Product Operation Overview

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Introduction

The following document provides an overview of the product *Solar Conductor*. A comparison section explains the difference between hot water heating with photovoltaic panels versus the commonly used solar hot water collectors.

A summary is provided for the three typical setups; Standalone System, Inverter System (grid-tied), Charger Based System (off-grid). This is followed by a summary for the three typical setups with a hot water storage tank, which can used with any of the systems used.

A guide for selecting the correct size heating element is also included.

See the document "User's Guide for Installation and Operation," for additional information.

The *Solar Conductor* can also be used in other applications such as forced hot water heat. However, the setup for this is beyond the intended scope of this document. Contact us for more information in regards to other uses with the *Solar Conductor*.

The Solar Conductor

The *Solar Conductor* is a solar direct product. This means it is powered directly from photovoltaic (PV) solar panels. It does not require any other power source to operate. The *Solar Conductor* functionality is similar to a on-demand hot water heater and a programmable thermostat.

The *Solar Conductor* is to be used with resistive type heating elements to provide heat and hot water. A resistive type heating element is typically found in heating appliances such as an electric hot water heater.

Traditionally solar panels need an inverter to convert solar power, which is similar to a battery in the form of direct current (DC), to the type of power a household uses, alternating current (AC). Most high power heating appliances such as electric hot water heaters require large and expensive inverters to operate making solar hot water with photovoltaic panels financially impractical. There is also the issue of limited solar power due to weather. The *Solar Conductor* overcomes these problems by allowing easy integration with existing heating appliances to allow the existing power, whether AC grid-tied power or other source, to work with the *Solar Conductor* allowing solar power to be used when it is available and the existing power source to be used when solar power is not available.

All solar panels have varying peak power based on the amount of sunlight and temperature, which is continuously changing throughout each day. The *Solar Conductor* performs maximum power tracking with solar panels by varying the amount of power delivered to the heating element to achieve maximum power draw from the solar panels. The result is an affordable, efficient and simple way to provide heat and hot water using just photovoltaic panels and the *Solar Conductor*.

Difference Between PV Hot Water and Solar Collectors

Solar hot water collectors have water heated directly by the Sun. The water is then pumped inside the residence to be stored and used. Typically antifreeze is used and a heat exchanger is required when using the solar hot water for domestic hot water purposes. Antifreeze is used to prevent freezing and to also prevent the fluid from boiling since the temperatures can exceed the boiling point of water.

This is a very good system and the efficiency of solar hot water panels is much higher than the efficiency of photovoltaic panels. However, with the cost of photovoltaic panels continuously dropping each year and the efficiency also increasing, the benefits of PV hot water outweighs traditional hot water collectors.

Traditional solar hot water requires a pump, power to run the pump, antifreeze and a heat exchanger. The fluid has to be checked and the heat exchanger may require cleaning to maintain optimal heat transfer. Installation is more expensive and complicated than PV panels because of the insulated pipes that have to be installed between the hot water collector and the storage tank.

In addition to installation, maintenance and the need of a mechanical pump which will almost always be the first part of the system to fail, there is a very important difference between hot water collectors and PV hot water. With solar hot water collectors, the maximum temperature is limited to the amount of Sun exposure. With photovoltaic panels, this limitation does not exist. Instead the quantity of hot water is limited by the amount of Sun exposure. For example, at the end of a cloudy day a solar hot water panel may have produced 40 gallons of warm water and the photovoltaic panel may have produced 10 gallons of hot water. The PV system allows the user to set the temperature, which in turn determines the quantity based on the Sun exposure.

The last notable difference is the effect on the two types of systems from the air temperature. In a cold climate the hot water collectors have to overcome the initial cold temperatures each morning before hot water can be produced. With photovoltaic panels, the colder the environment is higher the efficiency.

System Types

The different system configurations are described below.

Standalone System

The Standalone System includes the photovoltaic panels, the *Solar Conductor* and a hot water storage tank. The photovoltaic panels are dedicated for the *Solar Conductor*. The water is heated to the user desired temperature. When heating is done, the system remains idle until the water temperature has dropped enough to turn back on.

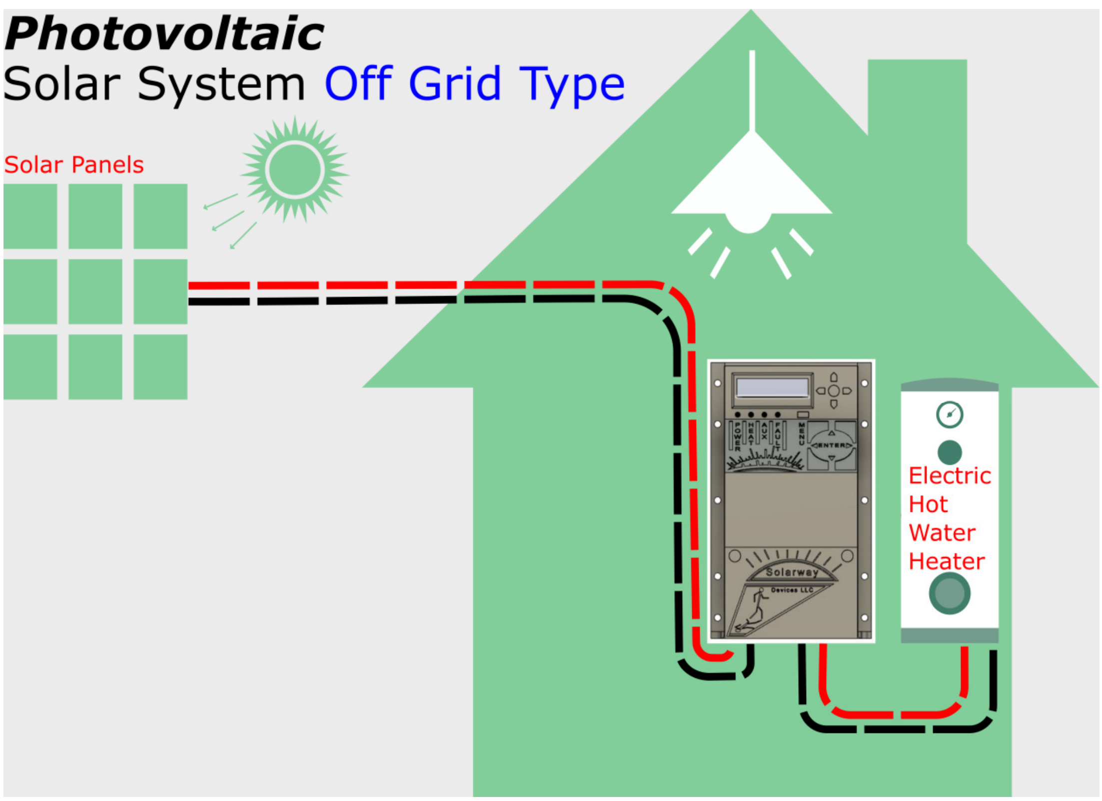

Figure 1 Standalone System

Inverter Based System (grid-tied)

The Inverter Based System includes the photovoltaic panels, the *Solar Conductor,* a grid-tied inverter and a hot water storage tank. The water is heated to the user desired temperature. When heating is done, the solar power is diverted from the *Solar Conductor* to the inverter. When the water temperature has dropped enough the Solar Conductor removes power to the inverter and resumes heating.

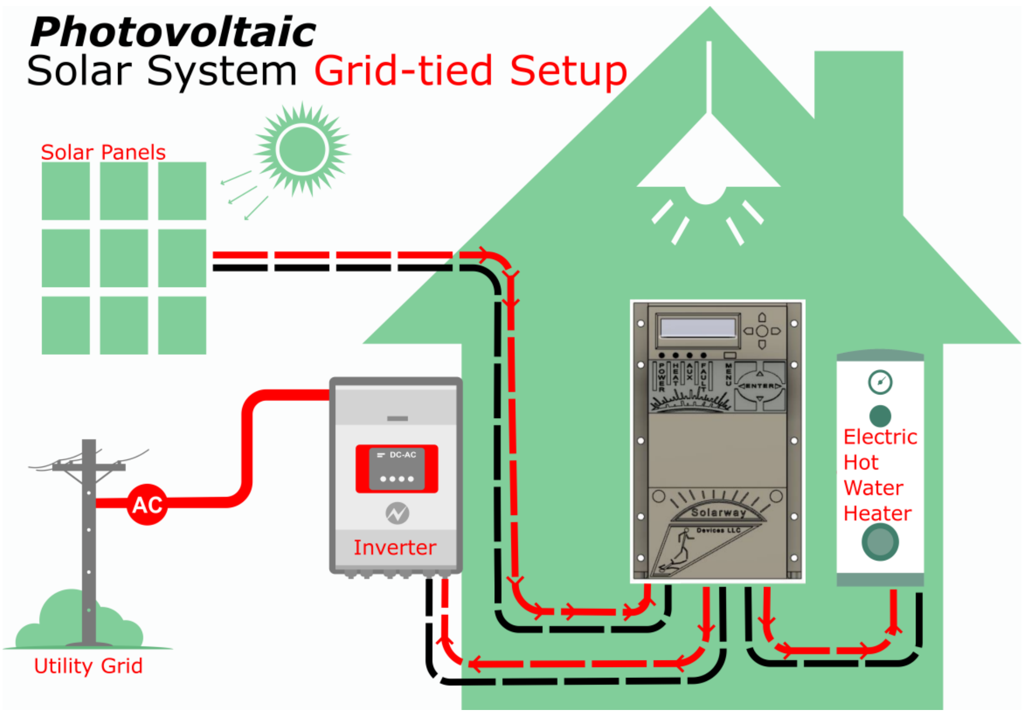

Figure 2 Inverter Based System (grid-tied)

Charger Based System (off-grid)

The Charger Based System includes the photovoltaic panels, the *Solar Conductor,* a MPPT charger with battery bank and a hot water storage tank. The water is heated to the user desired temperature. When operating in parallel with a charger, the *Solar Conductor* will determine if there is power available and if so will use it with the heating element. It allows the charger to remain as the top priority for power usage from the solar panels and will only take what is left over.

As soon as a MPPT charger exits bulk mode (constant current mode), there is unused power available from the PV panels.

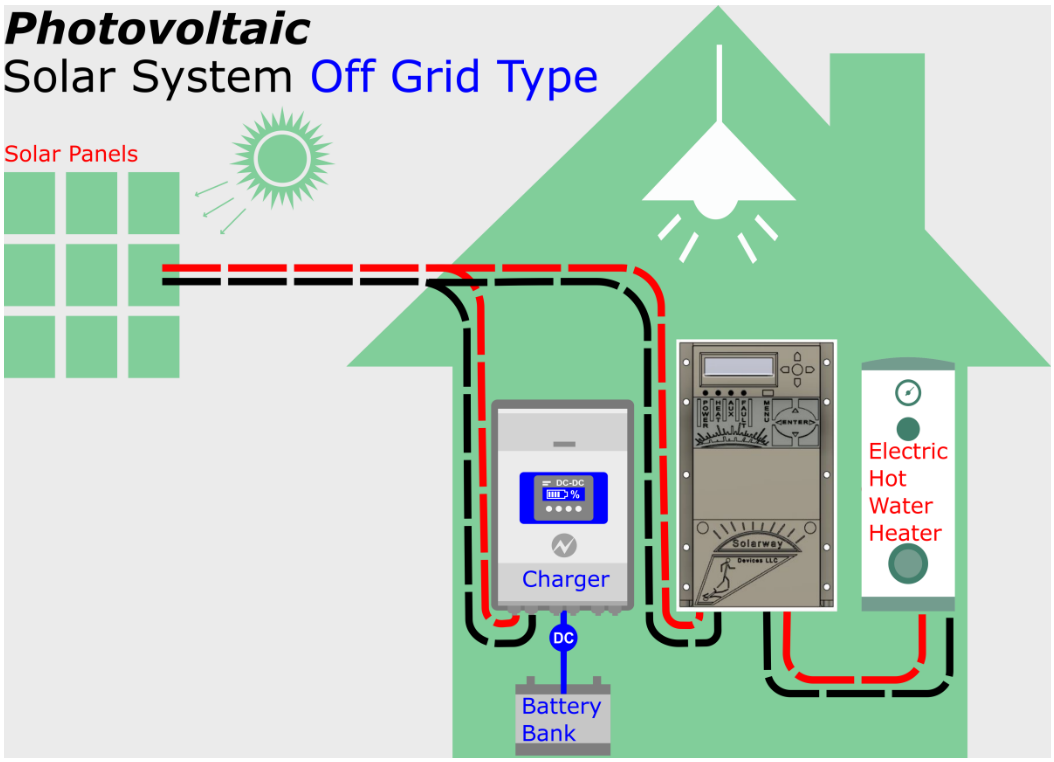

Figure 3 Charger Based System (off-grid)

Hot water tank setup

Three different hot water setups are discussed below. The tank setups are compatible with any of the systems previously described.

Hybrid Tank Setup:

This setup is with dual element hot water heaters. The upper element is used with AC power and the lower element is used with photovoltaic power. The *Solar Conductor* temperature should be set to a temperature 20-30F higher than the upper element thermostat, which will allow as much of the heat as possible to come from the solar panels. This setup guarantees hot water is available no matter the weather conditions, while allowing solar power to contribute to the existing setup.

- ***Pros:*** Solar power works alongside AC power to heat the water in the tank. Hot water is available on cloudy days. Cost effective and easy to integrate with existing electric hot water tanks.
- ***Cons:*** AC power only heats the upper section of the tank resulting in a lower quantity of hot water on cloudy days.

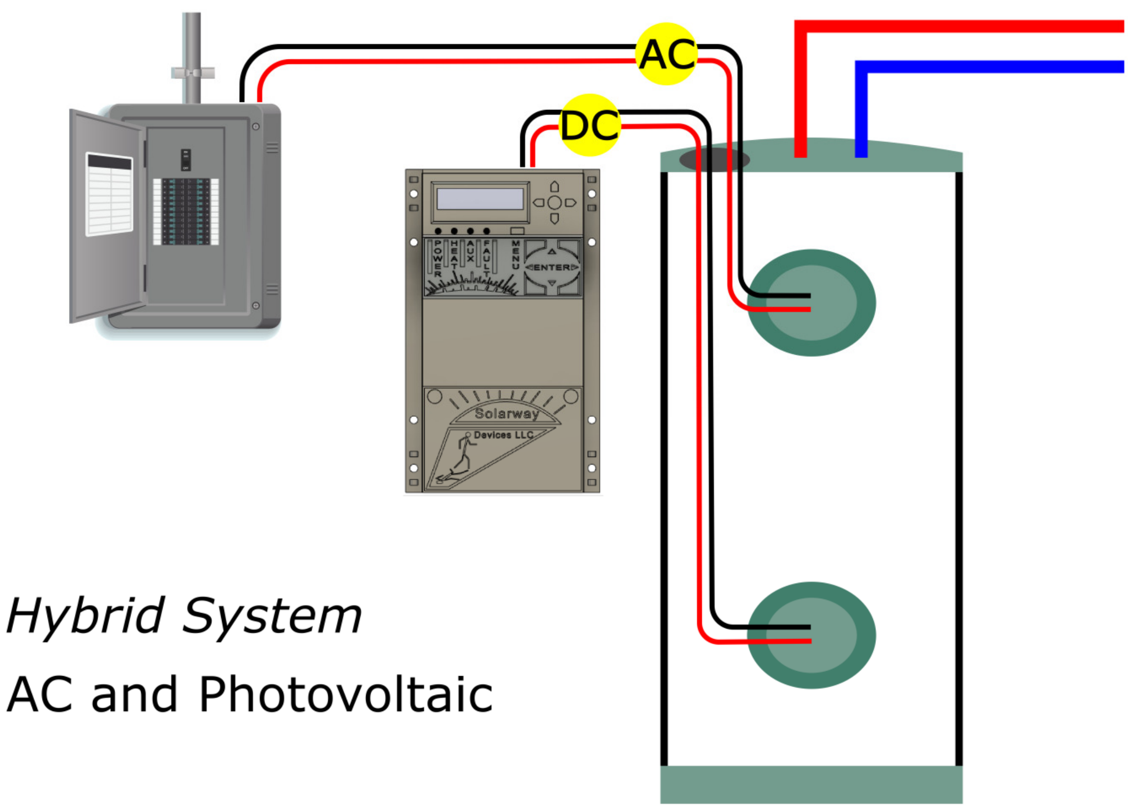

Figure 4 Hybrid Tank Setup

Dedicated Tank Setup:

This setup uses the hot water heater exclusively with photovoltaic power. This is for a single or dual element tank. For a dual element configuration, the elements can be wired in parallel to the *Solar Conductor*.

- ***Pros:*** All hot water is from solar power.
- ***Cons:*** The amount of hot water is weather dependant.

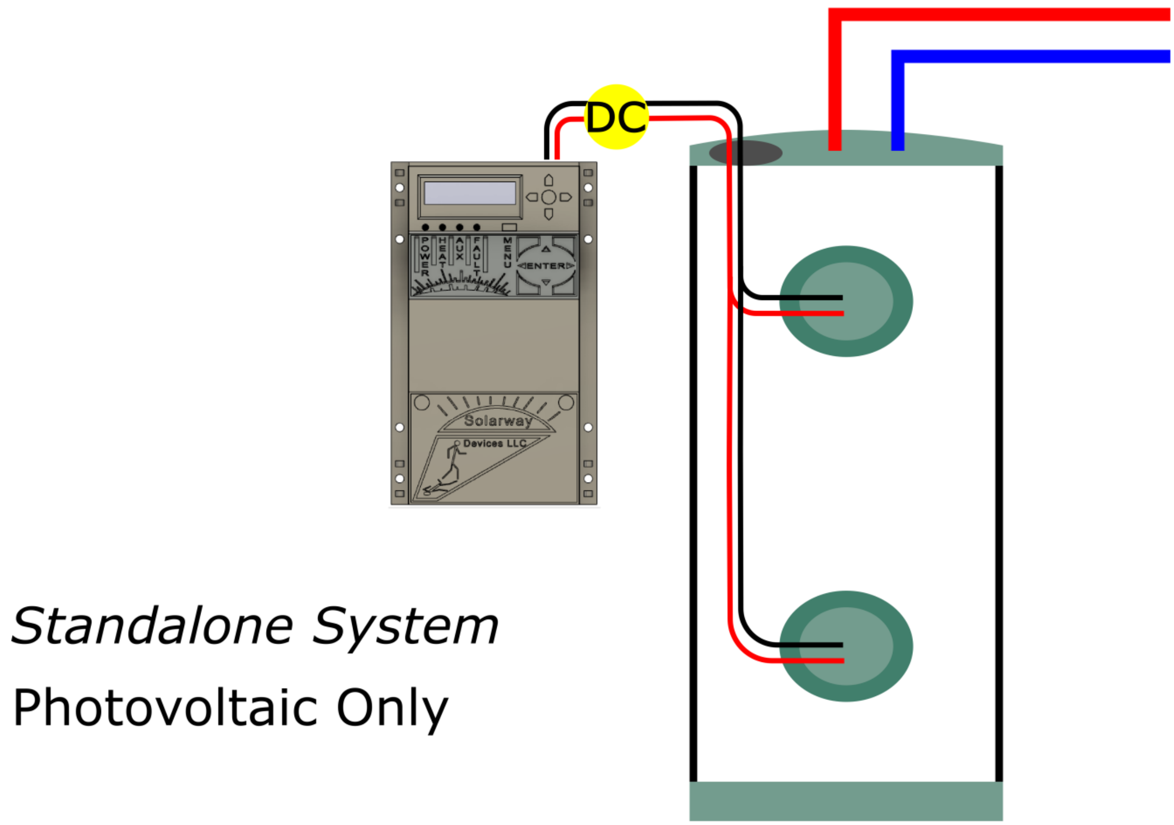

Figure 5 Standalone Tank Setup

Dual Tank Setup:

This setup uses a dedicated tank for photovoltaic power and a second tank which can be electric or gas. The second tank can also be an on-demand hot water heater. The photovoltaic tank acts as a pre-warming tank. This is the best of both worlds.

- ***Pros:*** Large quantity of hot water available using solar power as the primary power source. Overcomes the issue of limited hot water on cloudy days that exists in the Hybrid Tank Setup.
- ***Cons:*** Due to two heating units this setup requires the most space and cost.

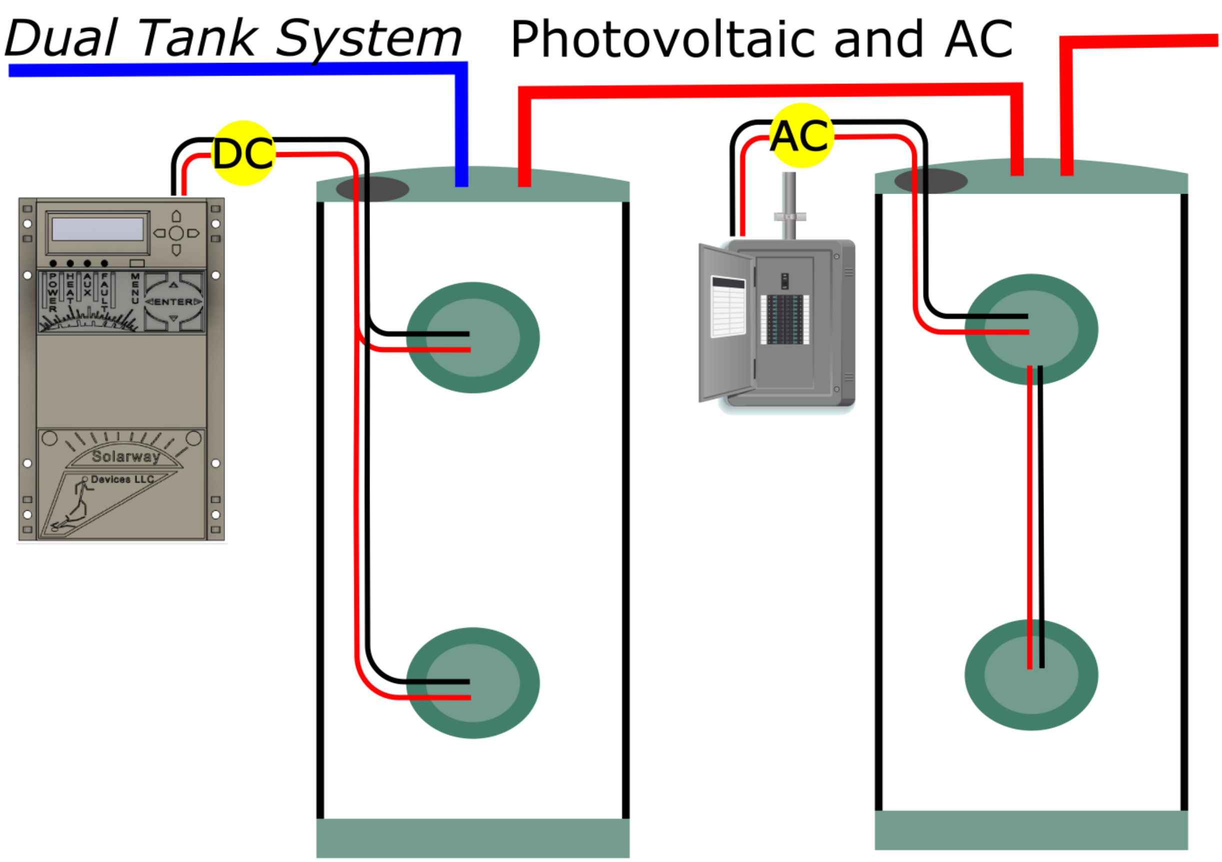

Figure 6 Dual Tank Setup

Element Sizing Guide

The acceptable size of the heating element is based on the power from the PV panels along with the operating limits of the *Solar Conductor* in terms of voltage and current. The following steps explain how to properly size a resistive heating element for PV power with the *Solar Conductor*.

<u>Step 1: Verify Element Voltage Rating</u>

The voltage rating of the element is typically in terms of AC voltage. To verify it is safe to use with solar power (DC voltage), convert the AC voltage to a peak voltage so it can be compared to the solar panel voltage. To do this, use the following equation.

Equation 1: $Vpeak = Vac * 1.414$

As long as the solar panel Voc is less than the element Vpeak, they should be compatible.

Safe Operating Voltage: $Voc <= Vpeak$

<u>Step 2: Determine the Maximum Power for the Element with Solar Power</u>

To convert from the original power rating of the element to the power rating while operating with solar power use the following equation.

Equation 2: $Psolar = \frac{Pac}{Vac*Vac} * (Vmpp * Vmpp)$

This will show what the expected power with FULL SUN for the element with the solar panels. The power used by the element with solar panels should be more than the power rating of the element with AC power.

Safe Operating Power: $Psolar <= Pac$

<u>Step 3: Verify Voltage and Current Maximum Values does Not Exceed the *Solar Conductor* Limitations</u>

The maximum voltage is the Voc for the solar panels.

The maximum current with the element can be calculated with the following equation.

Equation 3: $Imax[element] = \frac{Psolar}{Vmpp}$

Safe Operating Limits: $Imax[element] < Imax[Solar\ Conductor]$

$Voc < Vmax[Solar\ Conductor]$

(see Operating Specification Table from User's Guide for Installation and Operation for device values)

Example1: Solar Panel Array of 2000W, 110Voc, 100Vmpp, Element of 4500W and 240Vac

$Vpeak = 240 * 1.414 = 339.36V$ (acceptable: 110Voc less than 339.36V)

$Psolar = \frac{4500}{240*240} * (100 * 100) = 781.25\ watts$ (acceptable:781.25W less than 4500W)

$Imax = \frac{781.25}{100} = 7.8125\ amps$ (acceptable: 7.8125A less than 20A and 110Voc less than 200V)

Note: For a solar panel array of 2000W, two of these elements can be used in parallel without exceeding the power rating of the elements of the *Solar Conductor*.

Example2: Solar Panel Array of 1000W, 160Voc, 150Vmpp, Element of 1500W and 120Vac

$Vpeak = 120 * 1.414 = 169.68V$ (acceptable: 160Voc less than 169.68V)

$Psolar = \frac{1500}{120*120} * (150 * 150) = 2343.75\ watts$ (2343.75W exceeds the element power rating of 1200W, but it is acceptable because the solar panels are limited to 1000W, which is less than the element power rating of 1200W)

$Imax = \frac{1000}{150} = 6.67\ amps.$ (acceptable: 6.67A less than 20A and 160Voc less than 200V)

Note: Typically an element will not be compatible if Vmpp is greater than Vac of the element, but there are exceptions as shown in this example.

Glossary

AC Alternating current. This is used by households connected to the grid.

DC Direct current. This is used by solar panels and batteries.

Impp Current maximum power point. The amount of current while the maximum power is drawn from the solar panels. This is found on the solar panel datasheet and is typically at a temperature of 25C.

Isc The amount of current in a short circuit condition. This is the maximum current possible from the solar panels. This is found on the solar panel datasheet and is typically at a temperature of 25C.

MPPT Maximum power point tracking.

PV Photovoltaic.

Vmpp Voltage maximum power point. The amount of voltage while the maximum power is drawn from the solar panels. This is found on the solar panel datasheet and is typically at a temperature of 25C.

Voc The amount of voltage in a open circuit condition. This is the maximum voltage possible from the solar panels, which is with no load connected. This is found on the solar panel datasheet and is typically at a temperature of 25C.