- When the applet opens, are the generators making more or less power than the communities are using?

- **Reset** the system and notice the line leading from Substation 5 to Commerceton. How much power is this line carrying? Click on the up arrow to increase Commerceton's power demand. What happens to the arrows on the line? At what load do the arrows change to orange? What color are the arrows when the demand is 1000 MW? What happens when the load on the line is increased again? How can you fix it?

- Explore the applet to find the line maximum capacities for all the lines.

- **Reset** the system, put the nuclear power plant online and then increase the power demanded by Residenceburg to 1850 MW. What's causing a problem? Reduce the potentially dangerous line overload without taking the nuclear plant offline.

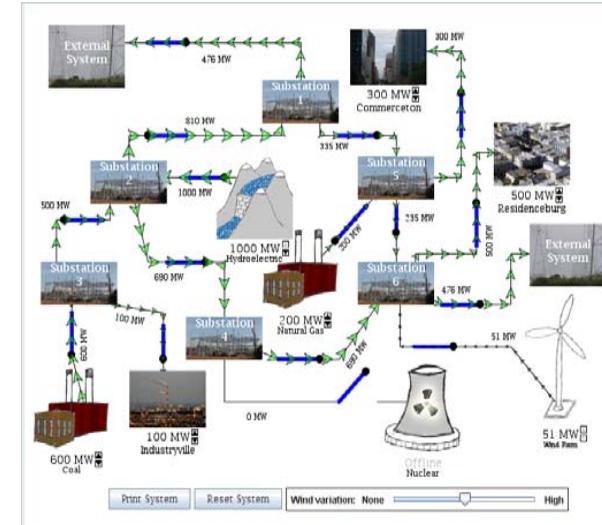Courtesy of DOE/NREL, Credit - Kelly Marguerite

You see some parts of the power grid all around you. There is a probably a power substation like the one in the photo nearby. Substations can split the power distribution into two or more directions, but they do not make or use power. So the power entering a substation is equal to the power leaving the substation. Another job of a substation is to take the high voltage power produced by a generator and transform it to a lower voltage that can be used in homes, schools and businesses.

- It's a hot summer day and power demand in Residenceburg is 1600 MW. Commerceton is demanding 850 MW and Industryville needs 800 MW. Put all of your generators online at maximum capacity. Are all of your lines operating safely? Are you able to produce enough power to meet the demand or do you need to get power from the external system?

- **Reset** the system, turn on the nuclear power plant and then open the line between substations 1 and 2. What happens? What is the problem? Fix it by changing one switch.

The Power Grid
Quick Start Guide

for the applet at http://tcipg.mste.illinois.edu/applet/pg

The **power grid** refers to the system of producers and consumers of electricity. It includes power generators, the users of electricity, switches that control the electricity, and the system of substations, power lines, and transformers that deliver the electricity.

A community might have a generator to provide its power. The generator may be able to vary its production as the usage of the customers changes, but there may be times when the demand for energy is too great for the generator. Then the community buys electricity from another source. At other times the generator may be making more electricity than the community is using, so the utility wants to sell it.

Quick Start -- The Power Grid

This applet provides a simulation of a large-scale power system network. Five generators are represented. The coal, hydropower, and natural gas generators have adjustable outputs; the others do not. Click on the up and down arrows to the right of MW output labels to change the production. All of the generators have blue connection switches. When the applet opens, power is being produced by four of the five generators. You can see the power moving from the generators through the substations and to the users in Commerceton, Industryville, and Residenceburg. Any power that is not used by the communities in the system is sent to users in other systems. If the generators in this system are not producing enough power, power will be purchased from other systems. In the applet, this is indicated by the two External Systems. This simulation is designed to black out if both External Systems are disconnected from the system.

The green arrows show the direction the power is moving. The current is flowing out of the generators, through the substations, and into the communities. Bigger arrows indicate more power. The transmission lines have varying capacities. Just as in an actual power system, if a line is asked to carry too much power, the line will be opened, creating a power outage. To make it easy for the system operator to see when lines are in danger of becoming overloaded, the arrows in the applet change color.

Hydroelectric generators use differences in water elevations to drive turbines. One famous example is the Hoover Dam.

Natural gas generators tend to be expensive to operate, but they are capable of changing their output quickly.
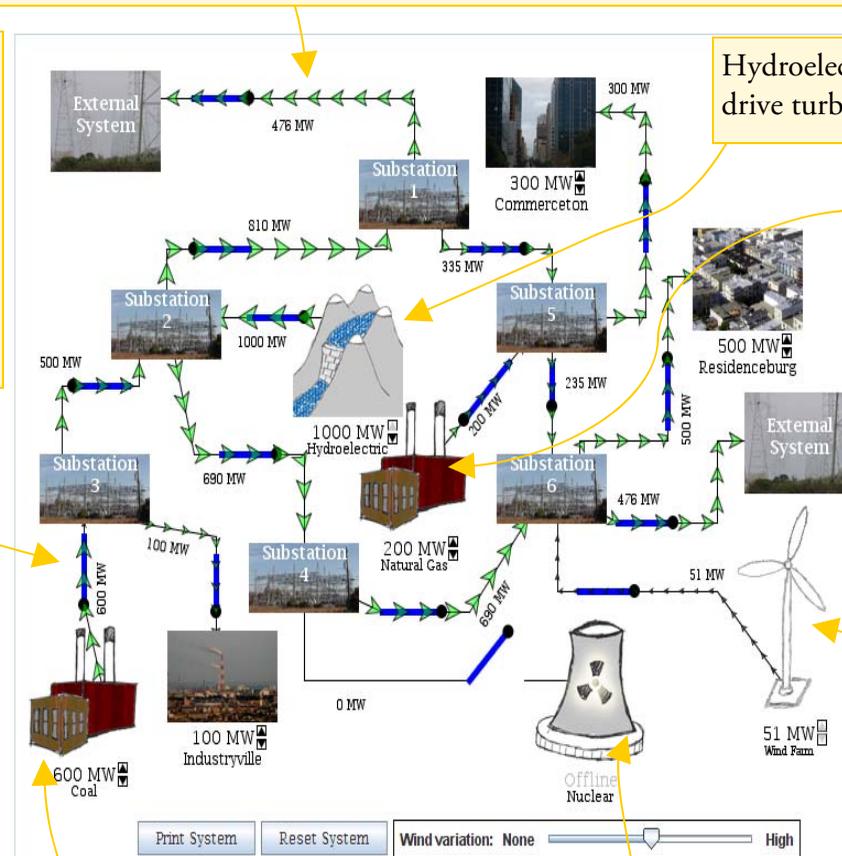
Power leaving the generating plant is carried by high-voltage, long-distance transmission lines to a distribution substation. The power leaves the substation on the lines you see strung from power poles. The transmission lines that have the largest diameters are designed to carry the most power. Transmission lines become hot and expand if they carry more power than they are designed to carry. This can cause the line to sag and touch the ground or some other object. When this happens, the line is opened and a power outage will occur.

Open or close the blue switches by clicking them with the mouse.

Wind turbines are clustered together to make wind farms capable of producing utility-scale power levels. Their power output varies with wind speed, and good wind sites are often far from areas that need the most power, so wind accounts for only a small portion of generated power. The U.S. Department of Energy proposes that wind might supply 20% of the nation's power by the year 2030.

Coal generators are the cheapest fossil-based generators. They can change their output a little less quickly than the natural gas generators.

Nuclear generators are powered by a uranium fission process. They are expensive to build, but inexpensive to operate. They provide large amounts of power.