Lecture 21. Power Generation at Utility Scale

"Nobody knew what electricity was until long after Edison's first grid was built and had burned down . . . [yet] it was uniquely capable of powering things at a distance and doing so very close to instantaneously."
— Gretchen Bakke [1]

1 Electricity Market Basics

Hopefully you remember from Lecture 3 that there are a few key divisions within the electricity sector. The entities involved in the operations of the power grid as a whole can be grouped as follows:

- Generators
- Transmission system
- Distribution system
- End users

Unless we're talking about distributed generation (and we will in the next lecture), the end user is usually far away from the generator. Also, an individual building typically needs only a tiny fraction of the power being produced at a power plant. Therefore, the two steps in the middle (transmission and distribution) are about getting power to a consumer to a group of consumers that are spatially separated (point-to-area flows [2]), and along the way stepping down that power to an appropriate voltage for the consumers (resulting in fast travel over longer distances and slower travel over shorter distances [2]).

Figs. 1 and 2 illustrate the basics of the current system architecture.

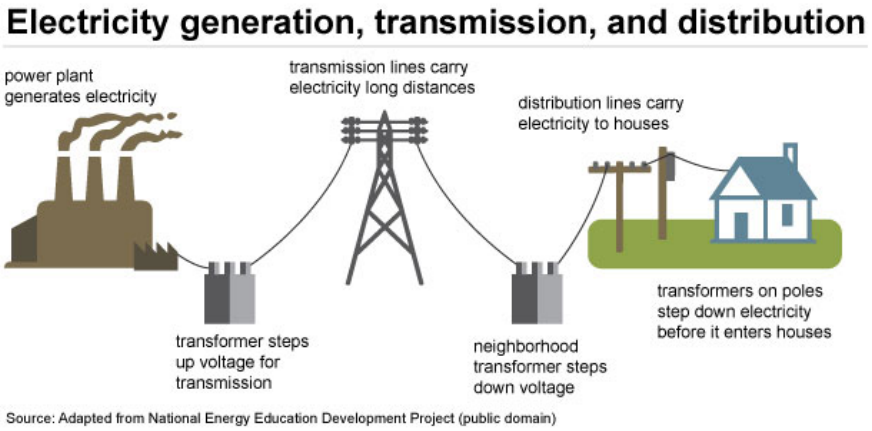

Figure 1: Electricity generation, transmission, and distribution basics [6]

Here on campus, most of our electricity demand is served by our local utility, and a small fraction of campus demand is met by electricity produced from our turbine power generation and hot water facility, a combined heat and power system (discussed in Lecture 22). Rocky Mountain Power (RMP) (a division of PacifiCorp utility company, which is itself a subsidiary of Berkshire Hathaway Energy) is a vertically integrated, regulated [8] utility company. They cover most of Utah (Fig. 3), and the small independent

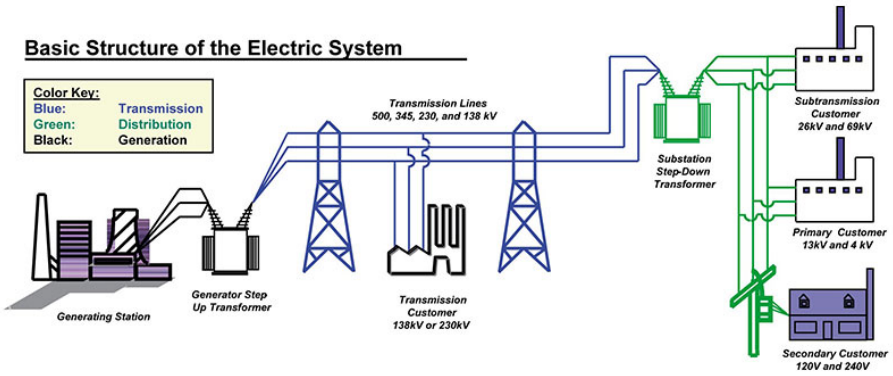

Figure 2: Basic Structure of the Electric System [7]

power districts (such as the municipal systems of Murray or Provo) still interact with them through, for example, purchasing electricity from RMP generators or paying to use their transmission services.

The region of the power grid that we belong to is called the Western Interconnect or simply the western grid. It includes Rocky Mountain Power's service area, as well as others including California—a large and complex system extending throughout the Rocky Mountains and encompassing all of the U.S. that is west of it, as illustrated in Fig. 4.

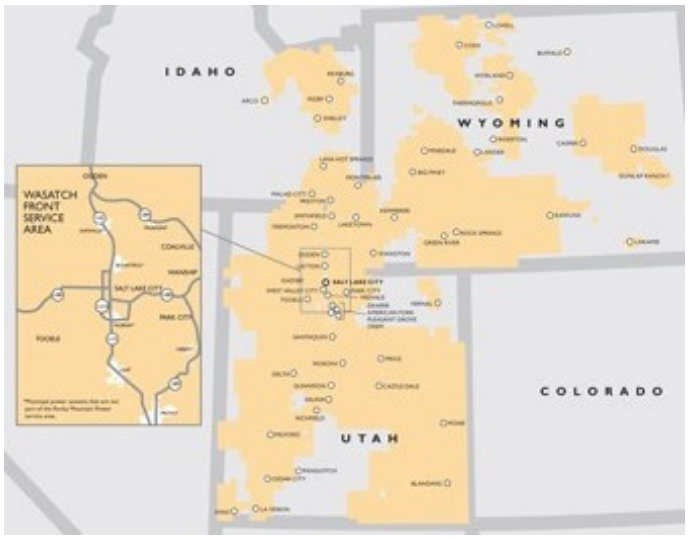

Figure 3: Rocky Mountain Power Service Area [9]

2 Power Generation Timing

Because the load that the generators on the grid are trying to meet is not constant over time, and neither is the set of available generators, the value of energy varies over time. We have historically been billed per kWh because it is only relatively recently in the history of the grid that the metering technology has existed to keep track of *when* electricity is being delivered (as opposed to how much). To get a look at how electricity demand (and, therefore, production) are varying in real time, take a moment and look at the California Independent System Operator (CAISO) website called "Today's Outlook" at http://www.caiso.com/TodaysOutlook/Pages/default.aspx and view today's demand trend profile (illustrating forecasted and actual demand so far today). California ISO is a large independent grid

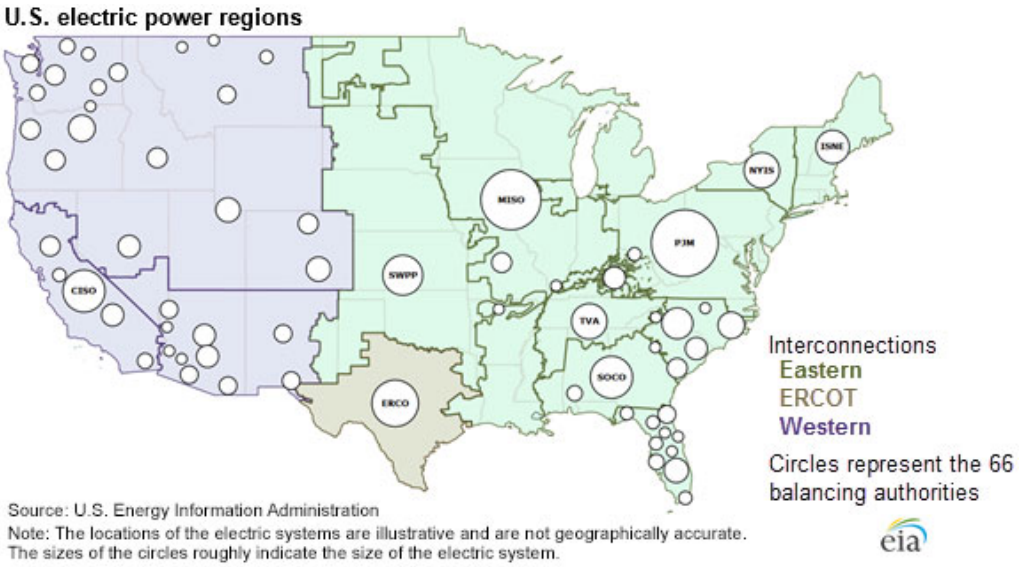

Figure 4: U.S. Electric Power Regions [6]

operator providing a great deal of information about the system they manage [3]. You can also find their real-time data app "ISO Today" in the app store for either Apple or Google Play.

3 Power Generation Terminology

These are key terms that will lay the foundation for our further discussions on comparing options for power generation, economic analysis and primary energy analysis.

capacity "The amount of electricity an electrical facility can carry or generate; usually applied to generators, transmission lines, substation equipment and distribution lines." [4]

capacity factor "The ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full power operation during the same period." [5]

demand "The number of kilowatts or megawatts delivered to the load at a given instant." [4]

electric power grid (a translation for the mechanically minded): "Envision the electrical grid as a big pressurized water system with hundreds of devices (generators) pumping water into the system through long pipes (transmission lines), and literally millions of customers sucking water out through smaller straws (utility distribution systems). There are hundreds of places (substations) where valves and adapters (switches and transformers) are used to break large volumes of water down into smaller units under less pressure for delivery through straws. The ISO['s] job is to make sure that the high-pressure system, the water pressure (voltage) and pump output (frequency) remain constant even though inflow and outflow (measured in wattage) are changing minute by minute." [4]

electric power plant "A station containing prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or fission energy into electric energy." [5]

electric utilities "Utility companies are responsible for the physical delivery of electricity to your home or business. Before deregulation, everyone was required to buy their electricity from their local utility company. With deregulation, the supply of electricity was opened to competition while the delivery of electricity continues to be regulated by the state's public utility commission." [10]

levelized cost "The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation)." [5]

load "Load is the energy use; the ISO refers to utilities as load serving entities (LSEs) because that's what they do, serve load. Load is frequently confused with demand, which is actually how much power the load requires." [4]

primary energy Energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy. For example, coal can be converted to synthetic gas, which can be converted to electricity; in this example, coal is primary energy, synthetic gas is secondary energy, and electricity is tertiary energy." [5]

References

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[3] *California ISO*. http://www.caiso.com/Pages/default.aspx. Accessed: 2019-3-4.

[4] *California ISO - Understanding electricity*. http://www.caiso.com/about/Pages/OurBusiness/Understanding-electricity.aspx. Accessed: 2017-5-1.

[5] *Glossary - U.S. Energy Information Administration (EIA)*. https://www.eia.gov/tools/glossary/index.php. Accessed: 2019-3-4.

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