The Technology of the Electrical Power Grid

In the age of utility deregulation and restructuring, the need for a well-maintained electrical power grid is paramount as we face higher electrical prices, potentially devastating service interruptions, and limits on capacity.

The reliability of the North American power system depends on the "grid," the system by which electrical power is transmitted and distributed to consumers. This is the highly sophisticated system that skilled IBEW members build and maintain as part of their jobs. But what exactly is this grid, and how does it work?

In 1882, Thomas Edison opened the first commercial electric power station at the Pearl Street Station in Lower Manhattan. From that moment in history, the United States power grid has grown into a highly interconnected, international system that crisscrosses North America.

The goal of modern-day power systems is to generate and deliver electric energy to customers as reliably, economically, and safely as possible while maintaining the important operating parameters (voltage, frequency and phase angles) within permissible limits. To achieve this goal, electric utilities use centralized automation technology incorporating high-speed digital computers, supervisory control systems, and a variety of communication systems.

The Interconnected Networks

There are about 3,000 electrical power utilities in the United States that are equipped with coordinated controls, operations, telecommunications networks, and sophisticated control centers. The utilities include investor-owned utilities; federal, state, and local government-owned systems; rural electric cooperatives; and manufacturing industries that also produce power. Nearly 80 percent of the nation's power generation comes from the nearly 300 investor-owned utilities.

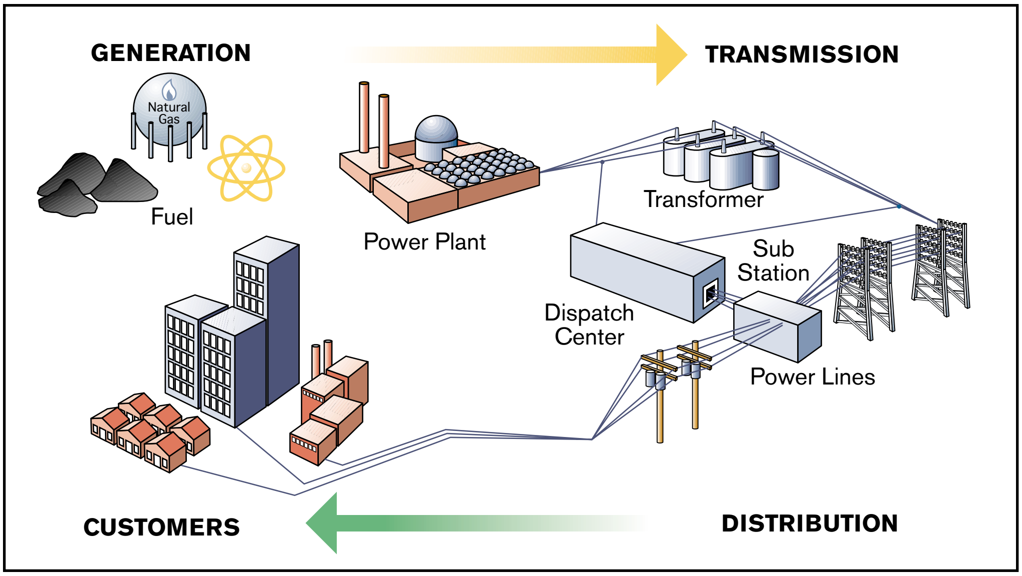
The federal government generates power primarily through 10 facilities, such as the Tennessee Valley Authority and the U.S. Bureau of Reclamation. The remaining power supply is generated by cooperatives and manufacturing industries. There are about 900 cooperatives, few of which have power-generation capacity. They focus primarily on transmission and distribution systems. In addition, some manufacturing industries generate power for their own use but sell surplus power to utilities.

The North American power grid includes the Eastern Interconnection System, the Western Interconnection System and the Texas Interconnection System. The Texas Interconnection is not integrated with the other two networks (except by certain direct current lines). The other two networks have limited interconnections to each other. Both the Western and the Texas Interconnections are linked with different parts of Mexico. The Eastern and Western Interconnections are integrated with Canada. Virtually all U.S. utilities are interconnected with at least one other utility by these three major grids. The exceptions are in Alaska and Hawaii.

Power Transactions

Power travels from the power plant to your house through an amazing system called the electrical power grid. An electrical power grid is a group of generation, transmission, distribution, communication, and other facilities that are physically connected and operated as a single unit under one control.

The flow of electricity within the system is maintained and controlled by dispatch centers. It is the responsibility of the dispatch center to match the supply of electricity with the demand for it. In order to carry out its responsibilities, the dispatch center is authorized to buy and sell electricity based on system requirements.



Authority for those transactions has been preapproved under interconnection agreements signed by all the physically interconnected electric utilities or under coordination agreements among utilities that are not connected.

Generating Electricity

Electrical power starts at the power plant. In almost all cases, the power plant consists of a spinning electrical generator that is powered by fossil fuel (coal), nuclear fuel, water (hydroelectric), natural gas, or a diesel engine. For the most part, the generator is a steam turbine. Commercial electrical generators produce three-phase alternating current (AC) power. This contrasts with the single-phase, 120-volt AC system that typically serves households and offices.

A three-phase voltage system has three voltages that are synchronized and spaced 120 degrees from each other. In comparison, a single-phase voltage system has one line of power with a neutral return line. Most power lines are equipped with three wires that contain the three-phase power. These systems power facilities requiring large amounts electricity, such as factories, malls and other large industrial centers.

In a residential neighborhood, less power is needed to power a home. If you use an oscilloscope to get a visual display of the power found at a normal wall-plate outlet in a house, that power looks like a sine wave, which can be expressed as the sine of a linear function of time, or space, or both. The wave oscillates, or fluctuates, between peaks and troughs at positive 170 volts and negative 170 volts. The peaks are at 170 and the average root-mean-square (RMS) voltage at 120 volts. RMS voltage is defined as the effective voltage as opposed to the peak voltage that corresponds to the maximum amplitude of the voltage variations. The rate of oscillation for the sine wave is 60 cycles per second. Oscillating power like this is generally referred to as AC. The alternative to AC is DC, or direct current.

Transmission and Distribution

AC has at least four advantages over DC in a power distribution grid: (a) AC suffers from significantly less line loss than DC when transmitted over long distances because it is easy to step it up to extremely high voltages; (b) large electrical generators happen to generate AC naturally, so conversion to DC would involve additional equipment; (c) transformers must have alternating current to operate, and we will see that the power distribution grid depends on transformers; and (d) it is easy to convert AC to DC but expensive to convert DC to AC.

The power plant, therefore, produces AC. However, it produces three-phase power. Out of every power plant come four wires: the three phases plus a neutral or ground common to all three. The power company essentially uses the earth as one of the wires in the power system. The earth is a good conductor and it is huge, so it makes a good return path for electrons. "Ground" in the power distribution grid is literally "the ground" all around you when you are walking outside. It is the dirt, rocks, groundwater, etc., of the earth.

The three-phase power leaves the generator and enters a transmission substation at the power plant. This substation uses large transformers to convert the generator's voltage (which is at the thousands of volts level) up to extremely high voltages for long-distance transmission on the transmission grid.

Typical voltages for long distance transmission range from 115,000 to 765,000 volts in order to reduce line losses. A typical maximum transmission distance is about 300 miles. For power to be useful in a home or business, it comes off the transmission grid and is stepped-down to the distribution grid. This may happen in several phases. The conversion from "transmission" to "distribution" occurs in a power substation, which typically does two or three things:

(1) its transformers step transmission voltages (in the tens or hundreds of thousands of volts range) down to distribution voltages (typically less than 50,000 volts);

(2) its "bus" can split off the distribution power in multiple directions; and

(3) its circuit breakers and switches permit the substation to be disconnected from the transmission grid or separate distribution lines to be disconnected from the substation when necessary.

Power goes from the transformer to the distribution bus. Transformers attached to the bus are stepping the power down to standard distribution voltages.

Three wires located at the top of poles are the three wires for the three-phase power. The fourth wire lower on the poles is the ground wire. In some cases, there will be additional wires, typically telephone or cable TV lines riding on the same poles. Higher distribution voltages need to be stepped down again, and that often happens at another substation or in small transformers located somewhere down the line. For example, you may see a large green box (perhaps six feet on a side) near houses or buildings. The box contains a small transformer that performs the step-down function to reduce voltages to usable levels.

Regulator banks are located along the line either underground or overhead. They regulate the voltage on the line to prevent undervoltage and overvoltage conditions. At this point, there is a typical distribution voltage at approximately 7,200 volts running through the neighborhood on three wires (with a fourth ground wire lower on the pole).

Located near a house is a set of poles with one phase of power at distribution voltage levels and a ground wire. Sometimes there will be two or three phases on the pole depending on the location of the house in the distribution grid. Transformers are positioned in a manner to provide electricity to one of many houses. In many suburban neighborhoods, the distribution lines are underground. The transformer's job is to reduce the distribution voltage down to the 240 volts that makes up normal household electrical service. The 240 volts enters your house through a typical watt-hour meter that records power usage.

The reliability and flexibility of a grid is of paramount importance. If a power plant shuts down unexpectedly, or an area experiences unusually high demand, the grid fills the gap with electricity from other power plants around the region. When power lines go down in a neighborhood, the grid is equipped to provide an alternate transmission path so power can be re-established as quickly as possible.