Forms of Energy: Electrical Energy & Electrical Power

Energy from the flow of electrons

All matter is composed of fundamental building blocks called atoms. The outer shell of an atom contains negatively charged particles called electrons. The electrons are attracted to the positive charges found at the center of the atom (protons). The electrons surrounding an atom are in constant motion and can be "bumped" free of the atom by upsetting the attraction forces between the electrons and protons. One way to do this is to spin a magnet through a coil of copper wire. This will "bump" free the electrons surrounding the copper atoms in the wire and create a flow of electrons through the wire generating **electrical energy**. **Electrical power** is electrical energy we harness to do work. **Electricity** is basically the flow of electrical power through a copper wire or any appropriate conductor. When we plug an appliance into a wall outlet we can use this available flow of electrons to conduct work. This form of **energy** can be used in systems designed to convert the electrical energy to **mechanical energy** (an electric motor) or to **thermal energy** (an electric iron or stove) or to light energy, also called **radiant energy** (a light bulb).

Electrical energy transmission lines.

Electricity is a very convenient form of energy and currently about 39 percent of all energy consumed in the United States is used to generate electricity. Traditionally, electrical power is generated by converting other forms of energy to heat. This heat is then most often used to heat water into steam. The steam rapidly expands and can be used to force large **turbine** systems to rotate. A turbine contains magnetic coils and when they are rotated an electrical **current** can be generated. Typical approaches for creating electricity from other forms of energy are not very efficient. In most electrical generation systems only about 30% of the thermal energy produced is actually converted to electricity. The rest of the heat generated is simply energy lost. It is important to note that electricity is a secondary energy source—it is only generated from other primary energy sources such as **coal**, natural gas, and wind. In this way electricity "carries" energy as opposed to being a standalone energy source.

The **electric grid,** composed of a network of power plants, electrical lines, **transformers**, and control centers, is used to carry electricity to where it is needed. The first step in electric power delivery is the previously discussed generation. The next phase is transmission. Electricity generated by a centralized power plant first enters a transmission substation where the **voltage** is increased or "stepped up" using transformers. High voltage electricity is used to increase the efficiency of transmission. A typical substation will push the electricity up to somewhere between 115,000 to 765,000 volts and can deliver this current over hundreds of miles. Once the electricity gets near its application its voltage is then reduced or "stepped down" by another substation. This begins the next phase called distribution. The electricity is spread out on the smaller wooden poles you see running along roads to individual homes and businesses. The final voltage of the electricity entering a home is reduced by small transformers again to 120 or 220 volts and passed through a utility meter to keep track of how much electrical power is consumed. Transporting electricity over long distances using power lines can result in an energy loss ranging from two to thirteen percent. Missouri sits in the middle at about 6.5% lost during transmission and distribution. However, the most significant portion of the electricity produced is lost as thermal energy during generation.

Every state is different, but in Missouri all of the phases of electric power delivery—generation, transmission, and distribution—generally come from one entity. An **electric utility** is an organization that is responsible for reliably providing electricity to consumers in a certain area. Electric utilities might be investor owned utilities (IOUs), electric cooperatives, or municipal public utilities. IOUs are usually large private companies that are very closely regulated by the state to ensure electrical power is reliably delivered to consumers in exchange for agreed upon electrical power rates and profits. Cooperatives often operate in rural areas and are managed by the members who receive their power from the cooperative. Municipal utilities serve one city and are governed by a small local board and local voters. Whichever electric utility operates in a certain geographic area is often a monopoly—that is they have no competitors. This is because of the extensive infrastructure required to generate, transmit, and distribute electricity. Think about how inefficient it would be to have three sets of power lines running down the same street from three different utilities!

How does electricity work?

Resistance measures the opposition to an electrical current. Resistance can be thought of in terms of a garden hose that constricts how much water can pass through it. Although the water pressure can be increased to cause more flow, the rate of flow is still "resisted" by the small size of the garden hose. In electrical systems small wires can act like a small hose and resist the flow of electricity. Thicker heavy-duty wires allow more electrical charges to flow through. Resistance is measured in Ohms. Small wires with high resistance will release energy in the form of heat and most homes are required to use a minimum size wiring to prevent potential fire risks.

Voltage is the measure of the "pressure" pushing electrical charges through a wire and is measured in volts (v). Voltage is actually a measure of potential energy. A standard battery separates positive and negative charges on metal plates creating potential energy. When the battery is connected, electrons flow from the negative terminal towards the positive terminal generating an electrical current. A 12-volt battery has more potential energy ("pressure") than a 1.5-volt battery. Higher voltage electrical currents such as in a home wall plug socket (typically 110 volts) can be quite dangerous because the "pressure" of the electrical flow is much higher than that of a flashlight battery.

Current measures the flow of electrons through a conductor such as a copper wire. The more electrons that pass through, the higher the current. Current is measured using the units of amps (I).

Alternating current (AC) is a form of electricity transmitted in reversing pulses called a sine wave. The electricity pulses back and forth at a rate of 60 cycles per second. AC current is used to deliver electricity to homes and businesses because the voltage can be increased or decreased as needed using transformers. A more efficient higher voltage is used during transmission over long distances with the voltage reduced for safety reasons prior to use in home or commercial applications.

Direct current (DC) is a form of electricity that provides a continuous flow of electrons. Batteries are examples of such devices and provide a direct current in one direction from the negative terminal to the positive terminal.

The Relationship Between Voltage, Current and Resistance

The higher the voltage ("pressure") the more push there is to move electrons and this often results in a higher flow of electrons (current). However, the current (flow) is also influenced by the resistance of the material conducting the charge. Ohms law describes this relationship.

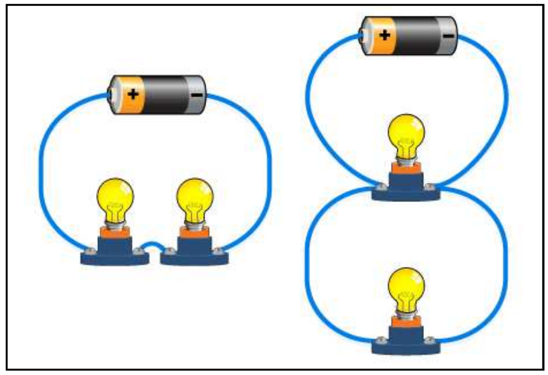
Voltage = Current X Resistance

Electrical Circuits

Describe the path of electricity through a given application. Such paths can be very complex such as that of a computer. Circuits are divided into two basic types:

Series circuits allow electricity to move in one direction through a single path (voltage will decrease after each lightbulb or resistor).

Parallel circuits split charges so that they travel through more than one path (the voltage remains the same for each light bulb).



A series circuit (left) next to a parallel circuit (right).

ELECTRICAL POWER:

Is a measure of the rate of electrical energy used by a circuit. This is usually measured using a unit called a Watt (W). The electrical power required by an electrical appliance is related to the voltage ("pressure") used and the current ("flow of electrons") required.

Power = Current X Voltage

The utility meter outside a home measures electricity consumed using units of kilowatt-hour (kWh) A kWh represents the electrical work done by a thousand (kilo) watts for one hour. The current average cost of electricity in the United States is around 10 cents per kWh.

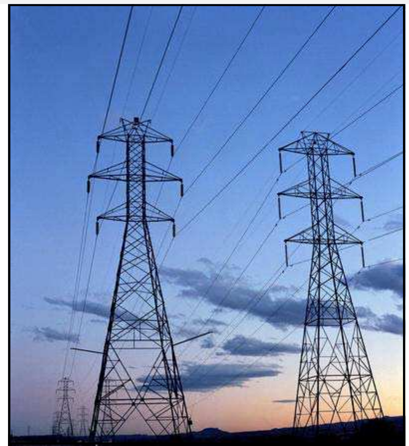


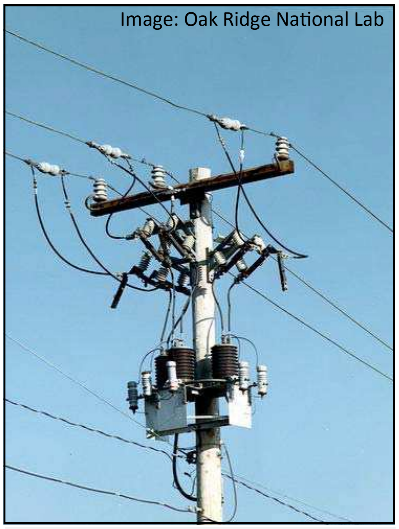
Image: W. Getz

Large metal towers like these usually carry high voltage transmission lines over long distances

Transformers use a system of copper coils to reduce or increase the voltage of an electrical current.

An **electrical conductor** is any substance that will allow the flow of electrons. Metals are in general excellent conductors and copper is most often used for electrical wiring purposes.

Image: Oak Ridge National Lab



The more familiar smaller wooden poles carry lower voltage distribution lines to homes and businesses

An **electrical insulator** is any substance that does not conduct electricity very well. Examples are plastics, wood, paper, and fiberglass. These materials are often used to cover copper wires for safety reasons and prevent any unwanted delivery of electricity.

For safety reasons it is often recommended that multiple appliances should not be hooked up to one wall outlet. Each appliance will draw a current and by hooking up several appliances a large total current (amps) will be required. This will increase the flow of electrons through the wiring in the wall and can lead to the generation of heat producing a fire hazard. Similarly using thin wired extension cords can lead to heat build up and fire risks. An appliance or tool that requires lots of power (voltage and current) should be connected using a heavy-duty extension cord (thick wire...low resistance).

When a person is hurt by electricity it is actually the flow of electrons through their body (current) that causes the damage. The human body is actually a poor conductor of electricity and the resistance of tissue results in lots of heat production. Most damage from electrical contact is related to the current passing through the body and the resulting heat produced. High voltage lines (high "pressure") or materials that are good conductors of electrons, such as an aluminum ladder can pose safety risks. Fuses and breaker switches are often used in an effort to provide protection for electrical appliances and people. The fuse is designed to “trip” and interrupt an electrical circuit when an excessive flow of electricity occurs (current).

Peak demand is a time period when many people want electricity at the same time. During the middle of night most people are asleep and businesses are closed so demand for electrical power is low. Power needs increase during the day and electric utilities must be ready to meet these spikes in demand. Seasonal factors also influence peak demand. During the summertime power needs are often significantly greater due to high demands for air conditioning. Utilities must design their facilities to be able to handle the changes in demand that occur over the course of a day and throughout the year.

Glossary of Terms

Alternating current (AC): A form of electricity transmitted in reversing pulses called a sine wave

Coal: A solid fossil fuel mined from the Earth’s surface and underground which is often used to produce electricity through combustion. There are several different qualities of coal including anthracite, bituminous, and lignite

Current: Measures the flow of electrons through a conductor in amps (I)

Direct current (DC): A form of electricity that provides a continuous flow of electrons

Electrical conductor: Any substance that will allow the flow of electrons

Electrical insulator: Any substance that does not conduct electricity very well

Electric grid: The network of power plants, transmission and distribution lines, transformers, substations, and control centers that deliver and monitor electrical power from generation to consumption

Electric utility: An organization that is responsible for reliably providing electricity to consumers in a certain area. Electric utilities might be investor owned utilities (IOUs), electric cooperatives, or municipal public utilities

Electrical energy: Kinetic energy as a result of moving electrons

Electrical power: Electrical energy used to conduct work; the measure of the rate of electrical energy used by a circuit. This is usually measured using a unit called a Watt (W)

Electricity: The flow of electrical power or charge. A commonly used secondary energy source

Energy: The ability to do work

Mechanical energy: The energy an object has from its motion or its potential for motion

Parallel circuits: Split charges so that they travel through more than one path

Peak demand: A time period when many people want electricity at the same time

Radiant energy/Radiation: Transmission or emission of kinetic energy as waves through space. Light is one type of radiant energy. Electromagnetic radiation can be classified by the electromagnetic spectrum

Resistance: Measures the opposition to an electrical current in Ohms

Series circuits: Allow electricity to move in one direction through a single path

Transformers: Use a system of copper coils to reduce or increase the voltage of an electrical current

Turbine: A device which harnesses the kinetic energy of an incoming force (often steam, water, or air) to spin rotors and create mechanical power. In electrical power generation the spinning motion of turbine rotors is used to turn generators which use rotating magnets inside copper wire to create an electrical current

Voltage: The measure of the "pressure" pushing electrical charges through a wire and is measured in volts (v)

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