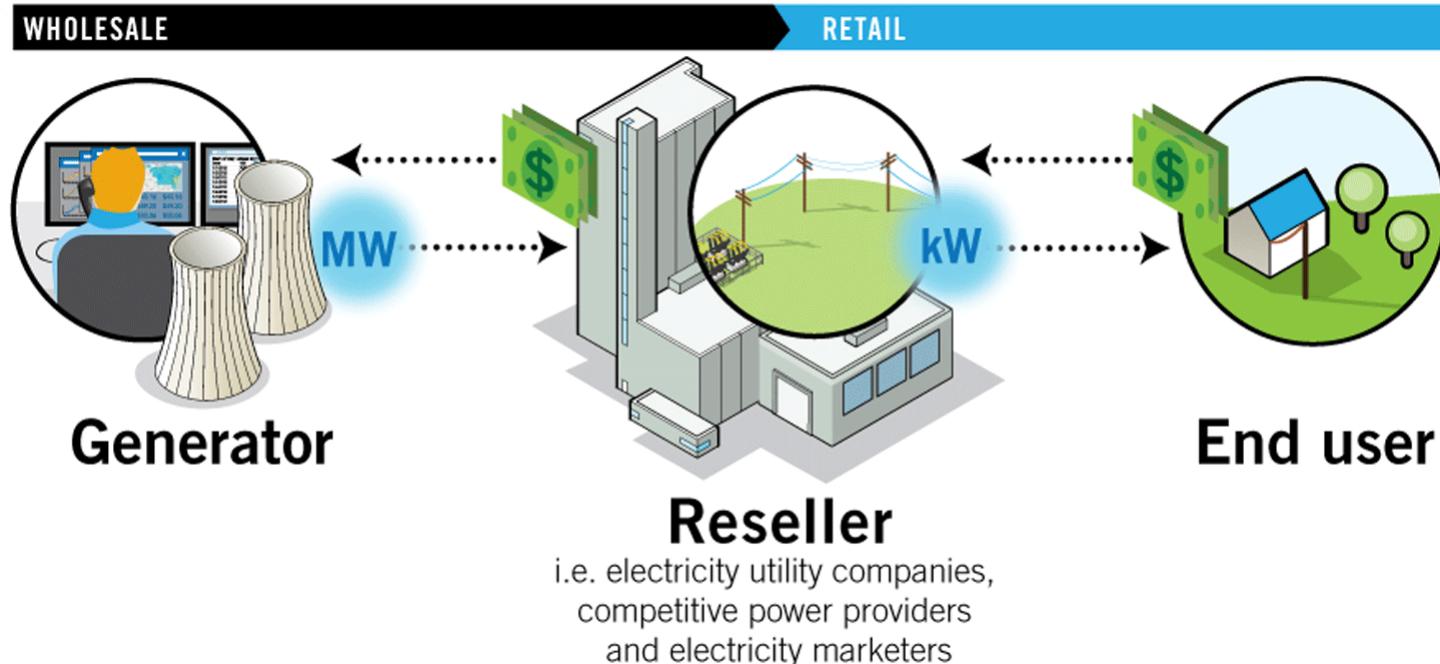
- **Early 1900's** – Private utilities supply all customers in a city; recognized as a **natural monopoly**; states step in to begin regulation
- **1935** – Congress passed Public Utility Holding Company Act (PUHCA) to establish national regulation, breaking up large interstate utilities (repealed 2005)
- **1973** – Oil Crisis: Increased fossil-fuel prices, calls for conservation and growing environmental concerns; Increasing electricity rates
- **1978** – Congress passed Public Utilities Regulator Policies Act (PURPA) which mandated utilities must purchase power from independent generators located in their service territory (modified 2005)

Development of Electricity Markets

- **1992** – National Energy Policy Act: Major opening to competition, utilities to provide nondiscriminatory access to the high voltage transmission to generator companies, in order to foster generation competition
- **1997 – 2001**: Creation of deregulated electricity markets



Wholesale Electricity Markets



Summary

- Introduced Electric Power System
- Learned about its brief history and key moments
- Look forward to Electricity Markets