Solar Powered System - 2

Student Objective
The student:
- given a photovoltaic system will be able to name the component parts and describe their function in the PV system
- will be able to access their systems data and be able to explain its function

Materials:
- Viewing access to school's photovoltaic system
- Computer with internet access
- Laboratory Manual

Key Words:
alternating current electricity (AC)
data acquisition system
direct current electricity (DC)
distribution panel
inverter
kilowatt hours
photovoltaic array
photovoltaic cell
photovoltaic module
semiconductor material

Time:
1 class period

Background Information

Most typical solar cells are made of the element silicon. When light shines on a solar cell, the energy of the light penetrates into the cell and 'knocks' negatively charged electrons loose from their silicon atoms. The freed electron has potential energy (voltage). These freed electrons flow through the internal electro-static field and out of the cell.

Because typical silicon solar cells produce only about ½ volt, cells are connected together to give more useful voltages. Usually 30 - 36 solar cells are connected in a circuit to give a final voltage of about 15-17 volts. To increase the power output further, modules are connected together to form an array.

Procedure
1. Divide students into groups for Data Acquisition activities according to how many computers are available.
2. Discuss background information with the class. Points to cover include:
   - Photovoltaic cells are made up of silicone, the main component of sand. Silicon is also commonly used in semiconductors
   - Photovoltaic cells are wired together into panels called modules. The modules in a system are wired together into a photovoltaic array
   - Photovoltaic cells generate direct current (DC) electricity. DC is the type of

electricity that battery operated devices use. The circuits in homes, schools and businesses carry alternating current (AC) electricity. The DC electricity produced by photovoltaic cells has to be transformed into AC electricity before it can be used by the school

- Electric meters measure how much electricity flows through them. This electricity is measure in kilowatt hours

3. Escort students outside to look at the school system. If possible, let them look at the system components that are housed inside also.
4. Students should complete their Laboratory Manual pages.

Further Research

1. Is your school system large enough to power your home? Compare your home electrical usage as listed on your monthly statement with the capacity listed for your school system.
2. What percentage of your school's electrical usage does the panel produce? Obtain a copy of your school's monthly electric statement to find out what the total electric usage of your school is, and calculate what percentage is being supplied by the PV system. How could you increase this percentage? Include ways that would mean an investment of money as well as those that could be done without costing the school any additional money.

Internet Sites:

http://www.energywhiz.com/

Website produced by the Florida Solar Energy Center that hosts the PV for schools data.

http://www.fsec.ucf.edu/pvt/pvbasics/index.htm

Florida Solar Energy Center, "Photovoltaic Fundamentals"

http://www.sunsmart.org/

Sun Smart program site.

http://wattsonschools.com/

Watts on Schools, the Texas PV for Schools program. Includes lesson plans and access to data from the Texas schools.

http://www.pbs.org/wgbh/amex/edison/sfeature/acdc.html

Public Broadcasting System animated page showing the difference between DC and AC electricity.

http://ourworld.compuserve.com/homepages/Bill_Bowden/

Bowden's Hobby Circuits. Site includes over 100 circuit diagrams. Most of the circuits can be built with common components available from Radio Shack or salvaged from scrap electronic equipment.

EnergyWhiz

Submit photos of your students with your PV system in the background. These photos will be posted on the EnergyWhiz website with your school name.

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Benchmark MA.B.1.4.3 - The student relates the concepts of measurement to similarity in real-world situations.

Benchmark MA.B.2.4.2 - The student solves real-world problems involving rated measures.

Benchmark MA.D.1.4.1 - The students describes, analyzes, and generalizes relationships, patterns, and functions using words, symbols, variables, tables, and graphs.

Benchmark MA.E.1.4.1 - The student interprets data that has been collected, organized and displayed in charts, tables, and plots.

Benchmark SC.B.1.4.4 - The student knows that as electrical charges oscillate, they create time-varying electric and magnetic fields that propagate away from the source as an electromagnetic wave.

Benchmark SC.B.1.4.5 - The student knows that each source of energy presents advantages and disadvantages to its use in society.

Benchmark SC.E.1.4.1 - The student understands the relationship between events on Earth and the movements of the Earth and the sun.

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alternating current electricity (AC) – an electric current that reverses its direction at regular intervals. This type of current in the United States is what is sent over electrical transmission lines, and typically used in homes, offices and schools.

data acquisition system – a system that collects data from several different sensors and sends them to the computer that posts the data on the internet where it can be monitored by students all over the world.

direct current electricity (DC) – an electric current flowing in one direction only. This type of electricity is typically used in battery operated devices, automobiles and boats.

inverter – changes the DC electricity produced by the modules into alternating current (AC) which is the type of electricity used in your school and homes.

kilowatt hours – the basic unit of electrical usage.

photovoltaic array – the term for the complete unit of solar modules.

photovoltaic cell – the individual units in a photovoltaic module. Each cell is manufactured separately. These may then be wired together to make larger modules and produce more power.

photovoltaic module – the term for a photovoltaic panel. Modules can be wired together to make a larger array.

semiconductor material – a material such as silicon that is arranged in an even crystalline structure and is used in microchips and PV cells to facilitate the flow of electricity.

silicon – the element that is the main component of photovoltaic cells. Silicone is most commonly found on the earth in sand.

transformer – changes the voltage of the electricity coming from the inverter to match the voltage of electricity that is used in the school building.

voltage – a measure of the force or 'push' given the electrons in an electrical circuit; a measure of electric potential.

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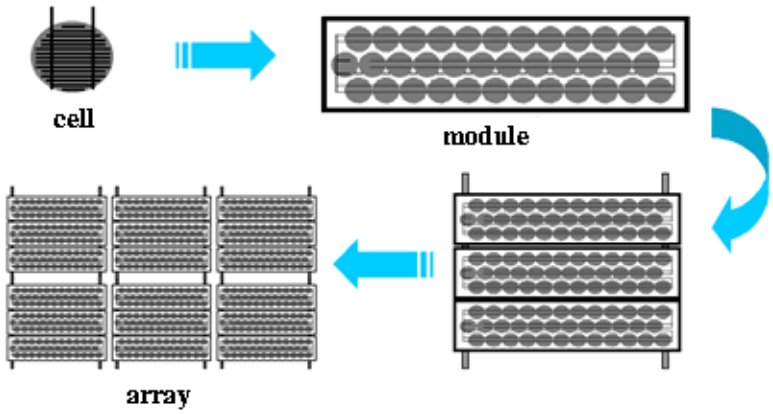
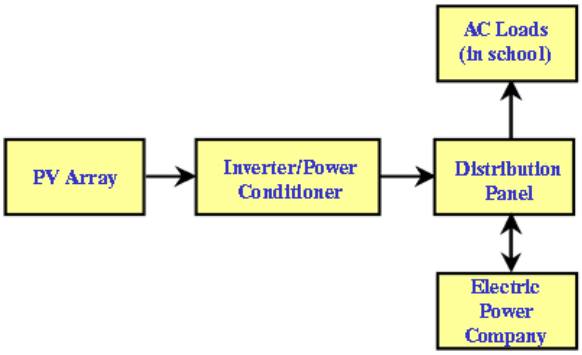
As part of the PV for Schools program, your school has a photovoltaic (PV) system that provides part of the electricity to power your school. In your PV system, groups of solar cells are connected together in 'modules' (or 'panels'), and the modules are connected together to form a solar 'array'. Each module consists of many different solar cells made of semiconductor materials (mainly silicon) which converts sunlight directly into electrical current, which is then conducted along wires into the school building. Inside your school, the current is conditioned to match the voltage and current type present inside the school building. The energy output from the system can then be used in the school for lighting, computers, air conditioning, or any application powered by electricity. Your PV system does not produce enough energy to power all of your school's needs, but it does reduce the amount of electricity the school needs to purchase from the electric company.

Parts of your Photovoltaic System



Photovoltaic array - The array which is made up of several photovoltaic modules converts sunlight directly into electric current. Like batteries, the current they produce is direct current (DC).



Inverter - The inverter changes the DC electricity produced by the modules into alternating current (AC) which is the type of electricity used in your school and homes.

Distribution panel - The point where the photovoltaic system output is wired to load circuits (in this case, your school) and to the incoming power lines from the electric utility. This allows the AC power produced by the system to either supply part of the electrical demands of your school or to feed into the general electric power lines if the school does not need the power at that time.

Electric meter - The electric meter keeps track of the amount of electrical energy produced by the photovoltaic system. Electrical energy is measured in **kilowatt-hours**.

Data acquisition system - The data acquisition system collects data from several different sensors and sends them to the computer that posts the data on the internet where it can be monitored by students all over the world.

Observations

1. With your class, observe your schools photovoltaic system. How many photovoltaic modules make up your school's array?

2. On your computer, go to the Energy Whiz website at: http://www.energywhiz.com/ Locate your schools live data page. The section "System Specifications" tells about the system that is at your school. The 'capacity' is how many watts of electricity your system is designed to produce. What is the total capacity (in watts) of your photovoltaic system?

3. Calculate the electric output of that each module adds to the total capacity of your system.

4. The current weather at the closest weather station to your school is shown on the right. At the present moment, is the weather at your school the same as what is being reported by the weather station?

   If the weather at your school is different, why do you think the weather reported is different than what you see outside right now?

5. Your data acquisition system sends five channels of data to the website. This data is turned into graphs that are then posted on the website:
   - PV system AC power
   - PV system DC volts
   - PV system DC current
   - Plane of array irradiance (amount of sunlight hitting the array)
   - Ambient temperature (air temperature at the array site)

   Each graph covers three days. The hours 12, 36 and 60 on the x-axis correspond to noon on the three days. Study the graph titled "Ambient Temperature" (air temperature at the photovoltaic array). Describe below what the graph tells you about the temperature for the three days listed. Make sure to include approximate high and low temperatures for each day and what time these temperatures occurred.

6. What is the tilt angle listed for your system?

7. From what you discovered in Solar Powered System I, why do you think your array is positioned at that angle?

8. Look at the AC Power and the DC Current graphs. Why do you think they are similar?

9. Why would having both channels of data be useful to someone monitoring the system?