The Grid: 101

What is "the Grid?"

The United State's electricity grid is a series of interconnected systems that includes the generation, transmission, and distribution of electrical energy. The first electrical distribution systems emerged in the late 1880s in New Jersey and New York. Those first systems did not produce electricity, but only transferred electricity from the generator to consumers. Advancements in electrical generation by Thomas Edison led to the first combined generation-distribution company, which in turn created the first grid system. [1] Today, the American electrical grid system has evolved greatly, and is divided into three regions, also called interconnections, which provide approximately 60 percent of the electricity used in the country [1].

The Process

Generation

Without electrical generation, there would be nothing to transmit to consumers and other end-users. In this phase, electricity is created in one of over 7,000 power plants in the United States [10]. Historically, these power plants have used fossil fuels like coal and natural gas as a fuel source. Today, the rise of renewable energy sources like solar, hydro, and wind power has created new challenges and opportunities in the generation phase.

Transmission

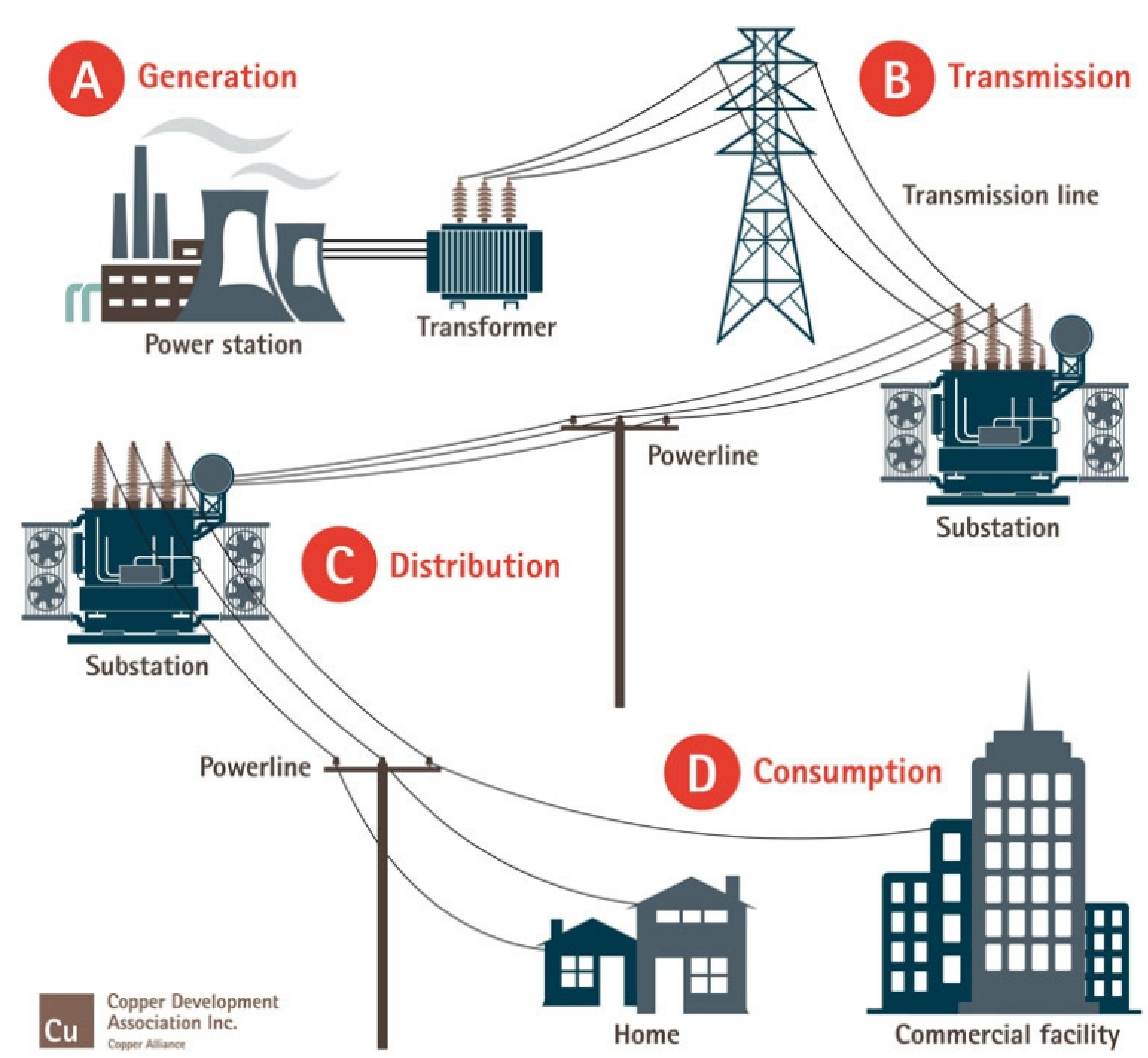
After electricity is generated, the process of transporting those electrons from the power plant to its end user begins. In the transmission phase, raw electricity leaves the plant through high voltage wires through equipment called transformers, often at locations called substations. Transformers are devices that either *step up* or *step down* the voltage of the electricity to the appropriate voltage for transmission. Substations are locations in which a transformer is located. Substations can be as small as a pole with a transformer sitting on top, or large fenced in pieces of land that house larger transformers used in other phases of transmission [11].

Once the elecricity is converted to the appropriate voltage, it is sent through high-voltage power lines away from the power plant and closer to population centers where the power will be used. In the United States, there is over 160,000 miles of high-voltage transmission lines that span the country.

Distribution

Distribution phase is the final phase of transmission in the grid system. In this phase, high-voltage electricity traveling through transmission lines are routed through transformers to *step down* the voltage. Lowering the voltage allows for the electricity to be conducted through low-voltage distribution power lines. These smaller distribution lines are also referred to as 'power lines' are used to transmit the energy to residential homes, businesses and other end users.

The Process Illustrated



Source: Copper Development Group Inc.

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Who Controls the Grid?

Managing a grid system is a complex endeavor. Grid stability, the ability to consistently and efficiently maintain generating capacity, voltages, and frequency values across the grid network, is crucial to meet consumer demand. [7] Historically, electric utilities were *vertically integrated*, meaning that one company owned the entire process from generation to end user distribution, leaving consumers with only one option when purchasing electricity. However, in the last 30 years, electricity markets began deregulating. This requried electric utility companies to sell their generation assets, allowing for other independent companies to generate power that would then be transmitted through utility-owned transmission and distribution lines. [2] Today, only one third of the United States is serviced by a regulated utility. [2]

Operation of the grid system is overseen by grid operators, which are organizations whose sole responsibility is to maintain grid stability through coordinating the flow of electricity and troubleshooting constraints in the transmission of electricity. These organizations vary in structure, but two types of grid operators, regional transmission organizations (RTOs) and independent system operators (ISOs) handle these responsibilities. These grid operators manage their own specified regions, but they are interconnected.

The Interconnections

The United State's grid system consists of three regions, called interconnections, which tie ISOs and RTOs together into a larger system. The three regions are as follows:

- The Eastern Connection connects states east of the Rocky Mountains
- The Western Connection which entails states from the Pacific Ocean to the Rocky Mountains, and
- The Texas Interconnected System, which services the state of Texas alone

Interconnections serve many purposes that are integral to the entire grid system's stability, coordinating or *balancing* the supply of electricity between the regional operators in order to meet demand.

RTOs and ISOs within an interconnection are regulated federally by the Federal Energy Regulatory Commission (FERC), and monitored by the North American Electric Reliability Corporation (NERC), an independent organization.[7]

The Future

Modernizations in electrical generation and consumer end uses have created new challenges, and opportunities, for the electrical grid system.

Renewable Energy

According to the Energy Information Administration (EIA), in 2021, 13% of the United State's energy came from renewable sources. That figure is only expected to grow in the coming decades, but these new energy sources pose issues for our aging grid system. The decentralized and intermittent nature of renewables can restrict access to transmission infrastructure, and grid-level energy balancing issues when the renewable energy source is not producing power. These realities present an opportunity for large-scale lithium ion batteries to address both issues, by providing storage for renewable energy that would have otherwise gone unused.

Electric Vehicles

Electric vehicles (EVs) present a unique challenge for the grid. As EVs rise in consumer popularity, so will electricity demand. Large power draws from EV charging can strain not only the physical infrastructure, but also to the power balance which could lead to insufficient electricity supplies for the given demand. Improvements in planning and predicting demands, such as the development of *smart grids* with advanced metering, will be necessary for future sustainability. [10]

Relevant Policies

Federal

Energy Policy Acts (EPAct)
Clean Air Act (CAA)
Mercury and Air Toxins Standards (MATS)
Cross-State Air Pollution Rule (CSAPR)

Pennsylvania State

Alternative Energy Portfolio Standards (AEPS)
Act 129
Distributed Generation Interconnection Standards
PA Climate Change Action Plan

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Works Cited

[1] Admin. (2022, September 22). What is the U.S Power Grid? A complete guide. Residential Solar Panel Company. https://www.lgcypower.com/what-is-the-u-s-power-grid-a-complete-guide/#:~:text=The%20History%20of%20the%20US%20Power%20Grid&text=The%20first%20recorded%20electric%20distribution,those%20used%20in%20this%20system

[2] Cleary, K., & Palmer, K. (n.d.). US electricity markets 101. Resources for the Future. https://www.rff.org/publications/explainers/us-electricity-markets-101/

[3]Copper Development Association Inc. (n.d.). Grid Infrastructure. Grid infrastructure. https://copper.org/environment/sustainable-energy/grid-infrastructure/

[4] EESI . (2013, July 9). ELECTRIC TRANSMISSION 101: How the High-Voltage Grid Works and Who Regulates It.

[5] Energy Information Administration. (n.d.). U.S. Energy Information Administration - EIA - independent statistics and analysis. U.S. energy facts explained - consumption and production - U.S. Energy Information Administration (EIA). https://www.eia.gov/energyexplained/us-energy-facts/#:~:text=Download%20image%20U.S.%20primary%20energy,natural%20gas%2032%25%20petroleum%2036%25

[6] Environmental Protection Agency. (n.d.). U.S. Grid Regions. EPA. https://www.epa.gov/green-power-markets/us-grid-regions

[7] Garg, P. (2022, March 9). Explainer: What are grid interconnections and what complicates them?. Clean Energy Finance Forum. https://www.cleanenergyfinanceforum.com/2022/03/09/explainer-what-are-grid-interconnections-and-what-complicates-them#:~:text=(FERC).,distribution%20at%20the%20local%20level.&text=(NERC)%2C%20an%20independent%20organization,keeps%20tabs%20on%20the%20interconnections

[8] How to improve grid stability?. Michaud Export. (2022, December 29). https://www.michaud-export.com/group/en/grid-stability#:~:text=Grid%20stability%20is%20ability%20to,correspond%20with%20the%20energy%20consumption

[9] Massachusetts Institute of Technology . (n.d.). (rep.). The Future of the Electric Grid. Retrieved July 18, 2023, from https://energy.mit.edu/wp-content/uploads/2011/12/MITEI-The-Future-of-the-Electric-Grid.pdf.

[10] U.S. electric system is made up of interconnections and balancing authorities. Homepage - U.S. Energy Information Administration (EIA). (n.d.). https://www.eia.gov/todayinenergy/detail.php?id=27152

[11] What is difference between substation and Transformer - Knowledge. Dalian Huayi Electric Power Electric Appliances Co.,Ltd. (n.d.). https://www.hyee-current-transformer.com/info/what-is-difference-between-substation-and-tran-37760798.html