LAB PROCEDURE 6

Off-Grid Photovoltaic Power Systems

Solar

OBJECTIVES

1. Test various battery configuration options.
2. Connect the Marcraft PV Array Generation circuitry to storage batteries.
3. Supply a DC load with the Marcraft PV Array Generation system.
4. Document battery charge/discharge rates.
5. Implement excess capacity management by driving auxiliary loads.
6. Connect the PV array circuitry to an AC inverter.
7. Drive an AC load with the Marcraft PV Array Generation system.
8. Document battery charge/discharge rates vs. inverter output (system efficiency).

RESOURCES

1. 12V, 12W Photovoltaic Solar Panels (2)
2. Variable Intensity Lamp with variable height adjustment
3. Marcraft Green Electron Generation Experiment Panel
4. Hand-held Digital Multimeter
5. Jumper Wires (12 AWG red, black, green)

DISCUSSION

The power output of a PV panel or array is not steady. The voltage and current levels produced from the panels varies with the time of day, time of year and atmospheric conditions. Therefore, the PV array alone is not dependable as the primary source of power for most applications. In most residential, the output of the PV array is either used to charge a bank of **storage batteries**, or it is applied to the **commercial power grid** to supplement the incoming power supply to the residence.

In large commercial **solar farms**, the outputs of several PV panels are combined to provide hundreds of **megawatts** (million Watts or **MW**) of power that is applied directly to the commercial power grid. These arrays work with complex controllers that monitor the operation of the array and control parameters such as its optimum horizontal and vertical positioning. These controllers are also designed to provide power to the grid in a format acceptable to the local electrical utility.

Batteries

Batteries are devices that produce DC electricity through a chemical reaction process. The chemicals in the battery react with its terminals when an external path for current flow is provided. The process causes free electrons to gather at the negative (-) terminal of the battery while a depletion of electrons occurs at the positive (+) terminal. This provides the push (-) and pull (+) to create current flow through an external circuit, as illustrated in Figure 6-1.

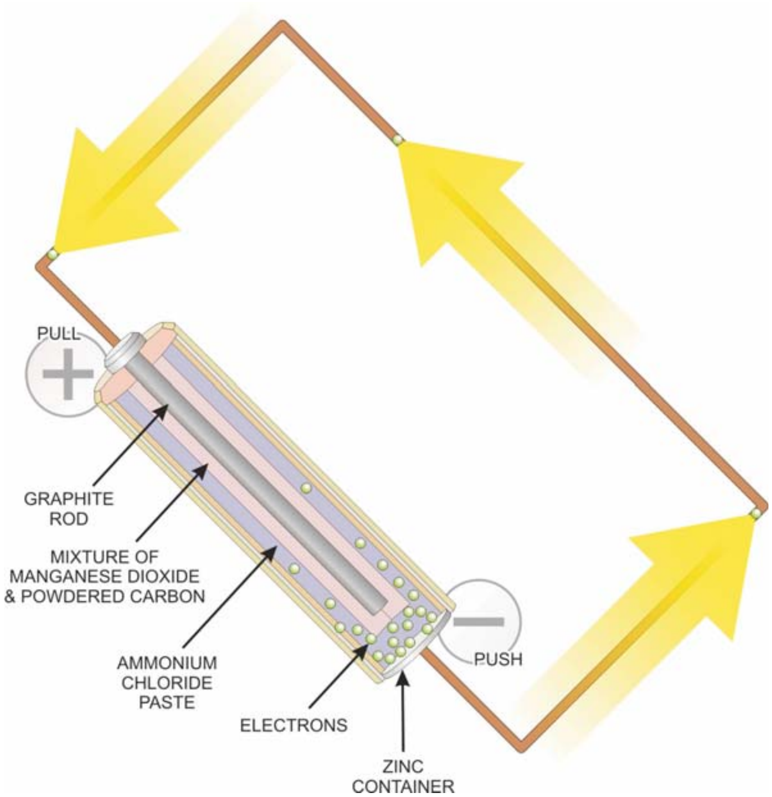


Figure 6-1: Operation of a Battery

When an external pathway is provided the electrons flow from the negative terminal through the external circuit (and the external load) and back into the positive terminal of the battery. If a very low resistance load is placed across the terminals, a large flow of electron current will occur. Larger resistive loads draw lower levels of current flow from the battery, as described by the basic Ohm's Law formula for current, voltage and resistance.

In cases where a wire or other good conductor is placed across the terminals without a load (referred to as a **short circuit** condition), the flow through the circuit and the inside of the battery as quickly as the internal process can generate more free electrons. The acceleration of the process causes the battery to heat up, which in turn can cause it to overheat and possibly explode.

Some battery types (referred to as **secondary cells** or **storage** batteries) can be recharged by applying a reverse current to them, as illustrated in Figure 6-2. By applying an external voltage source to the battery at a voltage level *slightly higher* than its terminal voltage, a reverse current is forced to flow back into the battery and the internal chemical process is reversed. Under these circumstances, the battery becomes the load in the circuit instead of the source.

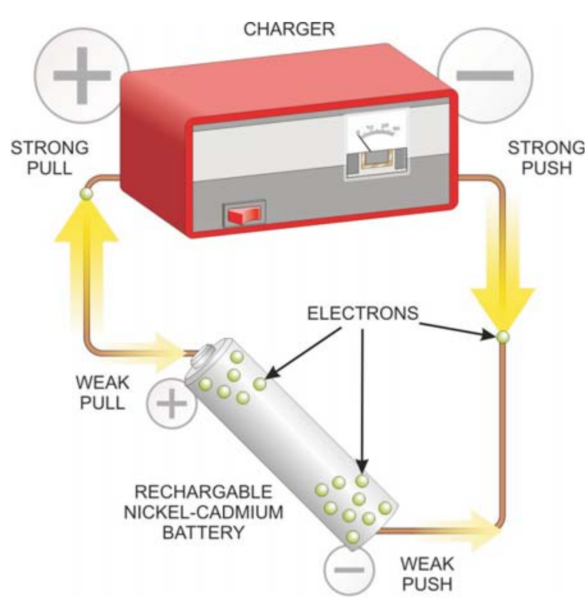


Figure 6-2: Recharging a Battery

Over time, the reverse current flow restores the original chemical configuration inside the battery. The rate at which the battery **recharges** depends on the chemical configuration and the amount of reverse current flowing through the battery. The amount of reverse current is dependent on the voltage difference between the battery and the recharging source.

The recharging option is not available with all battery types (not all chemical current generating processes can be reversed). Applying a reverse voltage to these batteries (**primary cells**) can cause them to overheat and possibly explode.

WARNING

Applying a reverse voltage to non-rechargeable battery types can cause them to overheat and possibly explode.

Battery Configurations

Batteries can be connected together to provide different voltage and current capabilities to fit different load/installation requirements. When batteries are connected in **series** (positive terminals are connected to negative terminals in a *daisy-chain* connection) as illustrated in Figure 6-3, the voltage level provided to an external load is equal to the sum of all the individual battery voltages. The current flow is the same through all the batteries and the load. This arrangement enables batteries to be combined to provide power to a piece of equipment that requires a higher voltage source—such as using two 6 volt batteries to provide a 12 VDC source for a portable lantern.

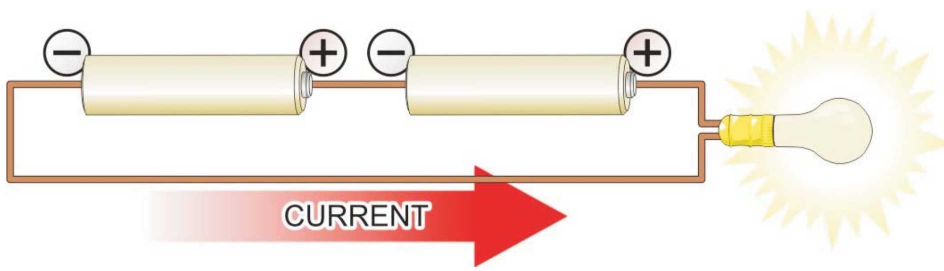


Figure 6-3: Series Connected Batteries

When batteries are connected in **parallel** (positive terminals are connected to positive terminals) as illustrated in Figure 6-4, the voltage level is the same as the individual batteries (all of the batteries should have the same voltage ratings). However the current delivery capabilities of parallel batteries is equal to the sum of the currents produced by each of the batteries. This is helpful in situations where devices that require heavy DC current loads need an acceptable source of power.

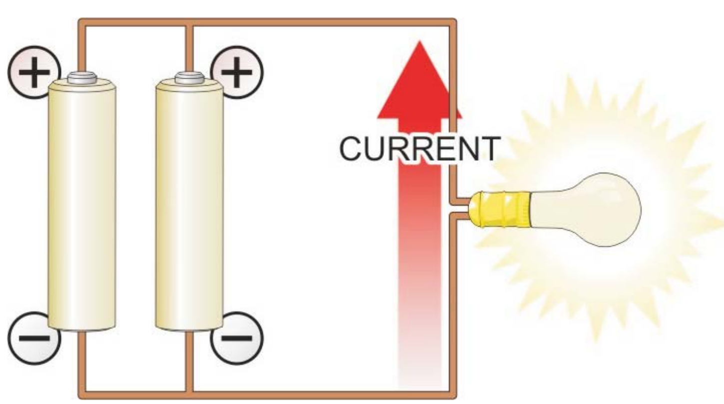


Figure 6-4: Parallel Connected Batteries

Inverters

Inverters are electronic or electro-mechanical device that converts DC into AC. DC sources such as wind turbines, photovoltaic solar panels and batteries are often connected to inverters to provide an AC output that has consistent voltage levels and frequencies. In a wind turbine system using a storage battery system, the inverter is used to convert the DC current coming from the storage batteries into AC power that can be used with typical household appliances.

Inverter Types

Most PV array installations require some type of battery-based storage system. Inverters designed to work specifically with this type of application are referred to as off-grid (or *no utility-needs batteries*) inverters. **Off grid inverters** are designed to work batteries and are not designed for connection to the commercial AC power system (the electrical power delivered by the power company, also referred to as **the grid**).

On grid (also called *no-battery-grid intertie*) **inverters** are designed for connection to the AC power system provided by the local electric utility company and do not require any batteries.

A third class of inverters referred to as **On-grid/Off-grid capable inverters** These inverters are designed so that they can be connected directly to the utility grid and can also work with a battery storage system to provide backup power in the case of a power outage.

Inverter Sizing

Off grid and On-grid/Off-grid capable inverters must be sized so they are compatible with the *maximum* load they are, or will be, expected to supply. This is simply a matter of installing an inverter with a power rating high enough to supply the sum of all the wattage ratings of the devices that will be supplied at any one time. For example, if 200 watts of lighting, 1000-watt refrigerator and a 1500-watt oven need to be supplied at the same time, the inverter must be capable of delivering at least 2700 watts of power. The inverter's input voltage specification must match the system's storage battery configuration.

Output Regulators and Load Diverters

When the storage batteries of a wind turbine installation become fully charged, the wind turbine will continue to produce additional power as long as the wind continues unless some control circuitry is used to shut down the power generation process. If power continues to be applied to the storage batteries, it will **overcharge** them creating a potentially dangerous situation. Overcharged batteries can overheat and possibly explode. The additional power being generated is also being wasted.

The Marcraft Green Electron Generation panel includes two types of charging regulators commonly used in alternative energy installations—an **open circuit regulator** and a **diversion style regulator** (also known as a *load diverter*) that can be used to control the charging of the storage battery system.

An open circuit regulator monitors the balance of voltage in the charging system and creates an open circuit condition to separate the PV array from the charging system. When the battery voltage falls off to a predetermined level, the regulator closes the circuit so the PV array can start charging the storage batteries again. The drawback to this type of regulator is that the PV array will continue to produce energy as long as light is present—the energy generated while the regulator is in the open circuit condition is simply wasted.

A **load diverter** is a device that monitors the voltage of the load battery. While the voltage level of the battery is below its stated fully charged value, the diverter applies voltage to the battery. However, when the battery voltage reaches the fully charged level, the diverter shift the current coming from the source to a different load. This load is most often some type of water heater that uses the excess power being generated by the source so that it is not wasted. Figure 6-5 shows the placement and configuration of the load diverter in the PV array/storage battery circuit.

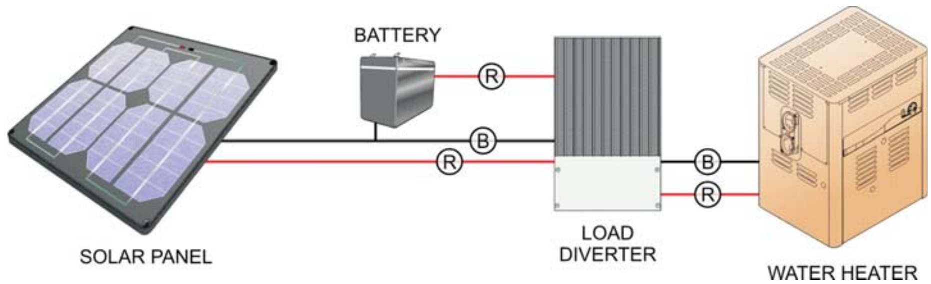


Figure 6-5: Implementing the Load Diverter

Safety Precautions

The inherent personal dangers from electrical current still exist in this procedure. Therefore you should always use caution when working with this and other electrical devices. The high current capabilities of PV arrays can create a potentially dangerous shock and burn hazard when the turbine is in operation. As before, using improper wire sizes (wires that are too small for the level of current they are required to carry) can result in excess heat that can damage the wiring, causing a fire, or cause a burn to humans.

CAUTION

It is important to follow the wire-sizing chart in Table 6-1 to insure a safe electrical system and to help avoid the risk of an electrical fire and personal injury.

Table 6-1: Wire Size Selections

# Turbines	0-30 Feet	30-60 Feet	60-90 Feet	90-150 Feet	150-190 Feet	190-250 Feet	250-310 Feet	310-390 Feet	390-500 Feet
1	8g/87	6g/13	4g/21	2g/34	1g/53	0g/53	00g/67	000g/85	000g/85
2	6g/13	4g/21	1g/44	00/67	000g/85	0000g/107	*	*	*
3	4g/21	2g/34	0g/53	000g/85	0000g/107	*	*	*	*

*If your system requires this length of wire, consider using additional, parallel wire(s).

Battery Hazards

Storage batteries are based on chemical reactions and can deliver dangerous amounts of current. If a short circuit situation occurs in the wiring from the batteries, a fire can result. In order to avoid this threat, a properly sized fuse or circuit breaker is required in the lines connecting the system to the storage batteries.

Solar

PROCEDURES

In this first procedure, you will connect a set of batteries in different standard configuration. Make sure you are confident with your connections before making them as connecting batteries incorrectly can lead to damage and/or personal injury.

CAUTION

Be sure not to connect the wires to the battery until everything else has been completed and you are instructed to do so in this procedure.

Battery Configuration Tests

1. Locate the protective battery enclosure and verify that there are four matching 12V batteries.

2. Designate each of the batteries with a number identification (i.e., battery1, Battery 2, etc.), as illustrated in Figure 6-6.

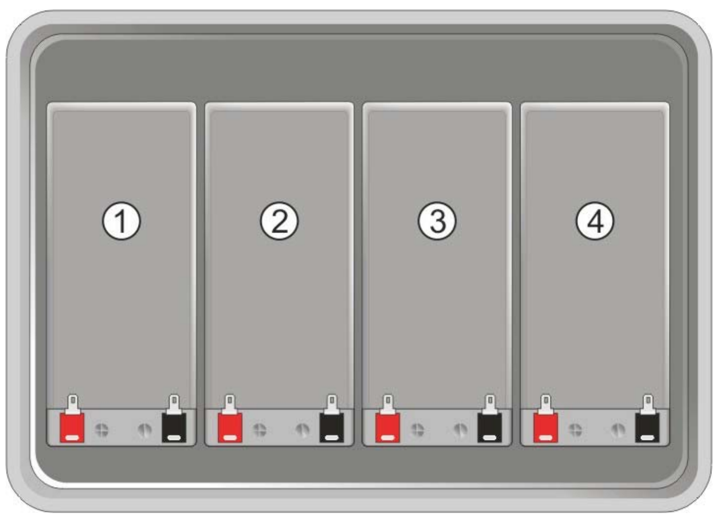


Figure 6-6: Identifying Batteries

3. Set the multimeter to the 20 DCV setting.

4. Measure the voltage level present at the terminals of each battery and record these values on the following lines:

Battery #1 ______________________

Battery #2 ______________________

Battery #3 ______________________

Battery #4 ______________________

5. Form a series battery connection by attaching a jumper wire between the positive (+) terminal of battery #1 to the negative (-) terminal of battery #2, as illustrated in Figure 6-7.

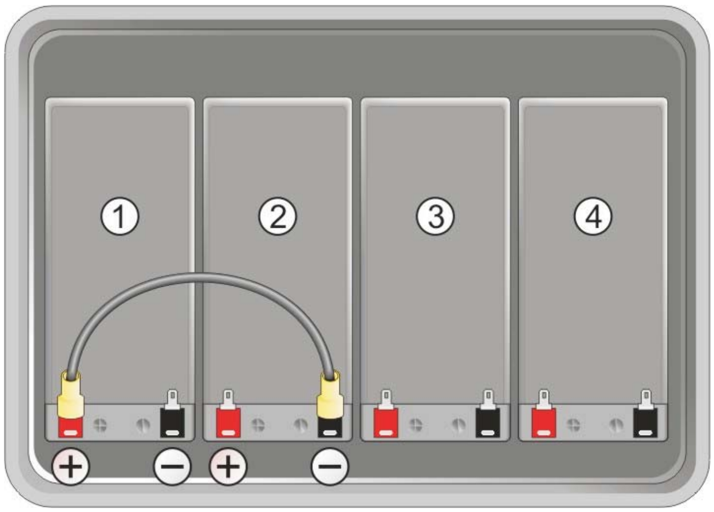


Figure 6-7: Connecting Batteries in Series

6. Connect the black lead of the meter to the negative terminal of battery #1 and the red lead to the positive terminal of battery #2. Record the total voltage level provided by the series batteries on the following line:

____

7. How does this value relate to the individual voltages of batteries #1 and #2 measured in Step 4?

____

8. Form a parallel battery connection by attaching a jumper wire between the positive (+) terminal of battery #3 to the positive (+) terminal of battery #4.

9. Attach another jumper wire between the negative (-) terminal of battery #3 to the negative (-) terminal of battery #4, as illustrated in Figure 6-8.

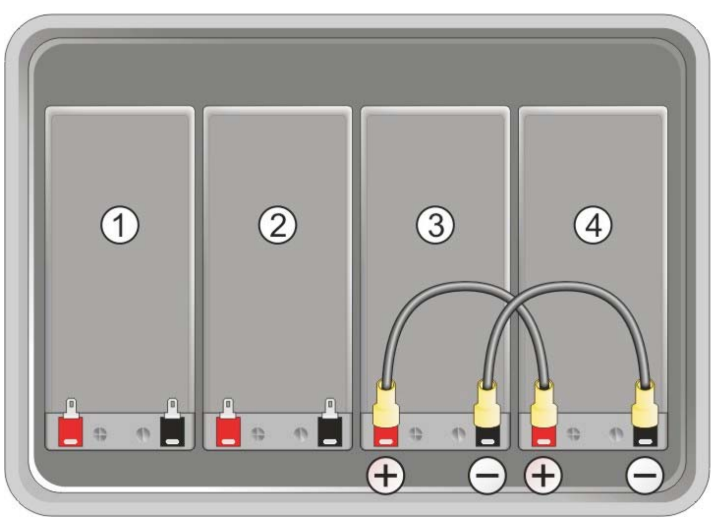


Figure 6-8: Connecting Batteries in Parallel

10. Connect the black lead of the meter to the negative terminal of battery #3 and the red lead to the positive terminal of battery #3. Record the total voltage level provided by the parallel batteries on the following line:

____

11. How does this value relate to the individual voltages of batteries #3 and #4 measured in Step 4?

____

12. Remove the jumper wires from batteries #3 and #4.

13. Refer to Figure 6-9 and connect batteries #3 and #4 in series so that they are wired in the same series configuration as batteries #1 and #2.

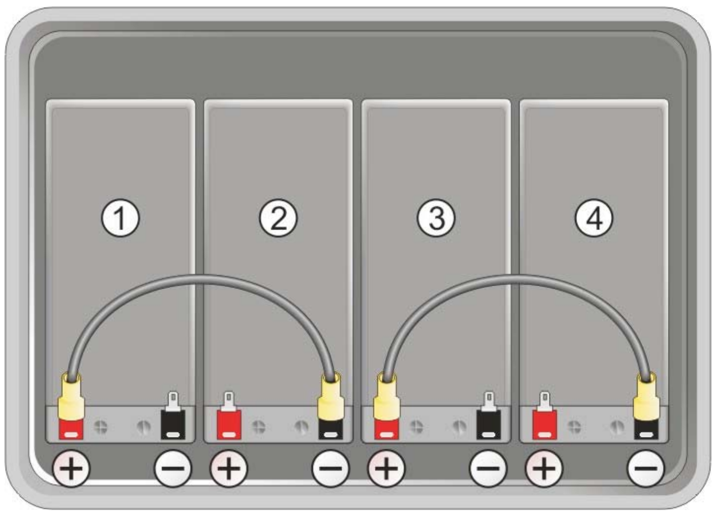


Figure 6-9: Two Sets of Series Connected Batteries

14. Create a parallel battery connection between series batteries #1/#2 and series batteries #3/#4 by attaching a jumper wire between the positive (+) terminal of battery #2 to the positive (+) terminal of battery #4.

15. Attach another jumper wire between the negative (-) terminal of battery #1 to the negative (-) terminal of battery #3, as illustrated in Figure 6-10.

16. Connect the black lead of the meter to the negative terminal of battery #1/#3 and the red lead to the positive terminal of battery #2/#4. Record the total voltage level provided by the series/parallel batteries on the following line:

____

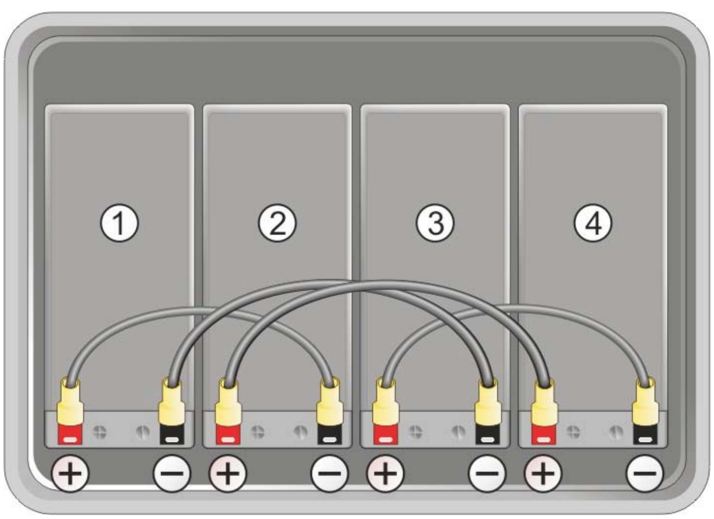


Figure 6-10: Connecting Batteries in Series/Parallel

17. How does this value relate to the individual voltages of all the batteries measured in Step 4?

____

18. Remove all the jumper wires from the batteries.

Preparing the Battery Storage System

Solar

The Marcraft PV array's support circuitry is designed to operate at a 12VDC level. With this in mind, which battery configuration from the previous procedure should be used as a storage system for this PV array?

____

1. Use four spade lug connectors to connect all four batteries in parallel with each other, as illustrated in Figure 6-11. This requires that you connect jumper wires between all the positive terminals, placing two wires in each spade lug connector except the first and last.

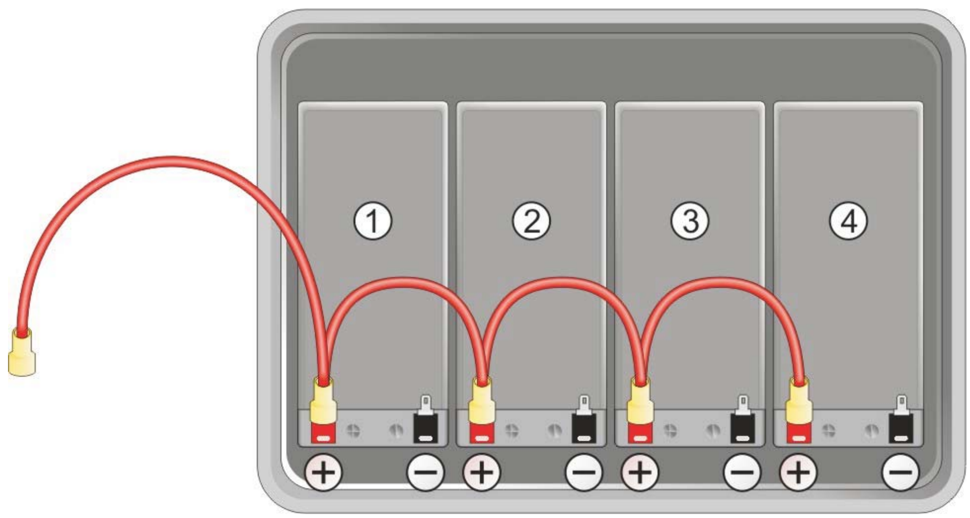


Figure 6-11: Connecting All the Batteries in Parallel

2. Attach an additional 12 AWG red wire to the last terminal so that it extends 4 to 6 inches outside the protective battery enclosure.

3. Crimp a female bullet connector to the external end of the wire.

4. Use the same process described in Step #1 to connect jumper wires between all four negative terminals on the batteries.

5. Attach an additional 12 AWG black wire to the last terminal so that it extends 4 to 6 inches outside the protective battery enclosure.

6. Crimp a female bullet connector to the external end of the wire.

7. Thread the external battery wires over the side of the case in positions that align with the exit openings in the side of the battery case's top cover. Fasten the top cover of the case in place with the external wires extending out of the case, as shown in Figure 6-12.

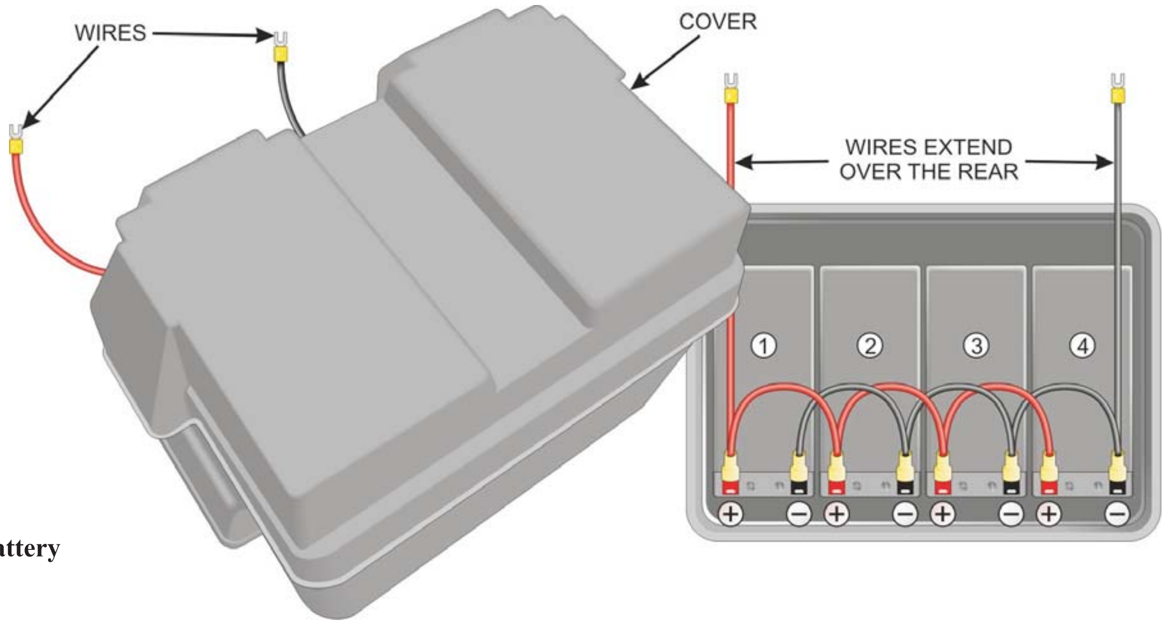


Figure 6-12: Securing the Protective Battery Case

8. Connect the black lead of the meter to the external negative battery lead and the red lead to the external positive battery lead. Record the total voltage level provided by this battery configuration on the following line:

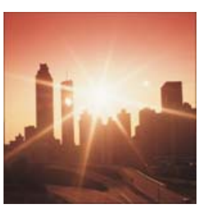
____

9. How does this value relate to the stated operating voltage level of the Marcraft PV array?

____

10. Remove the meter from the battery configuration.

11. Place the PV array's Disconnect Switch in the **Off** position.



Solar

Rewiring the Control Panel for External Connections

The Marcraft Green Electron Generation experiment panel contains an open-circuit charging regulator that monitors the voltage level of the external circuitry and isolates it from the PV array when the external voltage reaches a predetermined level. This prevents the PV array from overcharging the external batteries. You will use the following steps to connect the PV array charge controller into the PV array charging circuitry.

1. Disconnect the red and a black 12 AWG jumper wires from the two, left-most connection points on the top row of the PV Panel connection block.

2. Prepare and install a short red 12 AWG jumper wire to run between the top-left terminal on the PV panel connection block and the lower-left terminal of the PV Charge Controller connection block. (This jumper may be combined with the red parallel PV panel jumper from the previous procedure).

NOTE: This should produce a red-to-yellow connection with the PV Charge Controller wiring.

3. Prepare and install a short black 12 AWG jumper wire to run between the top-inside left terminal on the PV panel connection block and the lower-inside left terminal of the PV Charge Controller connection block. (This jumper may also be combined with the black parallel PV panel jumper from the previous procedure).

4. Crimp fork lug connectors to the red and black wires and secure them under the two, right-most connection points on the lower row of the PV Charge Controller connection block, as illustrated in Figure 6-13. (The colors should match the PV Charge Controller wiring).

5. Set the digital hand held multimeter to the 20-volt DCV setting.

6. Attach the red and black meter leads to the left-most connection points (Solar-In Connections) on the upper row of the PV Charge Controller connection block so that they connect with a red to yellow and black to black color scheme.

7. Plug in the adjustable light source and position it approximately 3 feet away from the panel, focused directly on the center of the upper PV panel.

8. Turn the lamp **On** and adjust the variable light to its **full-on** setting. Observe the reading on the digital multimeter. Record the reading from the meter on the following line:

________________(Volts)

9. Move the red and black meter leads to the right-most connection points on the lower row of the PV Charge Controller connection block so that they connect with the wires of the same color. Verify this connection against the one depicted in Figure 6-14.

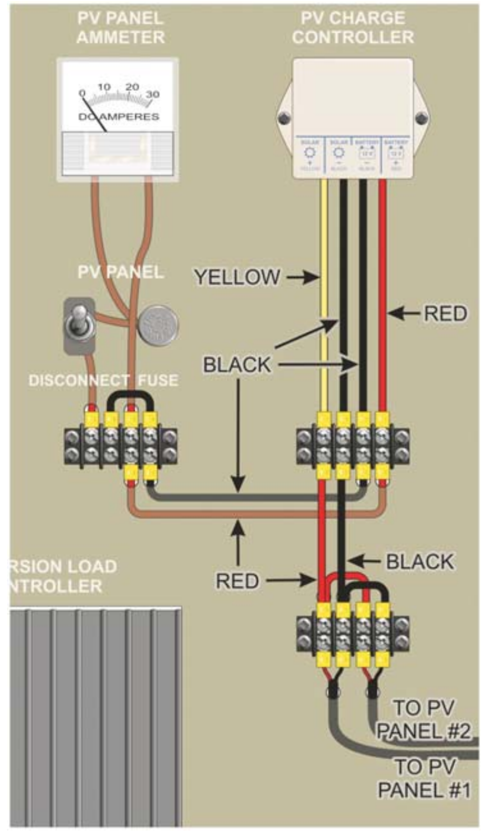


Figure 6-13: PV Charge Controller Wiring

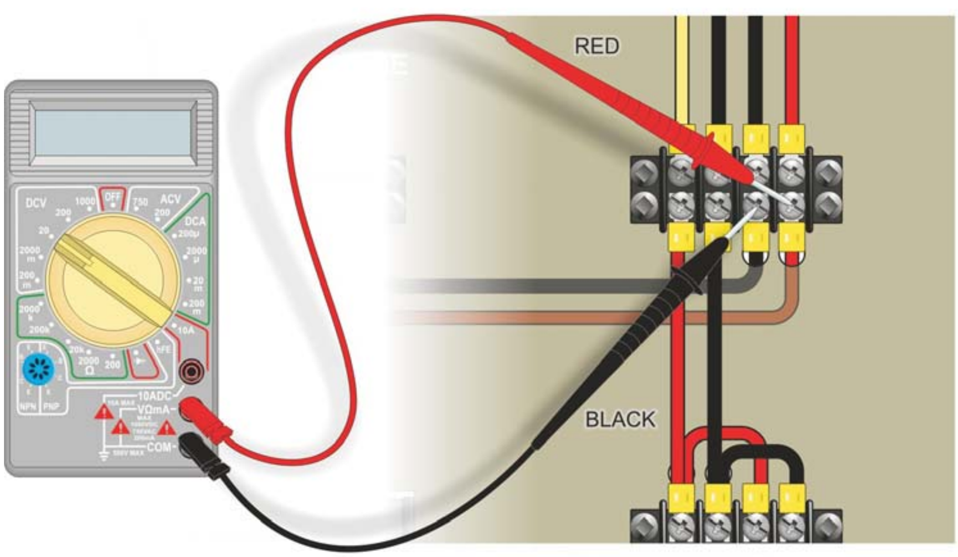


Figure 6-14: Attaching the Meter for Testing

10. Observe the reading on the digital multimeter. Record the reading from the meter on the following line:

________________(Volts)

11. Remove the meter leads from the panel and thread the free ends of the previously disconnected black and red wires from the PV Panel connection block through the two openings below the PV Charge Controller connection block.

12. Secure the wires to the lower right connection points on the PV Charge Controller connection block.

13. Turn the lamp on again and adjust the variable light to its full-on setting. Observe the reading on the digital multimeter. Record the reading from the meter on the following line:

    ________________(Volts)

Solar

Connecting the PV Array Directly to the Storage System

With the Solar Charge controller in place it is safe to connect the PV array to the storage batteries. This circuitry will prevent the PV array from overcharging the external batteries.

Grounding is another important part of any electrical installation. In this procedure you will be making **equipment ground** connections for the different pieces of support equipment. This type of ground is created to provide a common reference point for all of the electrical components and provide protection to personnel that might come into contact with the components in the event of a short circuit.

If the PV array installation were being made in the field, you would also need to create an **Earth Ground** connection to protect the system from environmental electrical discharges (lightning). This is dome by creating a ground path between all the devices and a copper rod placed in the ground.

1. Crimp a fork lug connector to a 12 AWG green wire and route it from the Diversion Load Controller's grounding lug to the ground terminal of the Inverter. Attach a crimp-on fork lug connector for this connection.

2. This provides the complete ground circuit for the Marcraft PV array charging system, as shown in Figure 6-15. Check with your instructor to make sure that your system is properly grounded before proceeding.

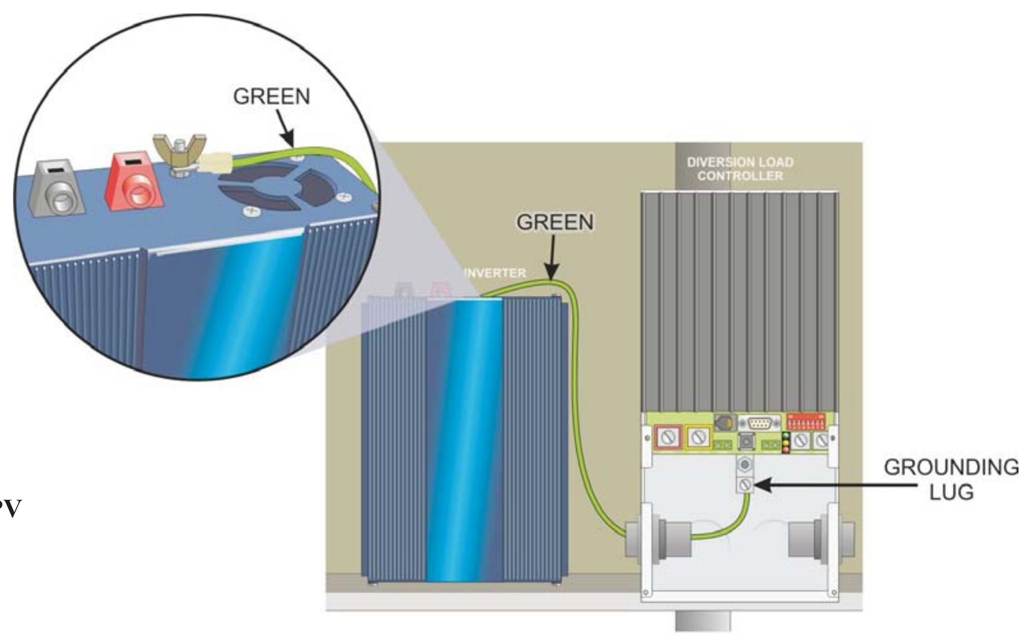


Figure 6-15: The PV Array's Complete Ground Circuit

3. Prepare a red and a black 12 AWG wire long enough to reach from the battery's external connections to the PV Control Panel connection block.

CAUTION

Do NOT connect the wires to the battery or the terminal block at this point. IF THE WIRES ARE HOOKED-UP BACKWARDS YOU WILL DAMAGE THE PV ARRAY'S PANELS. (If you are uncertain of the polarity of the wires, simply measure the voltage direction with the multimeter).

4. Crimp a fork lug connector to the red and black wires and secure them to the two, left most connection points on the bottom row of the PV Control Panel connection block, as illustrated in Figure 6-16. The color of each wire should match the wiring on the opposite side of the terminal block (red on the far left and black on the inside left). Do not connect the wires to the battery wires at this point. Be sure to crimp the connections using the appropriate sized connectors.

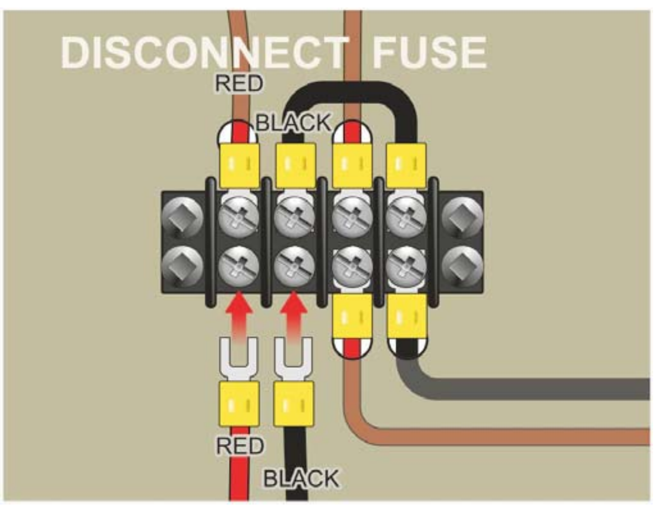


Figure 6-16: Preparing the PV Array's Battery Cables

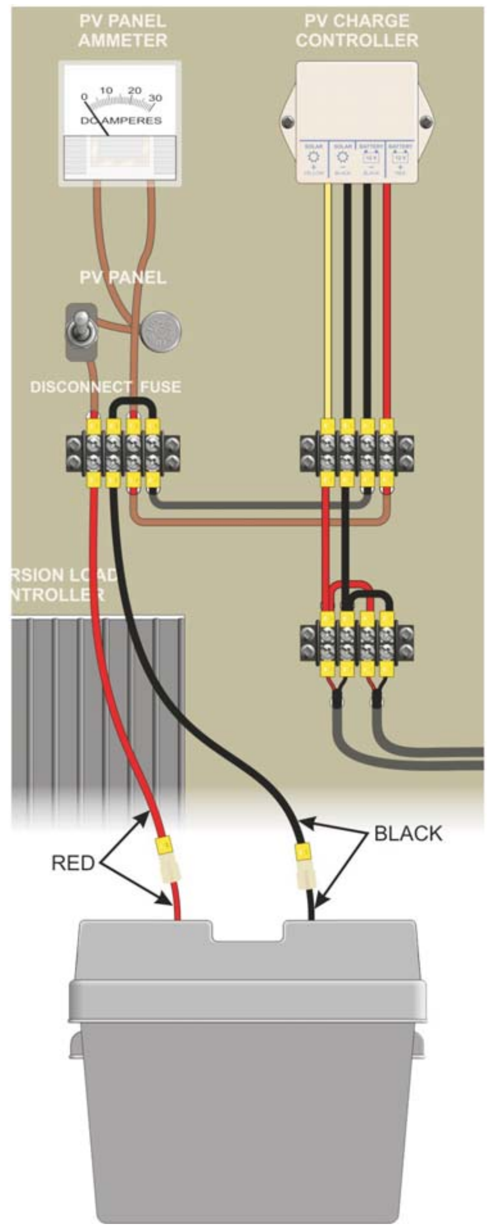


Figure 6-17: The PV Array's Battery Connections

5. Before attaching the PV array's wiring to the battery leads, make sure that:

- All Disconnect Switches on the panel are in the **Off** position
- The fuse is removed from the Fuel Cell fuse holder.
- The Wind Turbine's Stop Switch is in the **Stop** position.

6. Crimp male bullet connectors to the open ends of the red and black wires.

7. Attach the wires to the battery leads – Red wire to positive – Black wire to negative, as shown in Figure 6-17.

8. Set the multimeter to measure up to 20 VDC.

9. Connect the multimeter's leads to the PV array's charging leads at the lower left terminal of the PV Control Panel connection block, as illustrated in Figure 6-18.

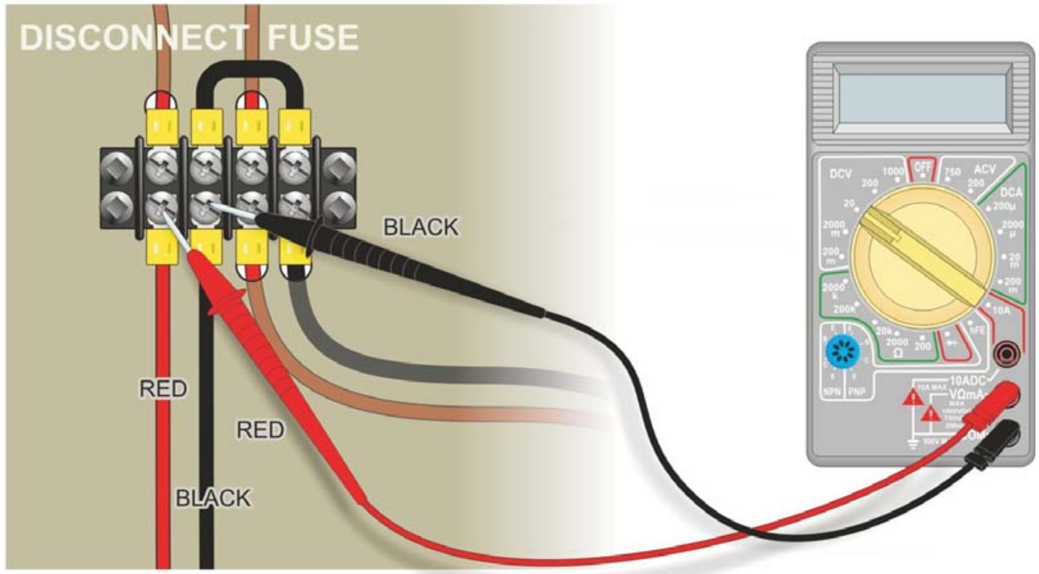


Figure 6-18: Monitoring the PV Array's Charging Voltage

10. On the following line, record the voltage level being measured with no input from the PV array: (The PV Panel Disconnect Switch prevents current from the PV array from flowing into the charging system so this reading represents the current battery voltage)

Battery Voltage ______________________

11. Move the PV Array's Disconnect Switch to the **On** position.

12. Turn the lamp **On** and adjust the variable light to its full-on setting while observing the PV array's ammeter and the hand-held multimeter. Record both values on the following lines:

Voltage (multimeter reading) ___________

Current (Ammeter reading) ___________

NOTE: If the meter does not produce a reading when the PV array is connected to a battery and the switch is closed, check the following items:

- *Verify all switch settings.*
- *Check all wiring between the PV array's output and the battery bank.*
- *Check to make sure there are no electrical short circuits in the system.*
- *Check the output of the PV Charge Controller to make sure it is passing the output from the PV array to the charging circuitry—this will not occur if the battery voltage is at (or above) the rated cut out voltage of the controller.*

13. Turn the variable light source **Off**.

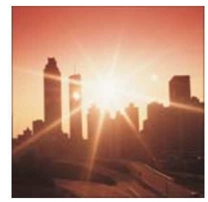
14. Move the PV array's Disconnect Switch to the **Off** position.

15. Unplug the red and black wires from the battery extension wires.

16. Remove the red and black wires from the left-most terminals on the bottom row of the PV Control Panel connection block and set them aside.

External Voltage Regulator/Load Diverter Operation

The Marcraft Green Electron Generation panel also includes a **diversion style regulator** (also known as a **Load Diverter**) that can be used to control the charging of the storage battery system. With the external load diverter controlling the charging system, the PV array will continue to produce output from light because the load diverter redirects the power to an external load such as a water heater. This allows the system to use the full output of the PV array even when the battery storage system is full. On the Marcraft training panel, a red 12VDC light represents this load. When the batteries are fully charged, the load diverter will redirect the generated power to the light.



Solar

Connecting the Load Diverter/Regulator

1. Obtain the Load Diverter's documentation information on the lines provided:

a. DIP Switch Settings

For 12V operation _______________

For Pulse Width Modulation (PWM) mode operation ____________

For charging a Type 3 battery ________________

b. State of Charge Indicator Lights

Red = On ___________

Yellow/Red = On ___________

Yellow = On ____________

Green = On _____________

c. Fault and Alarm Lights

Red/Green – Yellow ___________

Red/Yellow – Green ___________

No LEDs lit ________________

2. Prepare a red and a black 12 AWG wire long enough to reach from the wind turbine's terminal connection block to the positive and negative input terminals in the Diversion Load Controller's connection bay.

CAUTION

Do NOT connect the wires to the Diversion Load Controller or the terminal block at this point. IF THE WIRES ARE CONNECTED BACKWARDS YOU WILL DAMAGE THE PV PANELS OR ITS SUPPORT CIRCUITRY.

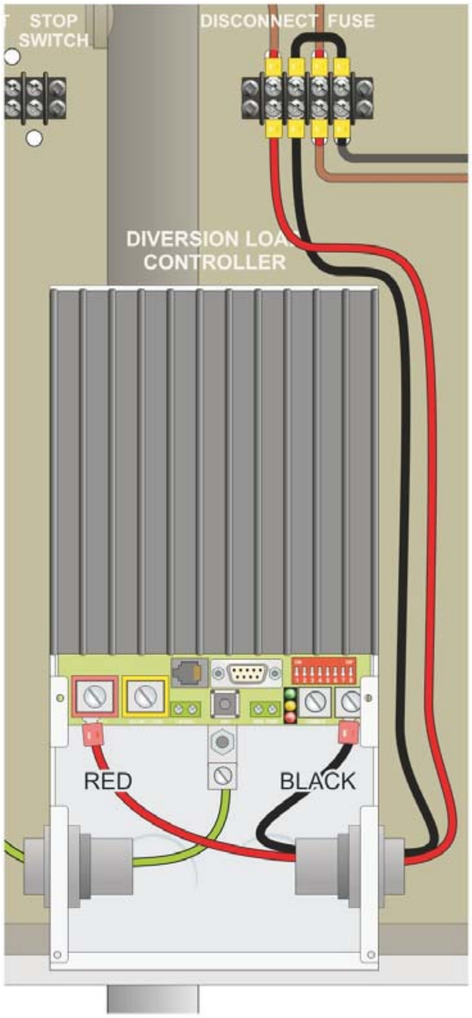


Figure 6-19: Preparing the PV Array/Load Diverter Connection Cables

3. Crimp fork lug connectors to the red and black wires and secure them to the two, left most connection points on the bottom row of the PV array terminal block as illustrated in Figure 6-19. The color of each wire should match the wiring on the opposite side of the terminal block (red on the far left and black on the inside left). Do not connect wires to the battery wires at this point. Be sure to crimp the connections using the appropriate sized connectors.

4. Route the red and black wires into the Diversion Load Controller's connection bay (through the connector in the side of the housing).

5. Insert the red wire into the Diversion Load Controller's positive lug and tighten the screw down connector until the connection is secure.

6. Insert the back wire into the neutral lug and tighten the screw down connector until the connection is secure. Figure 6-20 shows the connections between the PV array's terminal block and the Diversion Load Controller.

7. Prepare a red and a black 12 AWG wire long enough to reach from the battery's external connections to the Diversion Load Controller's connection bay.

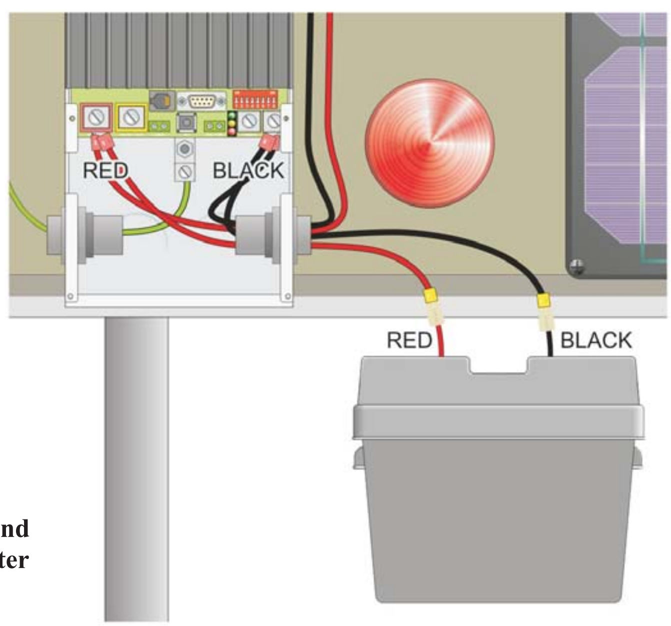


Figure 6-20: The Wind Turbine/Load Diverter Connections

8. Crimp male bullet connectors one end of the red and black wires. Do not connect the wires to the battery wires at this point.

9. Route the free ends of the red and black wires into the Diversion Load Controller's connection bay (through the opening in the side of the housing).

10. Loosen the positive screw down terminal and insert the red wire into the Diversion Load Controller's positive lug. Then tighten the screw down connector until both wires are securely in the lug.

11. Loosen the negative screw down terminal and insert the back wire into the neutral lug and tighten the screw down connector until both wires are securely clamped in the lug.

12. Before attaching the Load Diverter's wiring to the battery leads, make sure that:

- All Disconnect Switches on the panel are in the **Off** position
- The Stop Switch is in the **Stop** or shorted position.
- The fuse has been removed from the Fuel Cell fuse holder.

13. Attach the Load Diverter's red and black wires to the battery leads—red wire to positive and black wire to negative, as shown in Figure 6-21.

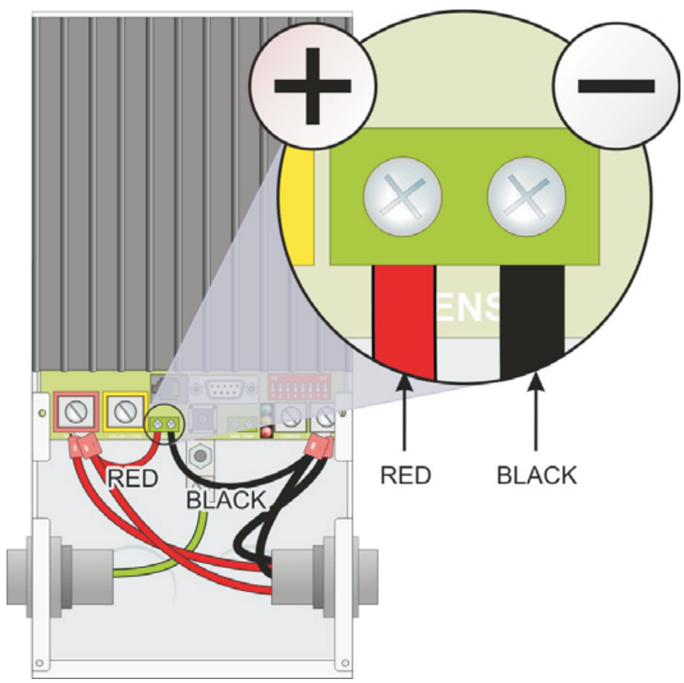


Figure 6-21: The PV Array's Load Diverter/Battery Connections

14. Attach two 12 AWG wires from the Load Diverter's Sense lines to the battery terminals as illustrated in Figure 6-22.

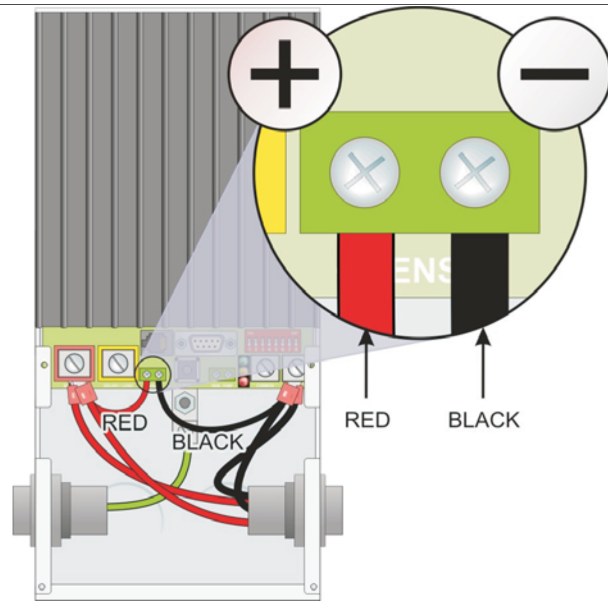


Figure 6-22:
The Load Diverter
Sensing Connections

15. Set the multimeter to measure up to 20 VDC.

16. Connect the multimeter's leads to the PV array's charging leads at the PV Control Panel connection block.

17. Record the voltage level being measured with no input from the PV array on the following line. This reading represents the current battery voltage:

    Initial Battery Voltage ________________________

18. Move the PV array's Disconnect Switch to the **On** position.

19. Use the variable light source to illuminate the panels while observing the PV array's ammeter and the multimeter.

20. Start slowing and steadily increase the intensity of the light while observing the measurement on the PV array's ammeter and the multimeter display. Record both values on the following lines:

    Voltage (multimeter reading) ___________

    Current (Ammeter reading) ___________

21. Continue charging the batteries until the light operating as the "external load" comes on. On the following lines, record the voltage and current levels from the meters when this first occurs:

    Diverted Voltage Point (multimeter reading) ___________

    Diverted Current Flow (Ammeter reading) ___________

22. Turn the variable light source **Off** and continue to monitor the voltage level on the multimeter display.

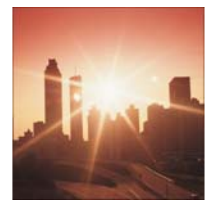
23. Record the level at which the Load Diverter switches power away from the external load light on the following line:

External Load Drop Out Voltage ___________________

> **CAUTION**
>
> Do NOT apply a short circuit across the batteries as THIS WILL CAUSE AN UNSAFE OVERLOAD CONDITION THAT MAY DAMAGE THE BATTERIES, START A FIRE, OR CAUSE THE BATTERIES TO EXPLODE.

24. Move the PV array's Disconnect Switch to the **Off** position.

GENERATING AC OUTPUT



Solar

The Marcraft Green Electron Generation panel includes an Off-Grid type inverter for generating power to run residential AC devices. This converted accepts direct current input and produces a 120VAC, 60 Hz (**Hertz** or *cycles per second*) output. The conversion occurs in two steps. First the incoming DC battery voltage is converted into a high DC voltage using high-frequency **pulse width modulation** (**PWM**) switching techniques. The high voltage signal is then applied to another PWM circuit to produce the 120VAC, 60 Hz output voltage.

The inverter can continue to produce this output as long as the input voltage stays between 10.5VDC and 16.5VDC. The length of time different batteries can apply this level of power to the inverter depends on it **amp/hour** (**AH**) rating and the current load placed upon it. The battery industry uses 20 hours and 80^{o}F as the benchmarks for rating batteries. This rating also indicates that the output of the battery is only useful until it falls off to 87.5% of its stated value (10.5V for a 12VDC system such as this trainer).

When two or more batteries are connected in parallel, as they are in this procedure, their voltages remain the same but their current capacities add together. Therefore, the AH rating for the battery pack, is equal to the sum of all the batteries in the pack added together.

1. Obtain the Inverter's documentation—locate and record the following information on the lines provided:

Model Number ________________

Input Voltage Range ______________

Output Voltage _______________

Low Input Voltage Shut Down ___________________

High Input Voltage Shut Down ___________________

2. Obtain the AH rating for the batteries being used in your trainer. Calculate and record the AH rating being applied to the inverter (when the batteries are charged within their stated operational range) on the following lines:

Stated AH rating of a single battery ______________

Total AH rating _______________

3. Prepare a red and a black 12 AWG wire long enough to reach from the inverter's positive and negative terminals to the positive and negative input terminals in the Diversion Load Controller's connection bay.

4. Plug in the red and black wires and secure them in the inverter's positive and negative connection terminals, as illustrated in Figure 6-23.

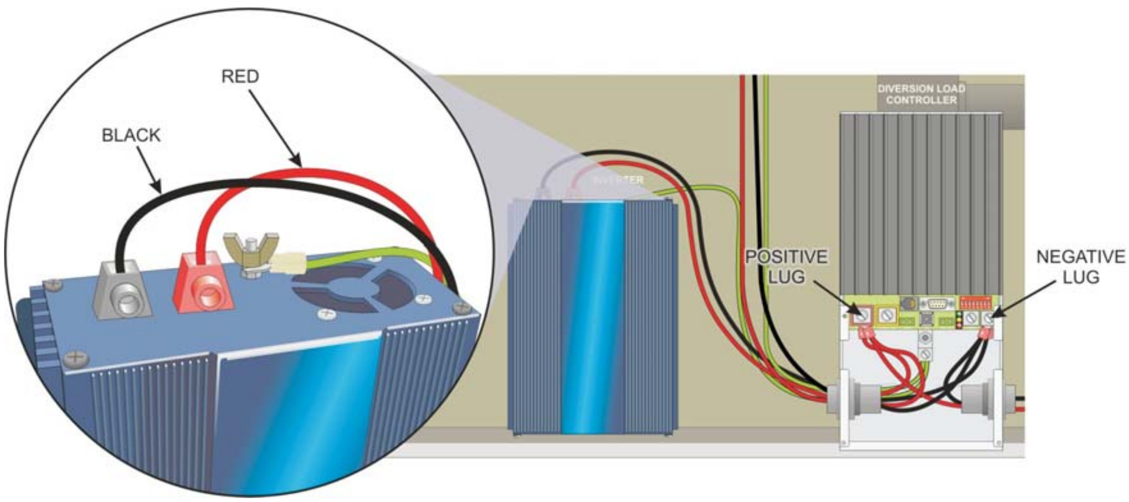


Figure 6-23: Inverter Connections

5. Route the red and black wires into the Diversion Load Controller's connection bay (through the connector in the side of the housing).

6. Loosen the positive screw down terminal and insert the red wire into the Diversion Load Controller's positive lug. Then tighten the screw down connector until all three wires are securely fastened in the lug.

7. Loosen the negative screw down terminal and insert the back wire into the neutral lug and then tighten the terminal screw until all three wires are securely fastened in the lug.

8. Plug a 120VAC, 60Watt lamp in the inverter's AC output connector and turn the lamp **On**.

9. Turn the Inverter **On** by pressing the rocker switch on its front panel.

10. The voltage displayed on the multmeter should steadily decrease until it reaches the stated operating voltage of the battery. Measure the amount of time it takes between turning on the inverter and when the reading on the meter stops falling. Record this time on the following line:

________________ minutes

11. Record the meter reading where the inverter's output leveled out on the following line:

    ________________ volts

12. Move the PV array's Disconnect Switch to the **Run** position.

13. Use the variable light source to illuminate the PV panels while observing its ammeter and the multimeter.

14. Start slowing and steadily increase the intensity of the light source until the ammeter shows a current flow and the voltage reading on the multimeter increases by 0.4 volts above its steady output voltage obtained earlier in this procedure.

15. While observing the measurement on the PV array's ammeter and the multimeter display, decrease the light source's intensity to determine when the battery voltage has increased by 0.2 volts without needing additional input from the PV array.

16. Continue to use the PV array to charge the storage battery bank until it holds the 0.2 volt increase. On the following line, record the approximate amount of time required for the PV array to produce this additional charge in the battery:

    ____

17. On the following lines, record both the PV array's current flow and voltage levels required to produce this increase:

    Approximate PV array Voltage (multimeter reading) ___________

    Approximate PV array Current (Ammeter reading) ___________

18. Turn the variable light source **Off**.

19. Move the PV array Disconnect Switch to the **Off** position.

20. This concludes the hands on lab procedure for Off-Grid Photovoltaic Power Systems. Have your instructor review your results before moving on to the next procedure.

LAB QUESTIONS

Feedback

1. What conditions can cause a PV Charge Controller to produce a 0-volt output? (Provide two answers.)
2. Why should the voltage produced by the PV array be higher than the voltage displayed by the battery?
3. What are the consequences of connecting the PV array's power leads incorrectly to the battery bank?
4. Using the information about the batteries that make up your battery bank, what current output level should it take to reduce the battery voltage to 10.5 VDC in 20 hours?
5. In an actual PV array installation would both types of charge controller be needed for safe operation of the system?