the gaia project
realistic environmentalism

Project Guide: Solar Photovoltaic Demonstration

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Solar Photovoltaic Demonstration

A guide to delivering a solar photovoltaic project in your classroom

The Gaia Project is a charitable organization dedicated to providing project based learning opportunities in the areas of energy, environment and sustainable engineering.

We develop projects, provide professional development, technical support and ongoing project support for teachers and students. Our projects aim to incorporate three key principles, which symbolise our focus on realistic environmentalism.

1. **Data Informed Decisions** – We want students to be able to explain why, and quantify the effect of each decision they made along the way to their final solution.
2. **Economic Assessments** – We expect students to be able to assess the cost effectiveness of their solutions, and be able to optimize their projects with limited budgets.
3. **Environmental Impact and Lifecycle Assessments** – We need students to take a holistic view to their projects. This means looking at their projects from cradle to grave, as opposed to just examining the use phase, and acknowledging that greenhouse gas reduction is not the only environmental issue at stake.

For more information, please visit www.thegaiaproject.ca

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Solar Photovoltaic Demonstration

This project is designed to introduce the concept of renewable electricity generation via solar photovoltaic (PV) technology. It will allow students to assemble a small solar photovoltaic array, test and record its performance against several variables.

The equipment required to assemble the small scale solar photovoltaic demonstration include:

- CSE 40W Solar Photovoltaic Panel
- Sunforce 7A Charge Controller
- UB12220 12V Battery
- PowerBright 200W Inverter
- Additional wire if required

Theory

The solar photovoltaic panel absorbs light energy in the form of photons from the sun. Using the photovoltaic effect, it is able to convert a portion of the energy in the light into electrical energy. The photovoltaic effect produces DC (direct current) electricity, and represents only a very small portion of our electricity supply that is produced in DC form.

The electricity generated is used to charge a 12V battery. In order to do this, the voltage at the terminals of the solar panel must be greater than the voltage at the battery so that there is a difference in electrical potential between the solar panel and the battery so that charge can flow to the battery.

It is possible to overcharge batteries, so it is necessary to install a charge controller. This device simply monitors the voltage of the battery, and electrically disconnects the solar panel from the battery when the battery voltage reaches 14.2V (which represents a fully charged battery).

Finally, the majority of our electrical appliances use 110V AC (alternating current) electricity as opposed to 12V DC. While it is possible to buy 12V DC electrical appliances, they are very limited. Instead, we use an inverter to convert the 12V DC power source into 110V AC power supply.

This is done using the principles of a transformer and switching circuits. The voltage is stepped up using a transformer, where two coils of wire are wrapped around a magnetic core. The ratio of the voltage in the first coil of wire to the second coil of wire is equal to the ratio of the number of turns in the first coil of wire to the number of turns in the second coil of wire. A switching circuit is used in the inverter to change the direction that the current flows through the transformer at a rate of 60 cycles per second, to ensure that the resulting current is alternating current and matches our standard electrical frequency of 60Hz.

Additional Resources

DC Current

http://en.wikipedia.org/wiki/DC_current

One-way flow of electric charge.

AC Current

http://en.wikipedia.org/wiki/AC_current

The movement of electric charge periodically changes direction.

Assembly

The following instructions are intended only for use with the CSE 40W solar PV panel, Sunforce 7A Charge Controller, UB12220 Battery, and PowerBright 200W inverter. See the individual equipment guides for more detailed installation, operation and safety instructions.

1. Connect the Sunforce 7A Charge Controller to the UB12220 12V Battery. Ensure that the positive and negative battery leads from the charge controller [1] are connected to the positive and negative terminals of the battery respectively [2]. Use the supplied nuts and bolts with the battery to make this connection. [2].

Figure 1: Battery Cords from Charge Controller

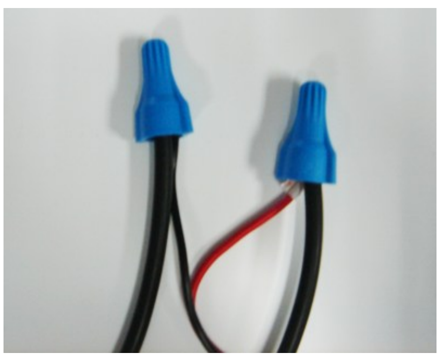
Figure 2: Battery cords connected to positive and negative battery terminals. Notice negative terminal is black with (–) sign, and positive terminal is red with (+) sign.

2. Connect the CSE 40W Solar PV panel to the charge controller. Ensure that the positive and negative solar panel leads from the charge controller [3] are connected to the positive and negative wires from the solar PV panel [4] respectively. Use twist on wire connectors to make this connection [5].

Figure 3: Solar Panel Array wires from Charge Controller

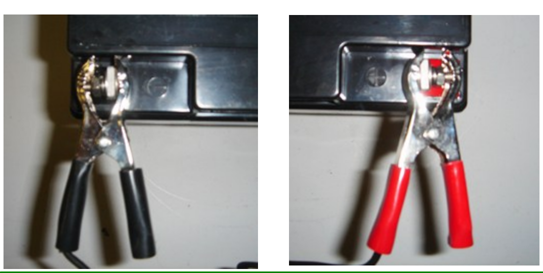
Figure 4: Positive and Negative wires from Solar Panel Array

Figure 5: Connected Solar Panel and Charge Controller Wires



3. Connect the PowerBright 200W Inverter to the battery. Ensure that the positive and negative battery clamps from the inverter [6] are connected to the positive and negative terminals on the battery respectively [2].

Figure 6: Positive and negative battery clamps attached to positive and negative battery terminals respectively



Circuit Diagram

The completed circuit diagram should resemble Figure 7 [see end of document].

Testing

Voltage

Voltage can be measured at several points throughout the circuit, using a digital multimeter or AC/DC clamp meter. Do not use the Pasco V-I Sensor with the Xplorer GLX, as it has a maximum voltage range of +/-10V, which is below the level we would expect in this circuit.

Voltage is the electric potential – the driving force behind the flow of charge - and used to overcome electrical resistance. Measuring the voltage according to Figure 8 [see end of document] should result in a measurement that is at or only slightly above that of the battery itself. This is because the voltage cannot be different at two neighboring points in a circuit without a resistor between them. Since the wire has minimal resistance, the voltage should be virtually identical.

Measuring the voltage at the point shown in Figure 9 [see end of document] would potentially yield more interesting results. This will show the voltage being produced by the solar PV panel. We should see it begin to rise from 0V as it is exposed to sunlight, and reaching its maximum voltage of 17.5V at times of peak electricity production.

Current

Measuring the current is a more useful activity than measuring the voltage of the circuit, since the voltage at the battery terminals will only rise slightly as it is charged. On the other hand, the current should change significantly as the solar PV panel is exposed to more light, and able to produce more power.

The current can be measured using the digital multimeter, the AC/DC clamp meter, or logged with the Pasco high current sensor. Do not use the Pasco V-I sensor, as it has a maximum current of +/- 1A which is below the threshold we expect here.

Again we can measure the current at many points in the circuit. At the point shown in Figure 10 [see end of document], we will see the amount of current generated by the solar panel and sent to the battery. If the battery is fully charged, the solar panel is electrically disconnected, and we will receive a reading of 0 for current, since it has nowhere to flow.

Measuring the current at the point shown in Figure 11 [see end of document] should produce a result related to that calculated in Figure 10. The reason for this is that the charge controller converts the voltage produced by the solar PV panel (maximum 17.5V), to the voltage at the terminal of the battery (maximum 14.2V). Since the amount of power produced doesn't change, and:

Power (Watts) = Voltage (Volts) x Current (Amps)

We can make an estimation of what the current should be at the point shown in Figure 11, compared to the value measured in Figure 10.

Power (Fig 11) = Power (Fig 10)

Voltage (Fig 9) x Current (Fig 10) = Voltage (Fig 8) x Current (Fig 11)

12V x Current (Fig 10) = 17.5V x 2A

$$Current\ (Fig\ 10) = \frac{17.5V \times 2A}{12V} = 2.9A$$

It would be expected that there would be some loss of power in the charge controller due to inefficiencies in the design.

Measuring current at the point shown in Figure 12 [see end of document], will indicate the amount of current flowing to the inverter. Since this has the potential to be in excess of 10A, **do not** use the Pasco high current sensor at this point in the circuit.

Power

To calculate the amount of power being produced at any given time by the solar panel, we need to do a simple calculation.

Power (Watts) = Voltage (Volts) x Current (Amps)

As mentioned previously, the power theoretically produced by the solar panel, should be identical on either side of the charge controller, but in reality there are losses.

Power Produced (Watts) = Voltage (Fig 9) x Current (Fig 10)

Power into Batteries (Watts) = Voltage (Fig 8) x Current (Fig 11)

$$\text{Charge Controller Efficiency (\%)} = \frac{\text{Power into Batteries}}{\text{Power Produced}}$$

The Charge Controller efficiency represents the ability of the charge controller to effectively convert the supplied voltage to the battery voltage. A higher number represents a lower power loss.

It is also possible to calculate the power flowing to the inverter.

Power to Inverter (Watts) = Voltage (Fig 8) x Current (Fig 12)

We can measure power coming out of the inverter and into our electrical appliances using a Watts Up Meter. This value would then allow us to calculate the efficiency of the inverter.

$$Inverter\ Efficiency\ (\%) = \frac{Power\ out\ of\ Inverter}{Power\ to\ Inverter}$$

The inverter efficiency indicates the effectiveness of the inverter at converting 12DC power into 110V AC power.

Efficiency

If your school has a weather station available to it, with a solar radiation module, it is possible to calculate the efficiency of the solar PV panel.

The solar radiation module measures the intensity of the solar radiation (energy) sun in Watts per m^2

Variables

There are multiple variables that can tested along the way to see how these impact performance. These include:

- Orientation
- Tilt
- Time of Day
- Time of Year
- Shading
- Temperature
- Weather

It is important to only try and change one factor during each test run so that any differences can be directly attributed to the variable being altered.

Additional Resources

Photovoltaics Systems Overview

http://www.cmhc-schl.gc.ca/en/co/maho/enefcosa/enefcosa_003.cfm

Canadian Mortgage and Housing Corporation Photovoltaics overview.

$$\text{Electrical Efficiency (\%)} = \frac{\text{Power Produced (Watts)}}{\text{Solar Radiation Intensity}\left(\frac{\text{Watts}}{\text{m}^2}\right) \times \text{Panel Surface Area (m}^2\text{)}}$$

Figure 7: Circuit diagram for completed solar PV array

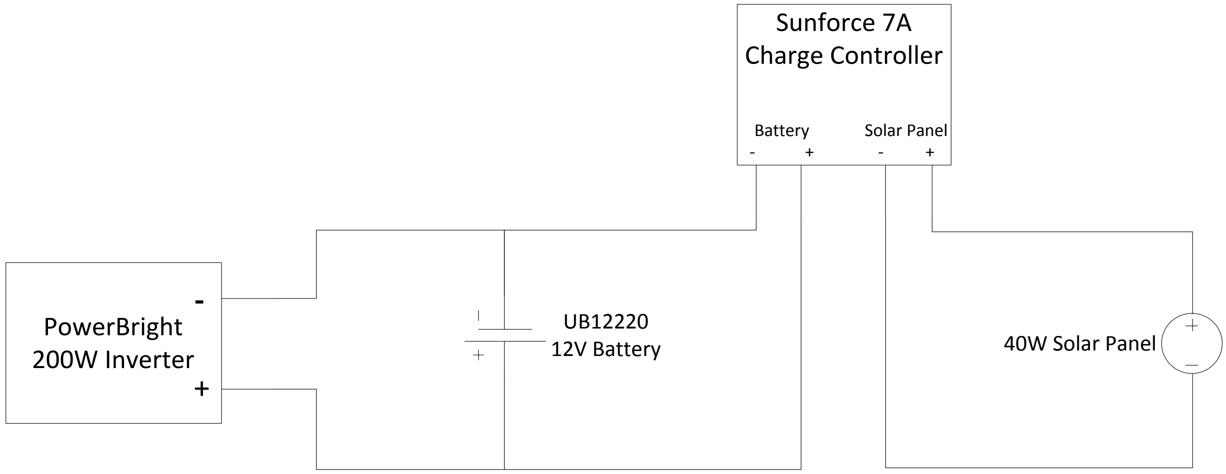


Figure 8: Measuring voltage across the battery

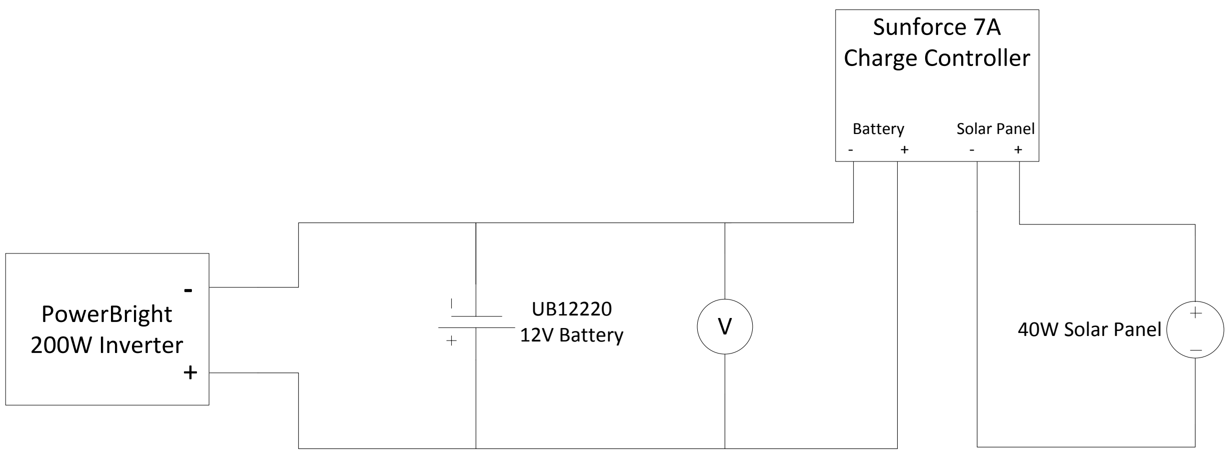


Figure 9: Measuring voltage across the PV panel

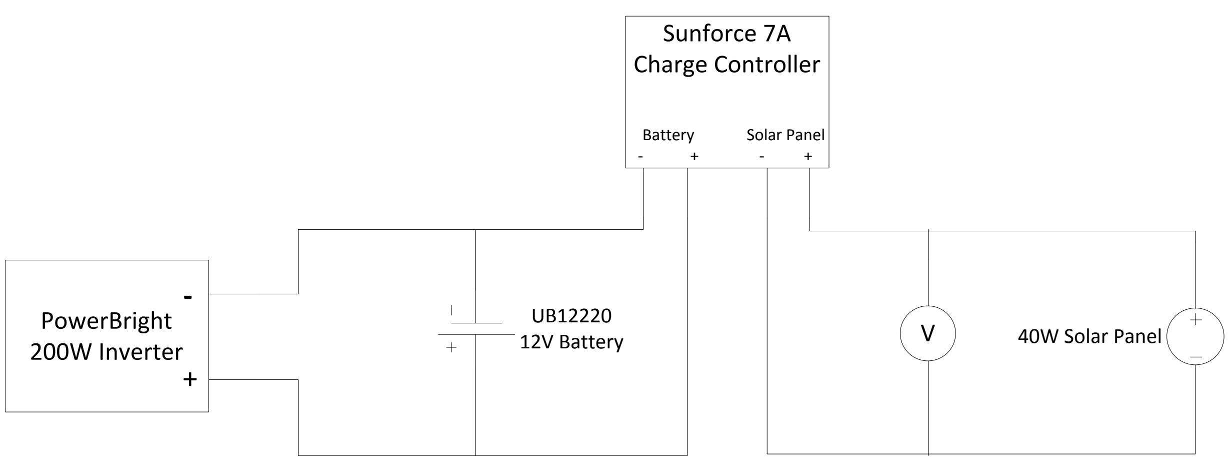


Figure 10: Measuring current from the PV panel

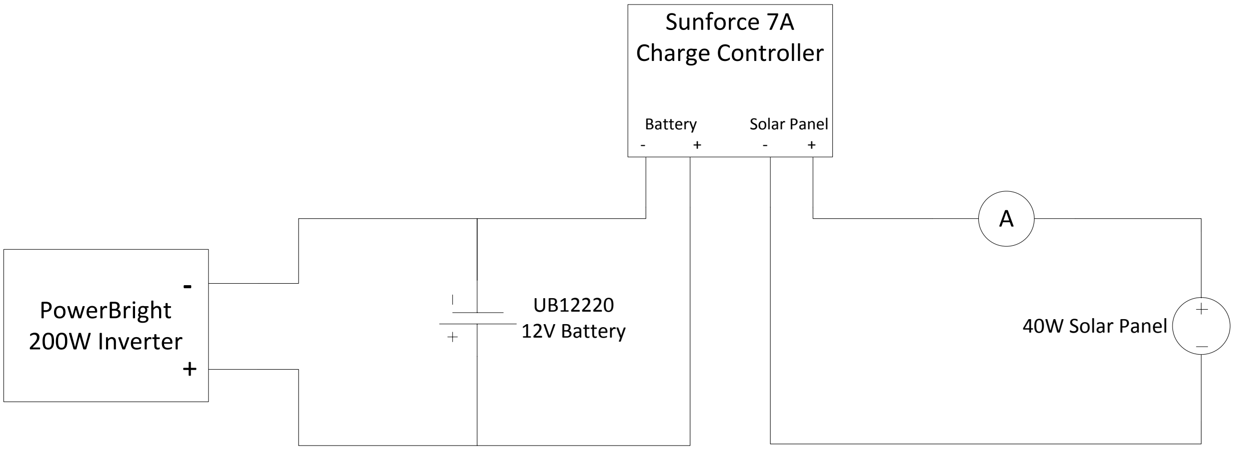


Figure 11: Measuring current into the Batteries

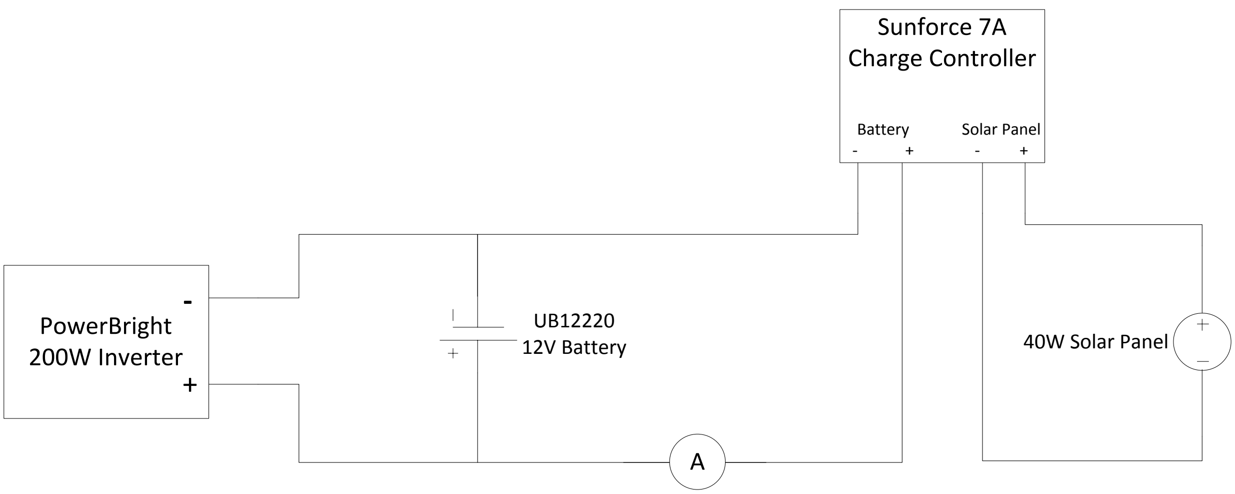


Figure 12: Measuring current into the Inverter