How to Use the Lake Pavilion Solar System

November 3, 2021

History of Our Lake Solar System

In November 2018, Climate Stewards of Greater Annapolis donated four large solar panels to our chapter in support of youth and Scout camping. The goal of the donation was to make our youth aware of the benefits of solar power and an opportunity for them to learn how it works. The gift came with strings: a requirement for a training program suitable for various ages. Tom Perazella worked with Girl Scout Troops 159 and 3577 to develop the training program. At the January IWLAR Board meeting, the Board approved up to $700 to install the system. The system became operational on June 1, 2019, and offered multiple USB outlets for phone and tablet charging, 12-volt power outlets, LED lighting with dimmers, and connections for a power inverter to offer 300-400 watt 110v AC output for any other use. We replaced the original solar panels on October 30, 2021, after the original panels stopped working.

How the System Works

Components of the System. Our solar system is comprised of:

- Four solar panels that generate direct current from the sun,
- A battery controller which regulates voltage to the battery and protects it from overheating, overcharging, depletion of power,
- A battery control display which gives a status of operation of the system,
- Two 12v batteries that store excess energy from the solar panels during the day for use during evening hours, and
- A power controller that permits users to use power from the solar system and the battery while it protects the circuits from overloads.
- A full sine wave power inverter that provides 110 volts AC power.

The Solar Panels. The four solar panels are Renogy model RNG-100D-SS 100W Monocrystalline Solar Panels. The panels were installed on October 30, 2021. They offer an optimum operating voltage of 17.9V and optimum operating current of 5.72 amps from each panel. Our system connects these four panels in parallel and therefore can deliver up to 17.9 volts at up to 22.88 amps (4 x 5.72 amps) to the battery controller. Panels are mounted on the roof of the lake pavilion (Figure 1.).

Figure 1. Solar Panels

The Battery Controller. The Tracer3215BN 30A battery controller is a critical component to our solar system and is designed to convert the DC voltage from the solar panels to a lower voltage for charging the battery and providing 12v power during the day. When the battery controller lowers the voltage, it increases the amperage proportionally, so if the solar panels can deliver 17.9 volts at 22.88 amps to the battery controller, this becomes 13.8 volts at 29.68 amps when charging the battery. Our controller uses the Maximum Power Point Tracking control algorithm, which can quickly and accurately track the best maximum power point of photovoltaic array. The manufacturer claims that the battery controller has a 99.5 percent efficiency rating.

The controller varies the charge rate based upon incoming voltage from the solar panels and the battery level. The controller has a three stages battery-charging algorithm (Bulk Charging, Constant Charging, and Float Charging) for rapid, efficient, and safe battery charging.

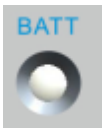
- **Bulk Charging.** In this stage, the battery voltage has not yet reached constant voltage (Equalize or Boost Voltage); the controller operates in constant current mode, delivering its maximum current to the batteries (MPPT Charging).
- **Constant Charging.** When the battery voltage reaches the constant voltage set point, the controller will start to operate in constant charging mode, this process is no longer MPPT charging, and in the meantime, the charging current will drop gradually, the process is not the MPPT charging. The Constant Charging has two stages, equalize and boost. These two stages are not carried out constantly in a full charge process to avoid too much gas precipitation or overheating of battery.

- **Boost Charging.** The Boost stage maintain 2 hours in default, user can adjust the constant time and preset value of boost voltage (14.4 volts) according to demand. The stage is used to prevent heating and excessive battery gassing.

The battery controller has a temperature sensor that can vary charging based on battery temperature. It has LED lights that can indicate its charging status and incurred faults.

Figure 2. The Tracer3215BN 30A Battery Controller used at the Lake

Interpreting LED Indications on Battery Controller

LED Indication	Color	Indicator	Status
	Green	On Solid	PV connection normal but low voltage (irradiance) from PV, no charging
	Green	Slowly Flashing(1Hz)	In charging
	Green	OFF	No PV voltage (night time) or PV connection problem
	Green	On Solid	Normal
	Green	Slowly Flashing(1Hz)	Full
	Green	Fast Flashing(4Hz)	Over voltage
	Orange	On Solid	Under voltage
	Red	On Solid	Over discharge
	Red	Flashing	Battery Overheating
Load Status LED indicator	Red	On Solid	Load ON
	Red	OFF	Load OFF
	Red	Fast Flashing(4Hz)	Load Short Circuit
	Red	Slowly Flashing(1Hz)	Load Overload
Charging (green), battery (orange) and load(red) indicator flashing simultaneously			System voltage error
Charging (green) and battery indicator(orange)flashing simultaneously			Controller overheating

Battery Voltage Parameters

Battery charging setting	Sealed	Gel	Flooded
Over Voltage Disconnect Voltage	16.0V	16.0V	16.0V
Charging Limit Voltage	15.0V	15.0V	15.0V
Over Voltage Reconnect Voltage	15.0V	15.0V	15.0V
Equalize Charging Voltage	14.6V	——	14.8V
Boost Charging Voltage	14.4V	14.2V	14.6V
Float Charging Voltage	13.8V	13.8V	13.8V
Boost Reconnect Charging Voltage	13.2V	13.2V	13.2V
Low Voltage Reconnect Voltage	12.6V	12.6V	12.6V
Under Voltage Warning Reconnect Voltage	12.2V	12.2V	12.2V
Under Volt. Warning Volt.	12.0V	12.0V	12.0V
Low Volt. Disconnect Volt.	11.1V	11.1V	11.1V
Discharging Limit Voltage	10.6V	10.6V	10.6V
Equalize Duration (min.)	120	——	120
Boost Duration (min.)	120	120	120

Battery Controller Display. The battery controller display provides a summary of operation of the battery controller and highlights any faults or problems with the system. There is a warning light above the display that will illuminate if there are any problems. At the top of display is a face icon. A smiling face indicates that the system is working well and has no problems. A face with angst means that the system is working but may be encountering a problem such as a low level of power on the battery. A frowning face indicates that there is a problem with the system.

Below the face icon and to the left is an icon indicating that the PVs are working or a moon icon indicating that the PVs are not generating power. The voltage and amps from the PVs are displayed below the icon. In the center of the display is a battery icon, which will indicate the charge level of the battery and the current voltage and amps to the battery. To the left of the display is a light bulb icon indicating the power load on the system. Below that icon will be volts and amps being used. These numbers may be misleading because some of the load may come directly from the battery and not through the battery controller.

Figure 3. The MT50 Charging Status Display

The Batteries. The solar system uses two 12-volt UB121100 sealed lead acid 110-amp-hour batteries. The solar panels, in conjunction with the battery controller, charge the batteries during daylight hours and the stored batteries power can then be used in the evening.

The Power Controller. The power controller permits the users to use the power generated by the solar system for lighting, 12-volt appliances, and charging phones and

tablets. The power controller has fuses, circuit breakers, relays, and diodes to protect the circuits and dimmers and timers to help control power usage.

Figure 4. Power Controller

The Power Inverter. The power inverter (Figure 5) converts the 12-volt battery power to full-sine wave 110 volt AC power. The inverter is a Renogy 700 watt inverter (model RNG-INVT-700-12V-P2-US) can provide up to 6.1 amps for 700W. Pure sine wave provides cleaner, smoother, and more reliable power. This gives users stable power to operate small tools, fans, lights, computers, and other electronics without any interference. Pure sine wave inverters are in many cases more efficient, allowing users to use less energy and allow for more device capability. The main advantage to pure sine wave inverters is that they are used to operate sensitive electronic devices that require a high quality waveform with little harmonic distortion. Almost any electronic device could be powered using a pure sine wave inverter The inverter has several safety

features including low voltage detection, high voltage detection, AC overload, and over temperature. It has excellent surge protection rating of two times the power rating. There is built-in ground fault circuit interrupt protection.

Figure 5. The Renogy Power Inverter

700W Inverter Specifications	
Input Voltage	12v DC
Output Voltage	115V AC
Peak surge	1400 watts
Efficiency	> 90%
Frequency	60Hz
Total harmonic distortion (THD)	< 3%
No load current draw	< 0.8 amps
Battery low alarm	10.5V ± 0.5V DC
Battery low shutdown	10.0V ± 0.5V DC
Over voltage shutdown	16.5V ± 0.5V DC
Cooling fan	Thermally controlled
Power output control	Remote AC On/Off Switch

Figure 6. The Renogy Remote Control to Power Inverter

Remote Control to the Inverter. The unit has a remote on/off switch (Figure 6) that shows the status of operation. The remote switch must be turned to ON position for the inverter to run. It has two LED lights to give the status of the inverter.

- Power LED (Green) — When this green LED is lit, the inverter is operating.
- GFCI LED (Yellow) — When the yellow LED is lit, the ground fault circuit has been interrupted. Shut down the inverter and restart.
- Fault LED (Red) — The red indicator turns on as the inverter shuts down due to overheating, overload, under voltage, or over voltage.

How to Use the System

Using Overhead Lights. Three strips of LED lighting attached to the pavilion rafters provide overhead lighting. To turn the lights on, users need to flip the main switch and the lighting switch (as shown on Figure 4). There are two dimmer controls that control the two strips of lighting running the length of the pavilion (Figure 5). A picture of the lighting is shown on Figure 6.

Figure 5. Light Dimmers

Figure 6. Overhead Lighting

The dimmed lights are on a timer set for two hours and will need to be reset when the two hours expires. There is a third LED lighting strip perpendicular to the dimmed lights. This light strip cannot be dimmed and stays on as long as the light switch stays on.

Using 12v Power Plugs or Anderson Powerpole Connectors. Both of the 12-volt outlets and both of the Anderson Powerpole outlets are wired for 12 volts, 30 amps (Figure 7). Any of these outlets can be used for power inverters offering up to 350 watts of 110 volt AC power. To use any of these outlets, you must turn on the main power switch and the Socket Outlets switch. All of these outlets have rubber waterproof seals; please close these when you are finished.

Figure 7. 12-Volt Power Outlets and Anderson Powerpole Outlets.

Using the Power Inverter. Members should evaluate the type of appliances that they wish to use with the inverter to make sure that it does not overload the system. Also, extended use of the inverter can create a high drain on the batteries and may result in system shutdown during nightfall. It is best to use higher load devices during daylight hours so that the power from the panels can partially offset power used and the solar system can recharge the batteries before nightfall. To use an appliance on the inverter, plug it into the AC outlet first and then turn the inverter on. When finished, unplug the appliance and turn the inverter off. This is important because leaving the inverter on with no appliance being used can still consume about 0.8 amps of battery power. The inverter can sustain a maximum of 700 watts of continuous power draw total with a 1400 watts surge. Here is a list of appliances that may and may not be used on the inverter.

Appliance Guide for Our Power Inverter

Examples of Appliances That May be Used	Examples of Appliances to Avoid
Laptop Computers	Toasters and Toaster Ovens
Small Blenders (short duration)	Electric Blankets
Overhead Projectors	Hair Dryers
Televisions	Microwaves
Keurig Coffee Makers (maybe)	Hot Plates
Small ice chests and refrigerators	High-amperage Tools
CPAP machine	Popcorn Makers
Radios	Hair Curlers
Battery Chargers that Require AC	
Air Mattress Pumps	
Ham Radio Equipment	
Small Fan	

Using USB Connectors. There are eight USB outlets to charge phones, tablets, and lithium batteries and running any devices that use USB ports for power. To use these, the main switch and USB switch must be turned on. Users must provide their own charging cables and should consider waterproof covers for phones and tablets. Zip lock bags and Tupperware containers work well for this.

Troubleshooting

Overhead Lighting not Working. If overhead lighting is not working:

- Verify that circuit breaker has not blown. If it has, reset the breaker,
- Verify that light dimmers are not on the lowest setting. The lights will not work if the dimmers are too low, and
- Verify that light timer has not expired. The main overhead lights are on a two-hour timer to prevent lights from being on too long. Flip the timer reset switch for another two hours of lighting.

12v Power Connectors or Anderson Powerpole Connector not Working. The 12v power connectors and the Anderson connectors use a common circuit 30-amp breaker. Reset circuit breaker if it has blown.

Power Inverter Problems. Our solar panel system has several protection features that can result in shutdown of an inverter or our whole system:

- Excessive loads can trip a circuit breaker,
- The system will shut down when the battery overheats, or
- The battery level gets too low.

When the battery level gets too low, the solar system will stop providing any power and will not recover until the battery is recharged again. Solar system batteries cannot be depleted more than 50 percent of their capacity without damaging the battery.

Similarly, the inverter itself will also protect against overloads and such that can make it stop functioning. These protections may include:

- Low battery shutdown,
- Low voltage audible alarm,
- Overload protection, and
- Short circuit protection.

Battery Controller Protections

Problem	Explanation
PV Over Current	The controller will limit battery-charging current to the Maximum Battery Current rating. Therefore, an over-sized solar array will not operate at peak power.
PV Short Circuit	When a PV short circuit occurs, the controller will stop charging. Clear it to resume normal operation.
PV Reverse Polarity	Fully protection against PV reverse polarity, no damage to the controller will result. Correct the miswire to resume normal operation. **WARNING:** Controller will be damaged when the PV array reverse polarity and the actual operation power of the PV array is 1.5 times greater than the rated charge power!
Battery Reverse Polarity	Fully protection against battery reverse polarity, no damage to the controller will result. Correct the miswire to resume normal operation.
Battery Over voltage	When battery voltage reaches the Over Voltage Disconnect Voltage (16 volts), the controller will stop charging the battery to protect the battery overcharge to break down
Battery Over discharge	When battery voltage reaches the Low Voltage Disconnect Voltage (11.1 volts), the controller will stop discharging the battery to protect the battery from becoming over discharged.
Battery Overheating	The controller detects the battery temperature through the external temperature sensor. If the battery temperature exceeds 65ºC, the controller will automatically start the overheating protection to stop working and recover below 50 ºC.
Load Overload	If the load current exceeds the maximum load current rating 1.05 times, the controller will disconnect the load. Overloading must be cleared up through reducing the load and restarting controller
Load Short Circuit	Fully protected against load wiring short-circuit. Once the load shorts (more than quadruple rate current), the load short protection will start automatically. After five automatic load reconnect attempts, the fault must be cleared by restarting controller.
Damaged Remote Temperature Sensor	If the temperature sensor is short-circuited or damaged, the controller will be charging or discharging at the default temperature 25℃ to prevent the battery damaged from overcharging or over discharged.
Controller Overheating	If the temperature of the controller heat sinks exceeds 85℃, the controller will automatically start the overheating protection and recover below 75℃.
High Voltage Transients	PV is protected against small high voltage surge. In lightning prone areas, additional external suppression is recommended.

Battery Controller Troubleshooting

Faults	Possible reasons	Troubleshooting
Charging LED indicator off during daytime when sunshine falls on PV modules properly	PV array disconnection or PV switch is off	Confirm that PV and battery wire connections are correct and tight and PV switch is on
Wire connection is correct, LED indicator off	1. Battery voltage is lower than 9V 2. PV voltage is less than battery voltage 3. PV switch is off	1. Please check the voltage of battery. At least 9V voltage to activate the controller 2.Check the PV input voltage which should be higher than battery‘s 3. Turn PV switch on
Battery LED indicator green fast blink	Battery voltage higher than over voltage disconnect voltage(OVD)	Check if the battery voltage is too high, and disconnect the solar module
Battery LED indicator orange	Battery under voltage	Load output is normal, charging LED indicator will return to green automatically when fully charged
Battery LED indicator red color	Battery low voltage disconnect	The controller will cut off the output automatically, LED indicator will return to green automatically when fully charged
All the LED indicators blink.(battery indicator orange blink)	Too high temperature of controller	When heat sink of the controller exceeds 85℃, the controller will automatically cut input and output circuit. When the temperature below 75℃, the controller will resume to work
All the LED indicators blink. (battery indicator red blink)	System voltage error	Check whether the battery voltage match with the controller working voltage. Please change to a suitable battery or reset the working voltage. Remove all faults and click the button to resume to work
Load terminals no output	Over load or Short circuit	Remove or reduce the load and press the button, the controller will resume to work after 3 seconds

Inverter Troubleshooting

Indicator	Potential Issue	Troubleshoot
Alarm Beeps	Input voltage is below 10.5V	Keep input voltage above 10.5V
	Input voltage is above 16.0V	Keep input voltage below 16.0V
Fault LED Lit, inverter shut down and alarm on	Input voltage is below 10V	Keep input voltage above 10V
	Input voltage is above 16.5V	Keep input voltage below 16.5V
	Inverter overheats	Allow inverter to cool down
		Check for adequate ventilation
		Reduce the load on inverter
	Operating equipment draws too much power	Use a lower powered device
	Inverter is short circuited	Disconnect the inverter and turn off the ON/OFF switch to reset
Yellow LED Lit - Inverter shut down	GFCI tripped*	Disconnect appliances and turn off the ON/OFF switch to reset

- Note that the system has two GFCI breakers. If there is no power at the outlet (green light is off), press the reset button on the outlet.

Who to Call When Problems Cannot be Resolved. Notify the Lake Chairman when you encounter problems that cannot be resolved by reading this manual.