GETTING ELECTRICITY

WHERE IT'S NEEDED

Electric Transmission Systems: Making the Vital Link to Consumers

EDISON ELECTRIC INSTITUTE

The electric power industry

provides a crucial service to the nation – one that has become essential to modern life. Electricity operates homes, offices, and industries; provides communications, entertainment, and medical services; powers computers, technology, and the Internet; and runs various forms of transportation. Americans depend on a plentiful and reliable supply of electricity and expect that the lights will go on when they flip the switch.

Electric power in the U.S. has been so plentiful and reliable that utility customers often take it for granted. For electric utilities, however, achieving this successful level of reliability requires constant commitment.

The generation, transmission, and distribution of electricity involve complex processes that depend upon a host of interrelated factors: economic conditions, fuel availability, technology development, and political and environmental concerns. Today, increased competition – in what was once a strictly regulated industry – is also an important factor.

This booklet focuses on the vital role that the transmission system plays in linking electric generating plants to consumers. It reveals how today's transmission network has evolved from a simple system into a complex, interconnected bulk power grid. And, it looks at ways transmission facilities can be expanded and enhanced to meet consumer needs and to improve reliability.

How the System Works

The nation's electric system is comprised of generating plants, transmission lines, and distribution facilities. Transmission lines carry electricity from generating plants to load centers or areas where a considerable amount of electricity is needed. From there, distribution lines carry electricity to where it is used.

An interlocking system of transmission lines is commonly referred to as a grid. About 12 percent of all power lines are transmission lines.[1] There are nearly 160,000 miles of high voltage (230 kilovolts and above) transmission lines in the U.S. The remaining 88 percent of the system is made up of distribution lines.

The electric power system is distinct from other energy sources, such as oil and gas, in two important ways:

1. Electricity by its nature cannot be stored easily or economically in any appreciable quantities. As a result, it must be generated, transmitted, and distributed the moment it is needed. Electricity is delivered almost at the speed of light – 186,000 miles a second – arriving at a destination at almost the same moment it is produced.

2. Electricity flows over the paths of least resistance. It is very difficult to direct it over a specified path, such as a specific transmission line, like oil or gas in a pipeline. Electricity will travel down whatever paths are made available to it.

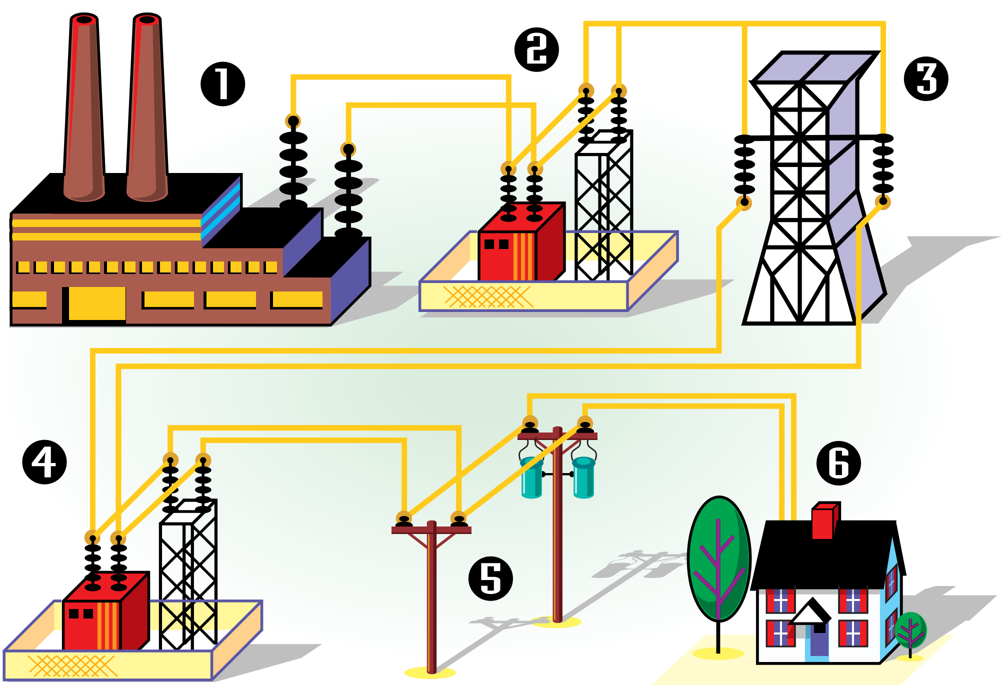
[1] This figure reflects transmission lines owned by shareholder- and government-owned utilities, and electric cooperatives.

Development of the Early Transmission System

Early power plants were small and generated electricity for the immediate, surrounding area to serve individual customers at the local level. However, as the demand for electricity grew, utilities built larger, more efficient generating stations to replace small, isolated plants. In many instances, these new plants were no longer immediately adjacent to their load centers or where electricity needs were concentrated, so transmission lines became necessary to send the power from the plants to local distribution areas. To increase efficiency and reliability of service, utilities not only connected plants and customers within their own systems, they also connected their systems with those of other utility companies to improve overall reliability and economy through coordinated operation and planning.

The Transmission Network

The transmission network provides the vital link between power plants that produce electricity and the distribution system that delivers electicity to the demand centers – homes, businesses, and industries – that use it. It is a highly complex and integrated network that works well because it has been carefully designed and constructed according to strict operating standards. The vast majority of the network is owned and operated by the shareholder-owned segment of the electric utility industry.



When electricity leaves a power plant (1), its voltage is increased at a "step-up" substation (2). Next, the energy travels along a transmission line to the area where the power is needed (3). Once there, the voltage is decreased, or "stepped-down," at another substation (4), and a distribution power line (5) carries the electricity until it reaches a home or business (6).

Siting Transmission Lines

Before an electric utility proposes a new transmission line, it conducts a thorough investigation of the costs, benefits, environmental impacts (if any), and reliability implications of the new line. The expense of construction and maintenance is weighed against the reliability benefits and/or projected short- and long-term savings that the line might offer. Using a computerized model of the entire supply system, engineers can project how a new line will affect such things as load supply, system reliability, and customer service.

In addition, planners must consider the area's topography, population distribution, location of industrial and commercial enterprises, and other factors (such as local environmental concerns) that will affect the construction of a new line. For example, going around a mountain may be more practical than obtaining a shorter right-of-way along a secondary highway that goes over the mountain. The process of obtaining permission to construct a power line varies from state to state. In some states, permission may be obtained from state authorities; in other states, it must be obtained from each county or jurisdiction that the line will cross. Public hearings allow the utility to answer questions from individuals who might be affected by construction of the new line.

Transporting Power

Substations serve as a gateway for transferring power from the generating plants to consumers. In much the same way as a pump builds up water pressure in a pipe, step-up transformers located in the substation adjacent to the power plants increase or "step-up" the electricity voltage in order to send it greater distances. While the electricity produced at the power station is frequently generated at about 20 kilovolts, transformers increase the voltage to levels ranging from 69 to 765 kilovolts, depending on the distance the electricity must travel and the amount desired. The power is then conducted over transmission lines to substations located in areas where the electricity will be used. Considerable attention is given to the design and siting of transmission lines. *(See box at left.)*

Two forms of measurement are used in describing the transportation of power: voltage and current. Voltage is similar to pressure in a water pipe, pushing water through the pipe. Current is the rate at which the water flows through the pipe. Electric utilities attempt to provide a constant voltage. The rate of its use (or current) depends on how many devices are plugged in and turned on. Power lines are made up of wires (called conductors) supported by metal towers or poles. Conductors are generally aluminum or copper.

The Distribution System

The nation's utility distribution systems deliver electricity locally to neighborhoods, businesses, and other consumers along millions of miles of power lines. Primary distribution lines, or feeder lines, carry electricity at levels from 2.4 to 34.5 kilovolts, and extend throughout the area in which electricity is distributed. Secondary distribution lines carry electricity at a lower voltage for use in homes and businesses. Residential voltage levels are usually 120-240 volts; commercial levels are 240-2,400 volts. Step-down substations connect transmission lines to primary distribution lines by lowering the voltage for local distribution.

Distribution transformers further reduce voltages from primary to secondary distribution lines to levels that the customer actually uses.

In 1999, the latest date for which data are available, shareholder-owned electric utilities spent over $10.4 billion in construction expenditures (including replacements, additions, and improvements) for distribution systems. Transmission system construction expenditures totaled $2.3 billion.[2]

Distribution systems – including their rates and reliability – are subject to state regulation; while the federal government regulates transmission rates and terms of use through the Federal Energy Regulatory Commission (FERC). Meanwhile, the North American Electric Reliability Council (NERC) develops standards, guidelines, and criteria for assuring transmission system security and reliability. Utility compliance with NERC standards, however, is currently voluntary and is not subject to government oversight. *(See box at right.)*

Electric Utility Interconnections

The nation's electric utilities are linked through system interconnections that lead to a highly coordinated bulk power grid, an efficient network of high and extra-high voltage transmission lines connecting generating plants with centers of electricity demand. Interconnected networks improve reliability and lower costs by providing electric utilities with alternative power paths in emergencies and by allowing them to buy and sell power from one another and from other power suppliers.

Electric utilities work together primarily within three major interconnected transmission grids: the Eastern Interconnection, which connects the Eastern seaboard and the Plains states and Canadian provinces; the Western Systems Coordinating Council Interconnection, which includes the Pacific coast and the Mountain states and provinces; and the Electric Reliability Council of Texas, which operates within Texas.

About NERC

On November 9, 1965, a power blackout left 30 million people across the northeastern U.S. and Ontario, Canada, in the dark. In an effort to prevent similar blackouts from happening, electric utilities formed the North American Electric Reliability Council (NERC) in 1968. NERC's mission is to promote the reliability of the electricity supply for North America.

As a non-profit corporation, NERC's owners are ten regional groups whose members include electric utilities and market participants from all segments of the industry across the U.S., Canada, and the northern portion of Mexico. NERC coordinates the activities of the regional councils and develops criteria and guidelines for the interconnected bulk power supply network. NERC also helps utilities work together to comply with established standards and voluntary codes of conduct for system-wide reliability.

As the electric power industry restructures, NERC is evolving to meet the needs of a competitive market. NERC endorses pending legislation to authorize the creation of an independent, self-regulating industry reliability organization, the North American Electric Reliability Organization (NAERO). This group would develop and enforce mandatory reliability standards, under the oversight of FERC.

[2] Federal Energy Regulatory Commission Form 1, 1999.

Interstate Transmission and Wholesale Transactions

A sale of power between utilities for resale to the ultimate customer is known as a *wholesale power transaction*. If the sale of power is to a utility with its own generating capacity, then the wholesale transaction is a *bulk power transfer or exchange*. Utilities routinely make business arrangements for bulk power transfers with other utilities for a number of reasons, such as to provide assistance in the event of an emergency, to supply backup power during scheduled plant maintenance outages, or to take advantage of lower-cost power from another supplier.

FERC regulates wholesale transactions and interstate transmission; however, the Commission has jurisdiction only over shareholder-owned utilities and not over federal and state-owned utilities or electric cooperatives, which control one-third of the U.S. transmission system. In 1996, FERC issued Order 888, opening the transmission lines owned by shareholder-owned utilities to all suppliers. Virtually thousands of suppliers are now able to transmit electricity over these transmission lines into wholesale electric markets.

In late 1999, FERC issued Order 2000 to encourage transmission-owning utilities to turn over control of their transmission systems to regional transmission organizations (RTOs) by the end of 2001. RTOs will have responsibility for regional transmission planning, which has the potential to support increased transmission construction and improved reliability. Order 2000 strongly supports the view that additional transmission facilities are needed and includes innovative ideas for pricing transmission services to encourage investment.

Transmission Reliability

A transmission network works like one big machine. What happens in one area of the machine affects other areas. The structure of the grid makes reliability possible, but what makes it a reality is the coordination in operations of the electric companies that make up this network. All transactions on the system must be coordinated, with utilities aware not only of the power flowing over their own systems by their own generators, but also aware of transfers of power between systems and how those transfers might flow through their system.

In order for a utility to determine if it has enough electric generating capacity and transmission capacity for its customers, it must run through a number of computer "tests." These computer models determine whether the system could handle a problem without deteriorating or losing power to large areas. When problems arise, such as a lightning strike, for example, they must be solved in split seconds to avoid causing a major outage. Because transmission lines can carry only so much electricity at a time, it is important to run these tests to ensure the system will provide reliable power.

To coordinate power flow, control areas have been formed. Control areas consisting of one or several transmission operators ensure that there is always a balance between electricity generation and the amount of electricity needed at any given moment to meet demand. An extra margin of electric power beyond what is customarily being used must always be available to ensure reliability at times of peak demand and to provide for maintenance down times. This is called a "reserve margin." Operators use computerized systems to exercise minute-by-minute control over the network and to ensure that power transfers occur during specified times in pre-arranged amounts.

Electricity Competition, Transmission Capacity, and Reliability

New Stresses on the System

The most important changes in the history of the electric utility industry are happening now. The industry is being restructured from one that is highly regulated to one in which there is significant competition in power generation and sales to consumers. (Electricity transmission and distribution will remain regulated.) As the electric utility industry continues its transition to more competitive markets, reliability has been put into sharper focus.

Transmission grids serve as the backbone for developing competitive power markets by providing the means to "transport" power generated from one area to other areas where the power will be used by customers. As competition evolves, the number of transactions on the grid has increased significantly. Moreover, transmission grids are being used today in ways for which they were not intended.

Most of today's transmission systems were not designed to be electrical superhighways to deliver large amounts of power over long distances, or to support the ever expanding number of competitive wholesale transactions. Between 1999 and 2000, transmission congestion, as measured by NERC, grew by more than 200 percent. In the first quarter of 2001, transmission congestion was already three times the level experienced during the same period in 2000, according to the latest NERC data.[1]

As a result of these pressures on the system, transmission capacity is being constrained in certain regions of the country. And, in some instances, demands for power among power suppliers and marketers exceed availability of transmission capacity, raising questions about the system's reliability and its ability to support the development of competitive power markets across the broad regions of the country.

Building new transmission facilities and upgrading existing facilities to expand their capabilities are two ways to address capacity shortages. However, while building new transmission might sound like a simple answer, current regulatory uncertainty and transmission ratemaking policies make doing it far more difficult. Three prominent problems include:

- Siting new transmission is extremely difficult. Unlike the strong federal authority that rests with FERC to site natural gas pipelines, states currently site transmission lines. This can lead to long delays, especially if multiple states are involved.
- The amount of money (or rate of return) that FERC allows transmission owners to earn on investments in transmission facilities is too low to attract the capital needed to finance new transmission investments.
- Public opposition to new facilities can keep utilities from building new transmission lines.

[1] See, Transmission Loading Relief Procedure Logs, North American Electric Reliability Council, http://www.nerc.com/~filez/logs.htm, May 2001.

What's Needed to Expand Transmission Capacity and Maintain Reliability?

Protecting transmission reliability and ensuring that consumers have adequate and economical power supplies when and where they need it is a top priority for America's electric power companies. But given the current state of the transition of the electric utility industry, there are more and more demands on the transmission grid, raising concerns about system capacity. That's why it's so important for policymakers to give careful consideration to reliability and adequacy issues.

Here are some ways to ensure that utilities have the flexibility and incentives they need to expand the transmission system and to maintain reliable, economic service:

- FERC should have authority to help site new transmission lines, similar to its long-standing authority to site natural gas pipelines, with appropriate state participation.
- FERC should utilize innovative transmission pricing incentives, including higher rates of return, to attract capital to fund needed investments in transmission.
- A self-regulating reliability organization, with FERC oversight, should be established to develop and enforce reliability rules and standards that are binding on all market participants.
- The Public Utility Holding Company Act (PUHCA) should be repealed because it acts as a barrier to the formation of interstate independent transmission companies.
- The transmission siting activities among multiple federal land management agencies should be coordinated, in a manner similar to the process used for natural gas pipelines.
- The Internal Revenue Code should be brought into line with changes in the electricity industry to enhance competition and reliability.
- Federal, state, and local decision makers must cooperate to address siting problems, and consumers must realize that transmission lines must be built to assure continued reliable electric service.

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