Power Primer

A Nontechnical Guide from Generation to End Use

by Ann Chambers

PennWell®

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Introduction

Lightning shears through the night sky as a prelude to the magnificent clap of thunder, and all eyes turn toward the show. Lightning and thunder command our attention and awe, but lightning is only static electricity—the very same thing a toddler creates by rubbing an inflated balloon back and forth on his hair. Static electricity spreads the child's hair and when he touches an ungrounded object, a spark emits.

The science of these two events is identical, although the magnitude is much different. Electricity sparks our wonder whether we are children with balloons or adults watching a thunderstorm. But it is science, and therefore understandable. And that's where this book comes in.

We will examine electricity from the plant to the plug—what it is, how it's made, how it travels, and how it arrives at the plug in the wall.

Electric Concepts

There are some terms and concepts that are basic to electric power that must be understood before electricity can make sense. In my opinion, at least half the battle of understanding the electric power industry is in learning the terminology.

The basic definition of *electricity* is the flow of electrons in a conducting material. This flow of electricity is called a *current*. Currents can be either *alternating currents* (ac) or *direct currents* (dc). They are usually referred to as ac voltage or ac current and dc voltage or dc current.

In dc current, the electrons flow in one direction. Batteries are dc power. Modern electric power systems, however, generally use ac power from ac generators and circuits. Alternating currents have the electrons flowing back and forth, rather than traveling in only one direction.

Electric power is measured in *watts*, in honor of James Watt, a Scottish instrument maker at Glasgow University who also made important improvements to the steam engine. Officially, a watt is a unit of power defined as the power available when a current of one ampere flows under a pressure of one volt. Unofficially, a watt is not very much power. Standard household light bulbs are generally 60 watt, 75 watt, or even 100 watt. A one watt light bulb would not give off much light.

Amperes are the unit of measurement for electric current. Electric power equals amperes times voltage (E = A x V). *Volts* are the measure of pressure that pushes electric current through a circuit. Probably the important thing to remember is that electricity measurements use watts and volts in metric amounts. For instance, your electric bill probably notes the number of *kilowatt-hours* (kWh) you use each month. These types of measures follow the standard metric system, so a kilowatt is 1,000 watts. And a kilowatt-hour is the amount of energy used if you used 1,000 watts for one hour. If you burned ten 100-watt light bulbs for one hour, they would use one kilowatt-hour of electricity.

When a measurement notes kilowatts or *megawatts* (1 MW = 1,000,000 watts), that is a measure of the amount of power at any given moment. There is no time element, only a measure of force. An electric power plant that is rated at 1,000 MW is capable of producing twice as much electricity at any moment in time than a plant rated at 500 MW.

When the word "hour" is tacked onto the end, as in kWh or MWh, that is the measure of the amount of energy made or used per hour. In a year's time, a utility power plant will produce thousands or millions of MWh of electricity, depending on the capacity (MWs) of the plant in question and how much of the time that plant is running. A 1,000 MW power plant running full power for an hour will produce 1,000 MWh of electricity. That same plant will produce 24,000 MWh of electricity if it runs at full power all day. A 1,000 MW power plant can provide base-load power for a small city.

Electricity is produced by converting other forms of energy—such as the chemical energy in fuels, wind energy, solar energy, or nuclear fission—into electrical energy. The most common fuels used are fossil fuels—coal, oil, and natural gas. These fuels are burned to heat water, just as we would use the gas flame on a stove to heat a pot of water. The water then turns to steam which blows through a fan called a *turbine*. The fan is hooked up to a *generator*. When the fan turns, the magnets in the generator turn, and electricity is produced.

Yes, the language of electricity can be intimidating, but it should not be a stumbling block to understanding electricity. To help readers understand and remember the language of electricity—the terms used in this book and other common electricity terms—definitions are provided in the glossary at the back of this book. The basic science of electricity generation is fairly easy to understand, when taken one piece at a time. Then, like a jigsaw puzzle, it becomes easier and easier to see the pattern and put the pieces together.

That is what this book does. We start with a very general discussion of how electricity is generated in a power plant and delivered to your home or business. Then we take a look at the history of the industry—its roots in the rivalry between Thomas Edison and George Westinghouse, its progress through the past century, important milestones in technology, and current data about electricity generation and use.

The second section of this book looks at the basic components of electric power generation and at the fuels used to run electric power plants. Included is discussion of the popularity of the various fuels, and their assets and liabilities in regard to electricity generation.

Section three examines transmission and distribution, which encompasses the equipment and systems that bring electric power from the plant to consumers. This book also discusses a few of the hot topics in electricity, such as electromagnetic fields, siting and rights-of-way issues, and emissions problems.

In the final section, there is a nontechnical look at deregulation, a trend that is going on in the United States and around the world, as electric companies change from government-owned or highly government-regulated entities to private enterprises. Also included is a convenient glossary of common electricity terms for quick reference.

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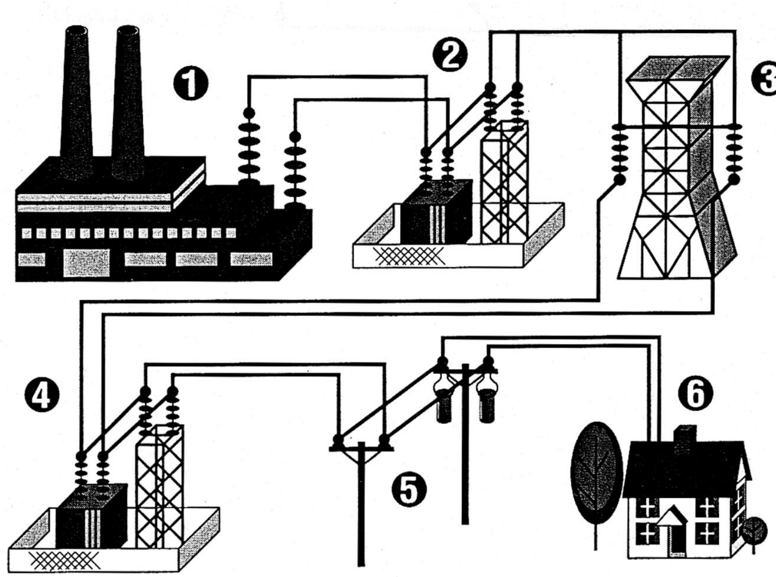
The Big Picture: From Plant to Plug

Electric power plants like other manufacturing facilities, process raw materials into products, generally with some waste products. For power manufacturers, the main product is electricity and the waste materials (depending on the fuel used) can include ash and emissions. Electricity is an unusual product in that it is both invisible and dangerous to handle. Also, it cannot generally be stored.

To most people the process of generating electricity is mysterious, yet the actual process is easy to understand.

In generating plants, fuel is converted into heat energy, then into mechanical energy, and finally into electrical energy. Fuel is burned to heat water, making steam, which turns an engine or turbine, which runs a generator. Figure 1–1 illustrates the steps involved in energy conversion to power.

Figure 1–4. Transmission and distribution system components.



substations. Transmission lines also run between substations to provide alternate routes for the electricity.

Substations receive the electricity from the transmission lines and switch it, adjusting the voltage to the necessary strength before passing it on to *distribution lines*, which carry electricity to customers. Transmission lines carry high-voltage (or highly concentrated) electricity from the power plant to the substation; the distribution lines carry lower voltage electricity (suitable for customer use), to businesses and residences in the area surrounding the substation. Transmission lines are the lines seen running through the countryside attached to big metal towers; distribution lines are the much smaller and lighter-weight lines that run up and down your street on wooden poles. The electric line that brings electricity from the pole to your home is also a distribution line.

The transmission system has three major parts:

- conductors
- structures
- insulators

MAJOR LEGISLATION AFFECTING THE ELECTRIC POWER INDUSTRY (CONT.)

transferred the other four power marketing administrations from the Department of the Interior to the Department of Energy.

The Public Utility Regulatory Policy Act of 1978 (PURPA). PURPA was passed in response to the unstable energy climate of the late 1970s. PURPA sought to promote conservation of electric energy. Additionally, PURPA created a new class of nonutility generators, small power producers, from which, along with qualified cogenerators, utilities are required to buy power.

The Energy Tax Act of 1978 (ETA). This act, like PURPA, was passed in response to the unstable energy climate of the 1970s. The ETA encouraged conversion of boilers to coal and investment in cogeneration equipment and solar and wind technologies by allowing a tax credit on top of the investment tax credit. It was later expanded to include other renewable technologies. However, the

at the time they were purchased or built, many are uneconomical in a free market. The big question is who should pay for these so-called "stranded" assets and how they should be valued.

Industry Statistics

The Players

Today's $200 billion U.S. electric power industry is considered the largest industry in the country. There are more than 3,000 separate electric utilities. Two out of three of them are *public utilities* and they generate 14% of the country's electric power. There are almost 900 *cooperative utilities*, generating 8% of the country's power. *Investor-owned utilities* number close to 200 and generate 76% of the electricity. Six *federal utilities* generate the remaining 2%.

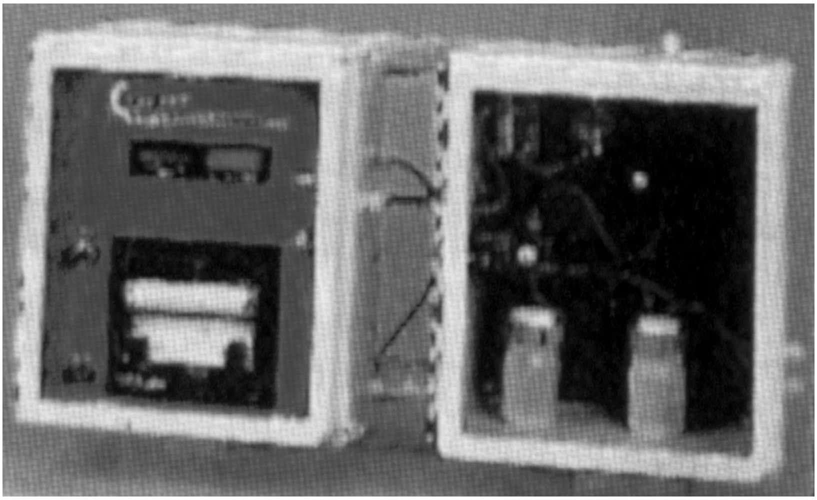
There are many more public utilities, but they are smaller than the IOUs, which generate by far the greatest amount of electricity.

Fuels

Coal is traditionally the most popular fuel for electric generating plants, although in the past few years, that has changed. Natural gas is the fuel of the 90s, at least in the United States. Natural gas has gained popularity because of its reasonable cost and clean-burning properties.

Coal capacity still represents more than

Figure 3–3. A particle monitor/sampler unit detects tiny particles in the water. The device automatically collects samples when water impurities exceed a specified level. It has alarms to alert plant operators to water purity problems.



piping as well as corrosion of the metal itself. Mud, clay, sewage, and other waste products can be present in water as suspended solids and can cause scale formation. Oil likewise can cause corrosion, deposits, or foaming in the boiler. Gases such as carbon dioxide can accelerate corrosion of metal parts.

There are several ways to combat these impurities in water. *Settling tanks* with filtration and water-flushing devices can help remove sediment such as mud or sand. Settling tanks with chemical coagulants may be used to turn sediment in the water into a jelly-like substance that can then be filtered out. Evaporation or distillation can remove all forms of impurities. Finally, chemical treatment can remove impurities such as calcium or magnesium salts (Fig. 3–4).

Treatment of feedwater can be expensive, but it is more economical than the reduction in boiler efficiency, maintenance problems, and down time that comes from using "raw" water as feedwater. Just as a household clothes iron will offer a longer period of worry-free use when it is filled with distilled water rather than tapwater, a utility boiler will run for a longer time without maintenance problems when it is filled with clean water.

Instruments would include:

- a steam flow meter to monitor boiler output
- draft gauges to check stack pressure and furnace draft
- thermometers to measure flue gas temperature
- air flow meters to monitor incoming air needed for combustion
- temperature indicators to measure steam temperature leaving the superheater
- a recording steam pressure gauge
- equipment to monitor fuel combustion rate
- a camera to allow operators to observe flame condition in the furnace, and
- a gas analyzer for smoke control

A nuclear facility would monitor steam flow and steam temperature just like a fossil fueled plant, but the nuclear plant would also monitor:

- radioactivity of the core
- position of the control rods
- temperature in the reactor
- temperature of incoming water or steam and of outgoing steam
- radioactivity, if any, of escaping gas, and
- radioactivity, if any, of air surrounding the reactor

These are just examples. There are similar lists of controls and meters for most systems in a power plant. Operators need to know an amazing amount of data to run the plants efficiently, from basic information such as the outdoor temperature and barometric pressure, to technical information delivered through power-measuring equipment such as voltmeters, ammeters and wattmeters.

In addition to the assortment of meters in a power plant, there are also alarm sound-and-light signals to call attention to abnormal conditions, including fire alarms. Alarms sound to alert the operators to problems or potential problems that could affect efficiency or cause downtime for the power plant.