FreeWave Solar Supervisor

Model: Monitor MPPT RTU 20A-702/215

Model: Monitor MPPT IP 20A-702/215

SERIAL# 0028826FFA080000AB (EXAMPLE)

Intelligent Solar Charging and Remote Monitoring Controller

Solar Energy Management Reimagined

Last Revised: July 02, 2022 – CONFIDENTIAL PROPRIETARY INFORMATION. REV 0.0

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MPPT RTU 20A-702/215

MPPT IP 20A-702/215

Intelligent Solar Charging and Remote Monitoring Controller

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Reference Manual

Patent Pending

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Warranty

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Warnings

- DO NOT OPERATE OR ATTEMT TO USE LITHUM TYPE BATTERIES WITH THIS DEVICE. RISK OF FIRE OR DAMAGE WILL OCCUR.
- The total battery voltage configuration CANNOT exceed a total 24 VDC. Damage WILL occur if more than two 12-volt batteries are placed in series.
- DO NOT MAKE CONNECTION WITH POWER APPLIED TO THE DEVICE. TURN OFF CIRCUIT BREAKER BEFORE CONNECTING BATTERIES, SOLAR PANELS AND LOADS.
- ALWAYS USE A CIRCUIT BREAKER BETWEEN THE PLUS "+" LEAD OF THE BATTERY AND THE MPPT 20A CONTROLLER. FAILURE TO DO SO MAY LEAD TO DAMAGE OR FIRE.
- ALWAYS USE A CIRCUIT BREAKER BETWEEN THE PLUS "+" LEAD OF THE SOLAR PANEL AND THE MPPT 20A CONTROLLER. FAILURE TO DO SO MAY LEAD TO DAMAGE OR FIRE.
- WARNING – EXPLOSION HAZARD. DO NOT REMOVE OR REPLACE BATTERIES WHILE THE DEVICE IS ENERGIZED.
- DO NOT SHARE GROUNDING SYSTEMS. ALL GROUNDS MUST REMAIN ISOLATED AND CONNECTED TO THEIR PROPER TERMINAL.
- DO NOT USE THIS DEVICE WITHIN A HAZARDOUS CLASSIFIED AREA.
- ALWAYS USE A CIRCUIT BREAKER BETWEEN THE LOAD OUTPUT OF THE MPPT 20A CONTROLLER AND ANY THIRD-PARTY EQUIPMENT.

Product support

Product support is available only to authorized registered users. We take security and data privacy very seriously.

New users must create an account using https://support.freewave.com/hc/en-us. You must log in to your account and register the serial number or serial numbers of each device in your account. This account will also serve as a management portal for remote device management, data collection, data aggregation, and monitoring.

Existing users may enter newly purchased products into the management system.

What's in the box (kitting)

FreeWave supplies ONLY the following items/products as part of a complete kit:

1) 1 X Maximum Power Point Tracking (MPPT) 20 amp solar monitor/charging controller
2) 2 X temperature sensors: external sensor and battery sensor
3) 1 X SD card for data-logging and event capture

Nothing in the manual should be construed or leave the impression that FreeWave will provide items outside of the above list. Anything mentioned within this manual outside the above list is sold or provided by the customer separately.

How to read the model number

The model number consists of a series of characters and numbers to identify the series type, communications type, charging amps, CPU BOARD revision and MPPT BOARD revision.

Example: Monitor MPPT IP 20A-702/215 is a

(Monitor) with a

(MPPT BATTERY CHARGER) and supports:

(IP which include Modbus TCP, MQTT and embedded web page) the

(CPU BOARD is REV 702) and the

(MPPT Charge Board is Rev 215)

The MPPT 20A controller comes in two models:

Monitor MPPT IP 20A-702/215	Ethernet Version (NO RS-485 Serial)
Monitor MPPT RTU 20A-702/215	MODBUS RTU RS-485 Serial version (NO IP)

Figure 1: Contents of the box

Watch me first

Please review the following videos:

[Solar Supervisor Part 1: Unboxing guide]

[Solar Supervisor Part 2: Activate and Connect]

Theory of operation

The MPPT 20A CONTROLLER was designed to support and overcome market and technical pain-points for remote, autonomous, solar powered sites. Major functions include an intelligent three-stage 12/24V Maximum Power Point Tracking (MPPT) charge controller, comprehensive system vital signs monitoring via Modbus RTU, Modbus TCP, and MQTT to:

- Reduce callouts to near zero. System callouts are the biggest maintenance cost.
- Predict the proper system battery and panel sizing in real-time.
- Determine system autonomy in real-time during bad weather or no-to-low solar exposure.

We understand callouts cannot be completely eliminated. Our goal is to significantly reduce callouts by monitoring all systems, predicting problems, maintaining battery health, and making notifications.

Most common solar-site pain-points with remote solar powered systems are:

- Improper solar panel and battery sizing.
- The lack of system vital signs visibility, performance, management, and integration into an existing Supervisory Control and Data Acquisition (SCADA) platform.

Often, customers are notified of a solar powered system failure when the equipment being powered by the solar equipment ceases to work for unknown reasons. The customer is left guessing at the cause of failure and is forced to send a field technician to troubleshoot the system. Most failures are caused by under-designed systems, exceeded equipment loads, battery life issues, and improper solar panel size.

Engineers at FreeWave solved many of the solar management challenges by designing a patent pending intelligent battery charging platform and a comprehensive monitoring, predictive maintenance, and predictive analysis platform.

The MPPT 20A CONTROLLER has several unique patent pending functions and features and has been designed to not only manage the proper battery charging process, but to also bring remote visibility from a remote solar site to a SCADA collection location. The MPPT 20A CONTROLLER can integrate into an existing SCADA monitoring system using Modbus serial RTU and a series of Modbus registers populated with vital signs, maintenance, and analysis data. Additionally, the system supports Modbus TCP, MQTT and an embedded web page on certain models.

The MPPT 20A CONTROLLER can support lead acid battery chemistries, several types of battery voltages with an enhanced ability to monitor the solar system and predict failures before they occur.

FreeWave products are designed to reduce the cost of system down time, reduce the cost of maintenance, technician rollouts as well as bring full visibility to system performance and operation. Dynamic, real time system sizing is a powerful feature. Typically, designing a solar system is a paper exercise that does not account for load changes, aging batteries and solar panels, and environmental changes. The MPPT 20A CONTROLLER creates real-time system analysis recommendations on the size of the panel and battery, and determine critical attributes such as determining how long a solar site will remain up during low-or-no solar exposure. No more guessing on required battery capacity and panel size, or when a system will likely fail.

We value our customers. If you have any suggestion to improve our products or if you find errors in this manual, please contact us.

https://support.freewave.com/hc/en-us

Product description

Many markets require the deployment of small-profile, low-power producing solar systems. Solar systems are largely deployed to power equipment such as sensors, telemetry radios, data loggers, process control equipment, video cameras, and so on. The cost of delivering typical 110 Volts Alternating Current (VAC) house power to a remote site prohibitive.

The challenge is to provide uninterrupted power to remote critical sites, and to balance sizing of solar panels and the number of batteries to maintain power through bad weather and sustained low to no sunlight to allow for a proper charging cycle and the changing dynamics of the user adding equipment over time.

Today, the practice of calculating or determining the size of a solar panel and the number of battery amp-hours is a "paper exercise" consisting of a user determining the estimated power load on the system, geographical locations to determine weather patterns and solar exposure, and the desired and required days of autonomy. This process is static. It's an estimate, and does not allow for dynamic changes such as aging solar panels, aging batteries, the adding of equipment over time, and the natural process of charging and discharging cycles.

The goal is to overcome:

- ✓ UNPREDICTABLE UPTIME
- ✓ LACK OF SYSTEM PREFORMANCE AND VISIBILITY
- ✓ UNKNOWN POWER DISRUPTIONS
- ✓ UNKNOWN STATE OF CHARGE
- ✓ UNKNOWN HOURS OF AUTONOMY
- ✓ PREMATURE BATTERY FAILURE
- ✓ DAMAGING DEEP DISCHARGING OF BATTERIES
- ✓ STATIC SYSTEM DESIGNS FALURES BY DYNAMIC SYSTEM ATTRIBUTES
- ✓ TECHNICAL ROLLOUTS

Return on investment

Technical rollouts and premature replacement of solar related components such as batteries are big cost factors in maintaining a remote solar powered site. Batteries that are not maintained and are not charged properly are leading contributors to early replacement and field failures. These types of failures, also known as a *roll-out*, are typically why abrupt and unpredictable failures occur and cause technicians to be sent to determine the cause. Certain industries adopt a policy of replacing solar batteries on a six-month schedule even if the batteries are in good working condition. The main

reasons for this policy are unknown battery conditions, equipment failures, and weather conditions that may over-consume battery current supply.

The MPPT 20A CONTROLLER can reduce the cost of battery maintenance and the risk of premature failure by bringing visibility of system vital signs directly to the SCADA operator or user, as well as enabling real-time predictive maintenance, system analysis, and the ability to analyze for the proper battery and panel size.

To understand how FreeWave's smart controller/monitor can pay for itself the very first time it's deployed, you should understand the cost of an unmanaged remote solar system.

Typical reasons technicians are sent to a solar site location

Leading causes for sending a technician out to a remote solar site to determine and troubleshoot system problems include battery failures, under-designed systems, third-party equipment that needs to be power cycled, and site equipment failures. Due to the lack of system performance and lack of visibility of vital signs, the reported failure cause is almost always unknown at the time a technician is dispatched. Improper battery discharge cycles, even a single deep discharge where the battery is discharged below 11.5/23 Volts Direct Current (VDC), will cause permanent, irreversible battery damage.

Cost related to rollouts

Some of the typical costs involved in sending a technician out to a site location are the cost of labor, vehicle trip mileage, travel time, failed equipment, and inventoried equipment. These elements add up to several hundred dollars an hour for each event where a technician is sent to a remote solar site to troubleshoot an issue. The cost can exceed $2,400 per site, per event. This can add up to hundreds of thousands of dollars in a single year. The cost of FreeWave's smart controller/monitor is less than $1000 per solar site.

ROI example 1: Communications failure

In this example, a radio telemetry device is powered by the MPPT 20A CONTROLLER and the data radio has stopped operating. The MPPT 20A CONTROLLER can monitor the Modbus traffic, and if the Modbus communications Watchdog Timer (COMM WDT) is enabled, the system will automatically cycle power to all connected loads after a user-defined communications silence period. There are instances where third-party equipment locks up and requires a power cycle. The cost savings gained by allowing a SCADA operator to remotely cycle equipment power under load control rather than sending a technician to the site can save as much as $2,400 per instance.

ROI example 2: Equipment power cycle

In this example, a third-party device is powered by the MPPT 20A CONTROLLER and the equipment attached to the load output has stopped operating. If the system SCADA telemetry is functioning a Modbus command may be sent to cycle power to LOAD-1 or LOAD-2. This allows a SCADA operator to remotely cycle power for 30 seconds to either or both loads. The cost savings by allowing a SCADA operator to remotely cycle power to equipment attached rather than sending a technician to the site could save as much as $2,400 per instance per trip.

ROI example 3: Identifying an under-designed site

Summary: The MPPT 20A CONTROLLER can make predictions and can bring visibility to an under-designed/under-performing or failing solar system. The MPPT 20A CONTROLLER considers many performance and environmental data points to make an analysis. This example shows how an under-designed system can be identified. Not only can a SCADA operator or technician plan on what equipment to bring to a site to facilitate a repair, a complete system performance analysis can be performed prior to dispatching a technician. In most cases, a technician would not have to be dispatched to correct the issue.

Example: A solar system abruptly stops functioning. A technician is dispatched, and the battery voltage is found to be extremely low (< 8.0vdc). The battery is replaced with no further analysis or troubleshooting. This scenario is repeated every three to six months.

In this example, the SCADA operator has no visibility to the performance, potential problems, or system vital signs. The root cause is an under-designed system due to weather conditions, and the current load demand on the battery from the equipment being powered. Because the battery was allowed to fall below 11.5vdc, this battery was permanently damaged and will not hold or accept a charge and will need to be replaced.

In contrast, the MPPT 20A CONTROLLER can communicate system vital signs to a SCADA operator. This includes battery voltage, battery current, solar voltage, solar current, predicted battery and solar panel size required, just to name a few. The MPPT 20A CONTROLLER also indicates days of autonomy of a system. Days of autonomy is an indicator of how long a battery should last without being recharged based on the battery state-of-charge and system performance. The MPPT 20A CONTROLLER also can indicate when a battery needs to be replaced.

The MPPT 20A CONTROLLER would have given the SCADA operator many indicators of problems before the solar site in this example failed. The following data points are accessible via Modbus RTU/TCP and MQTT:

- Battery voltage low
- Low hours of autonomy
- Battery not reaching peak absorption charge

- Voltage and battery voltage trending low for three contiguous days

The MPPT 20A CONTROLLER would have managed the loads attached by removing power to loads to keep the battery voltage from falling below a damaging level and placing a priority on which equipment to power during a potential charging issue.

Example of changing system attributes

This example is a typical view of a static system and the effects of dynamic/changing anomalies that will cause failures. The dynamic anomalies in this case are increased system amps and daily sun exposure. There are many, many more examples that may cause the same types of problems.

It is **CRITICAL** to understand that initial system designs and system calculations are typically paper exercises where a customer calculates battery and solar size based on hopeful numbers: Such imprecise calculations might include "I think the system will consume ten watts of power", "I need five days of system autonomy…", and so on.

The paper exercise **will not** account for a changing environment, and this is a leading cause of system site failures.

The innovation in the Solar Supervisor system is that the system dynamically and constantly collects system data, and then analyzes, calculates, and predicts the system power needs to maintain power during a contiguous "no charge" state.

The innovation also works backwards and notifies users of the estimated days of autonomy based on the same collected system data. This is different than the user-desired days of autonomy; it is a realistic prediction of days of autonomy.

This innovation will keep the system ahead of any problems; for example, the user requires five days of autonomy, but the system predicts a more realistic two days of autonomy. This system notifies the user how much solar and battery capacity to add to keep from having a system failure. and will also notify the user of upcoming failures.

The system will analyze, calculate, and predict true hours of autonomy remaining in real-time.

- Analyze, calculate, and predict the system SOLAR power needed to sustain the user's desired days of autonomy
- Analyze, calculate, and predict the system BATTERY AMP HOURS needed to sustain the user's desired days of autonomy
- Analyze, calculate, and predict the system SOLAR power needed to sustain the user's desired days of autonomy
- Calculate real and actual days of autonomy based on system performance. This is different than the desired days of autonomy.

Example: Panel/battery sizing predictions

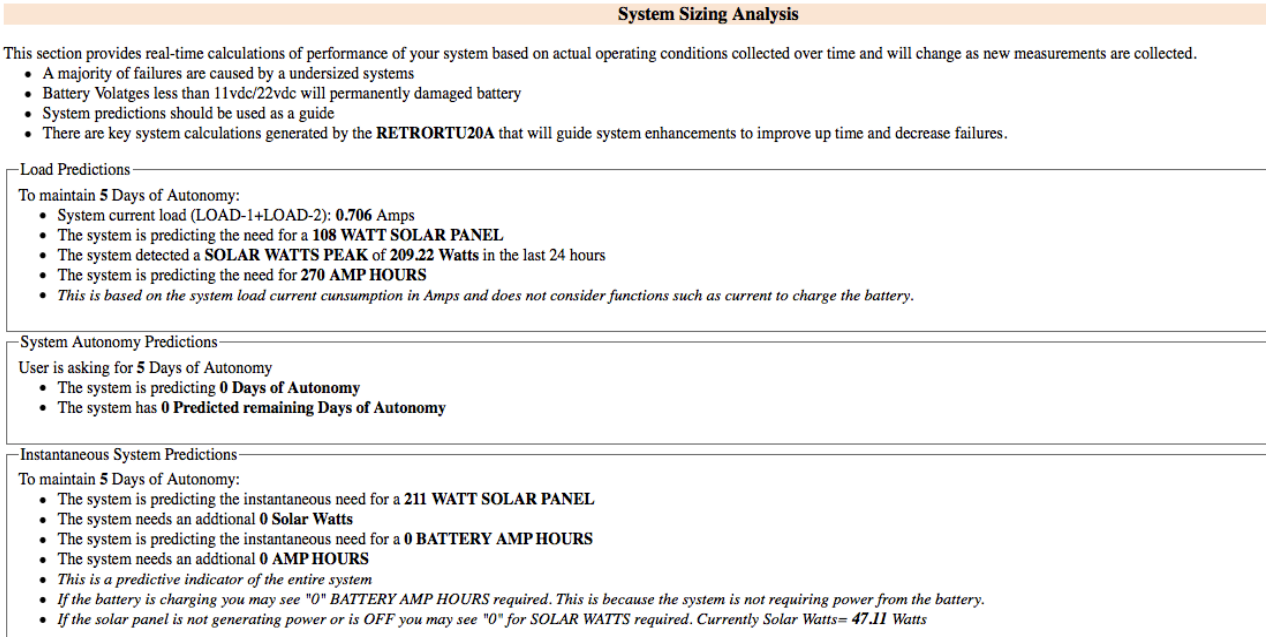
To maintain **five** days of autonomy:

- System current load (LOAD-1+LOAD-2): **0.791** amps
- The system predicts the need for a **26-WATT SOLAR PANEL**
- The system predicts the need for **300 AMP HOURS**
- The system predicts **0 Days of Autonomy**
- The system has 0 predicted remaining days of autonomy

This example analysis is on an under-designed system. The battery is not being charged properly and allowed to fall to damaging levels, and the number of battery amp hours must be increased. These results would be included in the audit report generated twice in a 24-hour cycle, as well as on the webpage, and on Modbus and MQTT.

The MPPT 20A CONTROLLER provides several methods of notifying you of how your system is performing and if adjustments need to be made. These telemetry systems include Modbus RTU, Modbus TCP, MQTT and an embedded web page within the MPPT 20A CONTROLLER. The following is an example of the embedded web page **System Sizing Analysis** tab. This web section outlines predictions of the proper size of the system and notifies the user of predicted recommendations.

Example ***system analysis*** embedded webpage:



System Sizing Analysis

This section provides real-time calculations of performance of your system based on actual operating conditions collected over time and will change as new measurements are collected.

- A majority of failures are caused by a undersized systems
- Battery Volatges less than 11vdc/22vdc will permanently damaged battery
- System predictions should be used as a guide
- There are key system calculations generated by the **RETRORTU20A** that will guide system enhancements to improve up time and decrease failures.

Load Predictions

To maintain **5** Days of Autonomy:

- System current load (LOAD-1+LOAD-2): **0.706** Amps
- The system is predicting the need for a **108 WATT SOLAR PANEL**
- The system detected a **SOLAR WATTS PEAK** of **209.22 Watts** in the last 24 hours
- The system is predicting the need for **270 AMP HOURS**
- *This is based on the system load current cunsumption in Amps and does not consider functions such as current to charge the battery.*

System Autonomy Predictions

User is asking for **5** Days of Autonomy

- The system is predicting **0 Days of Autonomy**
- The system has **0 Predicted remaining Days of Autonomy**

Instantaneous System Predictions

To maintain **5** Days of Autonomy:

- The system is predicting the instantaneous need for a **211 WATT SOLAR PANEL**
- The system needs an addtional **0 Solar Watts**
- The system is predicting the instantaneous need for a **0 BATTERY AMP HOURS**
- The system needs an addtional **0 AMP HOURS**
- *This is a predictive indicator of the entire system*
- *If the battery is charging you may see "0" BATTERY AMP HOURS required. This is because the system is not requiring power from the battery.*
- *If the solar panel is not generating power or is OFF you may see "0" for SOLAR WATTS required. Currently Solar Watts= **47.11** Watts*

*Image 2- The embedded web page **System Sizing Analysis** tab*

Failure cause	Typical time	Typical $/Hr	Typical cost
Battery life failure	6~12 Hours	$60 – $200/hour	$360-$2,400
Equipment power cycle	1~6 Hours	$60 – $200/hour	$60-$1,200
Under-designed system, autonomy issues	1~8 Hours	$60 – $200/hour	$60-$2,400

Table 1 – Failure cost on one single unit

Avg number of events per day	Average cost	Ext cost	# Sites	Ext cost
10	$160-$2,000	$1,600-$20,000	100	$16,000 - $200,000

Table 2 – Failure cost across ten systems

Example charging cycle use case

The following example is an actual charge/discharge cycle and represents how the MPPT 20A CONTROLLER manages, predicts sizing, predicts failures, and predicts how long a system will safely maintain power to the equipment attached.

The following use case shows a remote system that is powering pressure sensors, a data radio and a programmable logic controller (PLC).

All equipment is attached to LOAD-1 and all equipment has the highest power-up priority.

Remote powering of sensor, radio telemetry, and PLC use case:

This system uses two 12-volt, 98-amp hour batteries in parallel to create a 12-volt, 196-amp hour-powered system. The goal is to increase days of autonomy over a 24-volt 98-amp hour system. The system was allowed to fully charge then the solar power was removed to emulate a scenario where the system was not being charged for many days. The equipment attached consumed a constant 400-MilliAMPS or 0.400 amps.

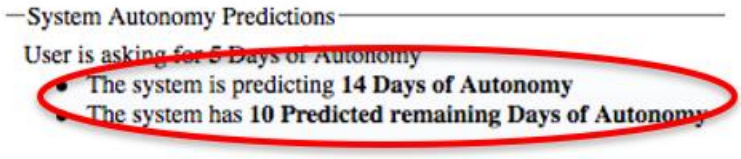


Figure 3 – System autonomy prediction

The user wants to maintain a safe power distribution for five days, but the system estimated and predicted 14 days of autonomy. A snapshot taken indicates the system is predicting 10 days of remaining autonomy. In other words: the system estimates the batteries will maintain power to the sensors, data radio, and PLC for ten more days, and has already been without power for four days. This unique, patent-pending function alerts a SCADA operator or the proper personnel with real-time updates and real-time visibility to potential problems, and where to prioritize a sense of urgency. These are dynamic measurements. If more equipment is added to the power system, or batteries and panels begin to age and become less effective, the system will continue to make days-of-autonomy estimates with the changing environment.

Also modeled is the recovery phase when sunlight eventually returns.

Unpacking and setup

Lead acid solar batteries and solar panels contain large amounts of energy. **It is important that you read this manual in its entirety.** Failing to do so could cause harm, and in some cases, may cause a fire.

The MPPT 20A CONTROLLER is designed to be mounted via DIN rail within a weather rated housing/cabinet. Best practices and proper installation practices **must** be used to include installing cable glands, cable strain devices, circuit breakers, and proper cable termination.

The MPPT 20A CONTROLLER is equipped with two load-output connections used to power and manage external equipment such as radios, RTUs, PLCs, and so on. Never assume your equipment is protected from reverse polarity. Permanent damage **WILL** occur if the polarity is reversed to your equipment. The MPPT 20A CONTROLLER **does not protect against improper polarity connected from the load connections to your equipment**. Double, even triple-check system connections before applying power to any device.

The MPPT 20A CONTROLLER has few support components to deal with. Within the shipping box you will find only the controller, an SD data card, and an external and battery temperature sensor.

This section assumes a fully constructed solar system exists, such as installed solar panels, batteries, cabinets, and so on.

Installation guide

1. DO NOT SHARE GROUNDS. Solar panel grounds, battery grounds, and load grounds must be kept separate and connected to their respective termination. DO NOT CONNECT ANY OTHER GROUNDS TO THESE GROUNDING SYSTEMS OR CONNECT GROUNDS TOGETHER.
2. Use #10 to 12AWG wire for all connections. **BLACK** wire for (**-**) **negative** connections and RED wire for **positive** (**+**) connections. Do not use wires smaller than #12AWG.
3. Ensure the positive lead of the solar panel is fused. A 20A circuit breaker is typically used. DO NOT operate your system without current limiting protection; the risk of a fire is high.
4. Ensure the positive lead of the battery panel is fused. A 20A circuit breaker is typically used. DO NOT operate your system without current limiting protection; the risk of a fire is high.
5. **Turn off and verify that all circuit breakers are off. This means NO power is applied to any components.**
6. Insert the SD card into the SD card slot of the MPPT 20A CONTROLLER. It is located on the right of the controller. Pushing the SD card will seat the card; pushing the SD card again will unseat the card. Do not pull on a seated card. and ensure the card is seated properly.
7. Solar panel connection: MAKE SURE THE SOLAR PANEL CIRCUIT BREAKER IS OFF. On the lower left bottom of the SOLAR SUPERVISOR controller are two "wire-push" type connections. Push the **BLACK OR NEGITIVE** wire from the solar panel into the "(**-**)" **negative** connection of the MPPT 20A CONTROLLER wire-insert labeled "SOLAR PANEL". Push the **RED OR POSITIVE** (**+**) wire from the solar panel into the (**+**) **positive** connection of the MPPT 20A CONTROLLER wire-insert labeled "SOLAR PANEL".

Figure 3 – Solar panel connection

8. BATTERY connection: MAKE SURE THE BATTERY CIRCUIT BREAKER IS OFF. On the lower right bottom of the controller are two "wire-push" type connections. Push the **BLACK OR NEGITIVE** wire from the battery into the "(**-**)" **negative** connection of the MPPT 20A CONTROLLER wire-

insert labeled “BATTERY”. Push the **RED** **OR** **POSITIVE** “(+)” wire from the battery into the “(+)” **positive** connection of the MPPT 30A CONTROLLER wire-insert labeled “BATTERY”.

Figure 4 – Battery connection

9. Load connection: There are two prioritized power loads. See
10. Figure *12 – Typical connection* overview
11. Load distribution for details on connecting loads to the MPPT 20A CONTROLLER. Keep load grounds separate and Isolated. **DO NOT** connect any other ground to the load grounds. Use current limited devices such as fuses or circuit breaker between the load output and any third-party equipment.

Figure 5 – Load connection

10. There are two battery temperature sensors: a temperature monitor and a battery compensation monitor.

Figure 6 – Temperature sensors (thermal compensation sensors)

Both sensors must be secured as close to the battery as possible and as close together as possible. The battery temperature sensor comes fully assembled and connected to the MPPT 20A CONTROLLER. Taping the sensors to the side of the battery case is ideal.

Figure 7 – A sensor taped to the battery case

Do not mount the sensors onto metal surfaces due to thermal conduction. If it's not possible to mount the sensors directly on the battery, then allow the sensor to hang in mid-air as close to the battery as possible.

11. Tamper connection: Tamper detection is possible by using the *Tamper connections*. Use a dry contact, normally open-type switch. The tamper status is available via Modbus by reading digital input MODBUS register 10026. The number of tamper events is accumulated and available as a 32-bit number via MODBUS register 30072-73.

Figure 8 – Tamper connection

12. External temperature sensor: The "EXT TEMP" temperature sensor allows the MPPT 20A CONTROLLER to monitor external ambient temperature. A typical use case is to mount the temperature sensor out of the bottom of the solar cabinet by using a properly sized cable gland to monitor outside air temperature. The temperature sensor **MUST NOT** be exposed to direct sunlight.

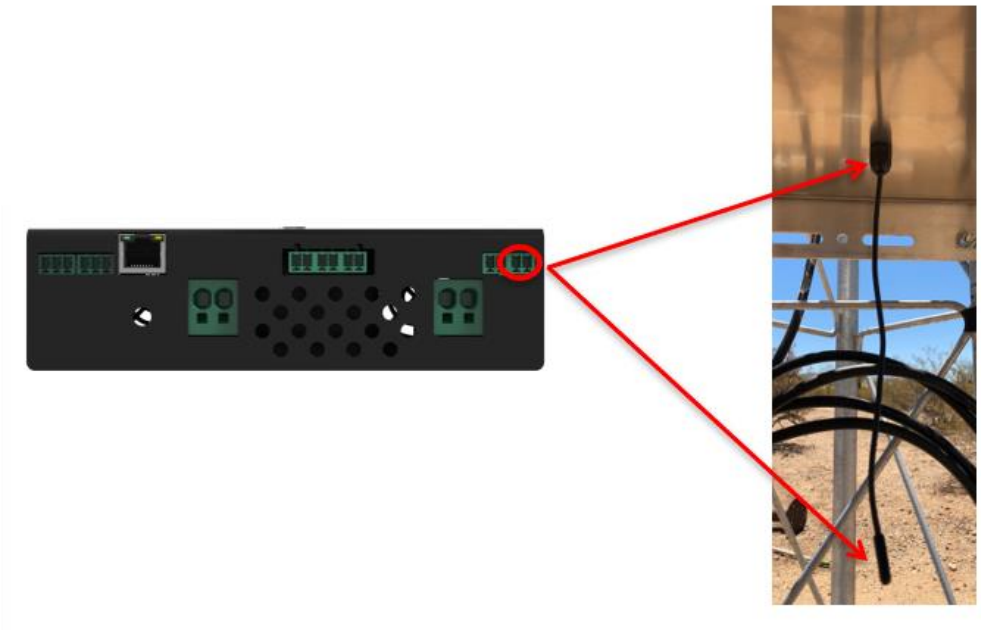


Figure 9 – External temperature sensor connection

13. **Take a second look at the previous instructions to ensure all connections are made correctly, polarity is correct, and all wiring is secure and properly connected and seated. Review the image under Effects of improper wire sizing: Solar panel for a big-picture view of how a system is connected.**
14. Starting with both the **solar panel** and **battery** circuit breakers **OFF**, turn on the **battery** circuit breaker, and allow the MPPT 20A CONTROLLER to start. All loads will start in the *off* state and will take several seconds to initialize all system parameters. You will notice several of the status LEDs cycling through a sequenced pattern. Once the boot-up sequence is completed, the MPPT 20A CONTROLLER enables the load outputs and begins to rotate though the liquid crystal display (LCD) pages.
15. Turn on the solar input voltage circuit breaker.
16. Verify all equipment is powered and operating correctly.

WARNING – FIRE HAZARD. DO NOT REMOVE OR REPLACE BATTERIES WHILE THE DEVICE IS ENERGIZED.

Effects of improper wire sizing

Using wire that is too small from the controller to the battery, solar panel, charge controller, and loads will result in a voltage drop during large current load consumption events.

This could result in the battery not being charged properly, premature load-shedding, and improper solar voltage input.

Effects of improper wire sizing: Solar panel

To test if there is a voltage drop across the NEG or POS wires, you need to place your meter into DC Volts Measurement mode.

Place the **positive** lead as close to the RETRPRTU-20's solar (-) input and the **negative** lead as close to the solar panel (-) as possible. The reading should be close to "0.000". Any voltage displayed is an indicator of a voltage drop, and the wire may be too small to carry the current. This test should be conducted when the panel is supplying a large amount of current.

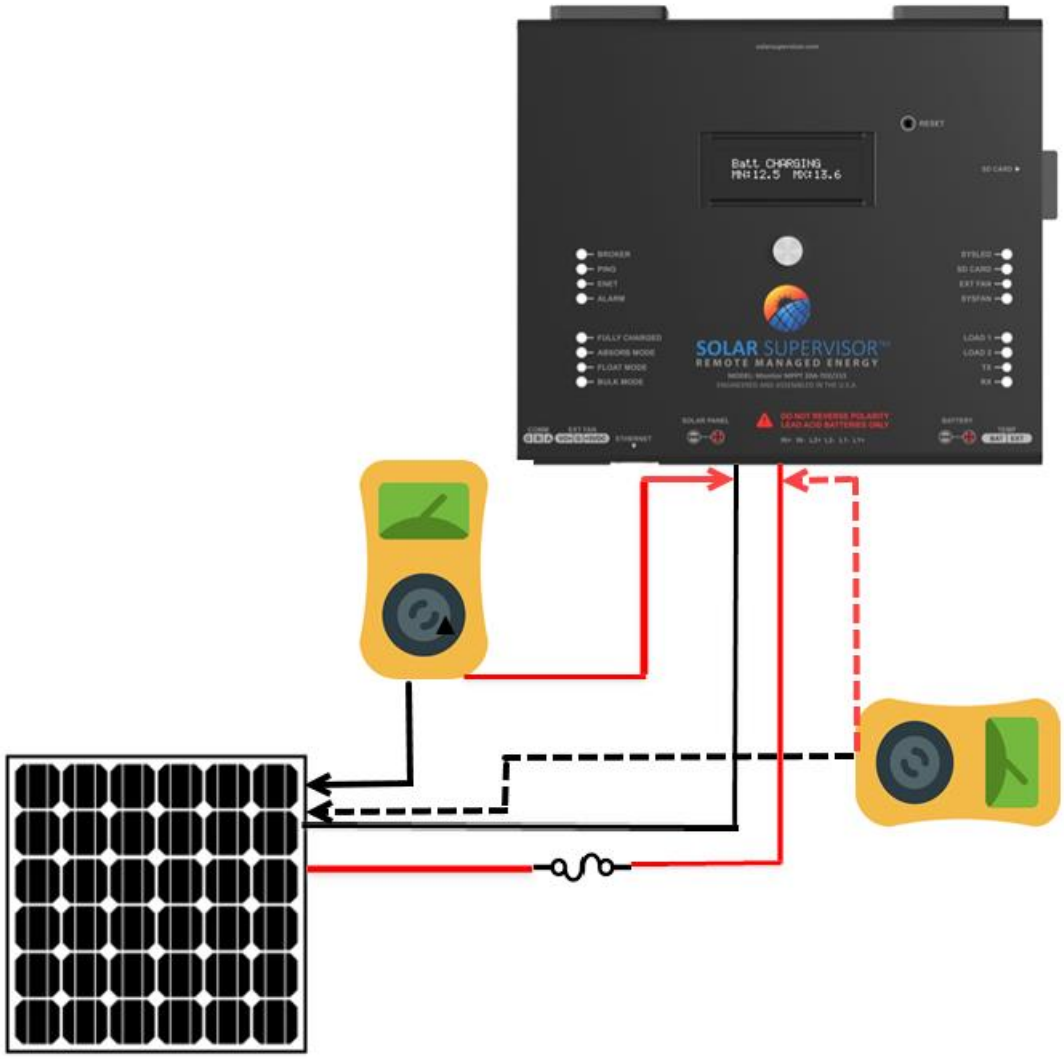


Figure 10 – Effects of improper wire sizing: batteries

Effects of improper wire sizing: Batteries

Placing your meter into **DC Volts Measurement** mode; Place the **positive** lead as close to the RETRPRTU-20's BATTERY (-) input and the **negative** lead as close to the BATTERY (-) as possible. The

reading should be close to “0.000”. Any voltage displayed is an indicator of a voltage drop, and the wire may be too small to carry the current. This test should be conducted when a large amount of current is being supplied to the batteries.

Figure 11 – Improper wire sizing

The following image shows a typical use case consisting of a solar panel, tamper switch, external temperature sensor, equipment attached to LOAD-1, equipment attached to LOAD-2, solar panel, battery, and battery temperature sensors. Also illustrated are circuit breakers between the solar panel and the MPPT 20A CONTROLLER, and between the battery and the MPPT 20A CONTROLLERS.

WARNING – EXPLOSION HAZARD. DO NOT OPERATE THE SYSTEM WITHOUT THE PROPER CIRCUIT BREAKERS.

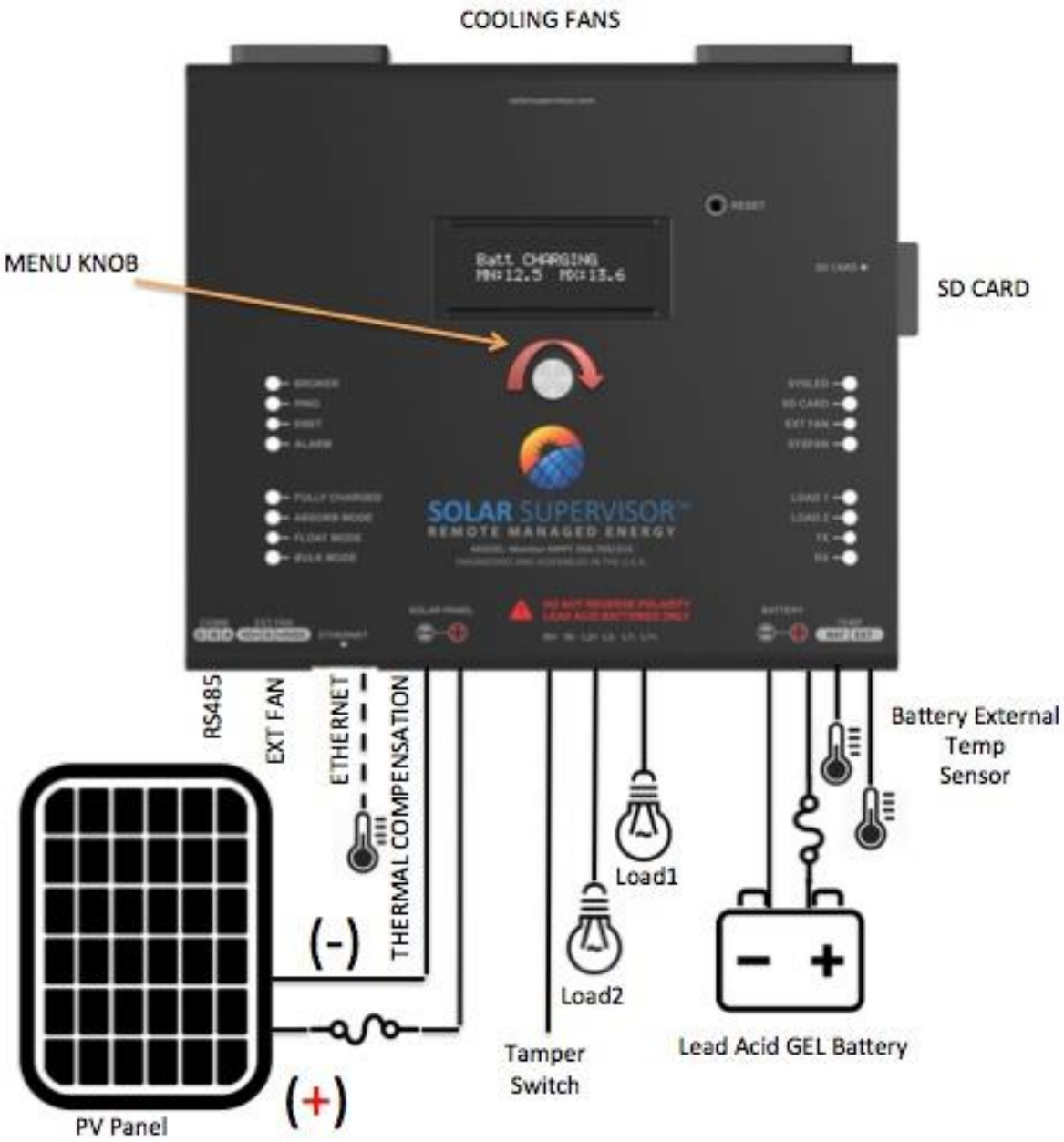


Figure 12 – Typical connection overview

Load distribution

The following image represents a typical load distribution connection scheme. The MPPT 20A controller has two separate equipment connections labeled LOAD-1 and LOAD-2. This document outlines how the loads are managed, controlled, connected, and prioritized.

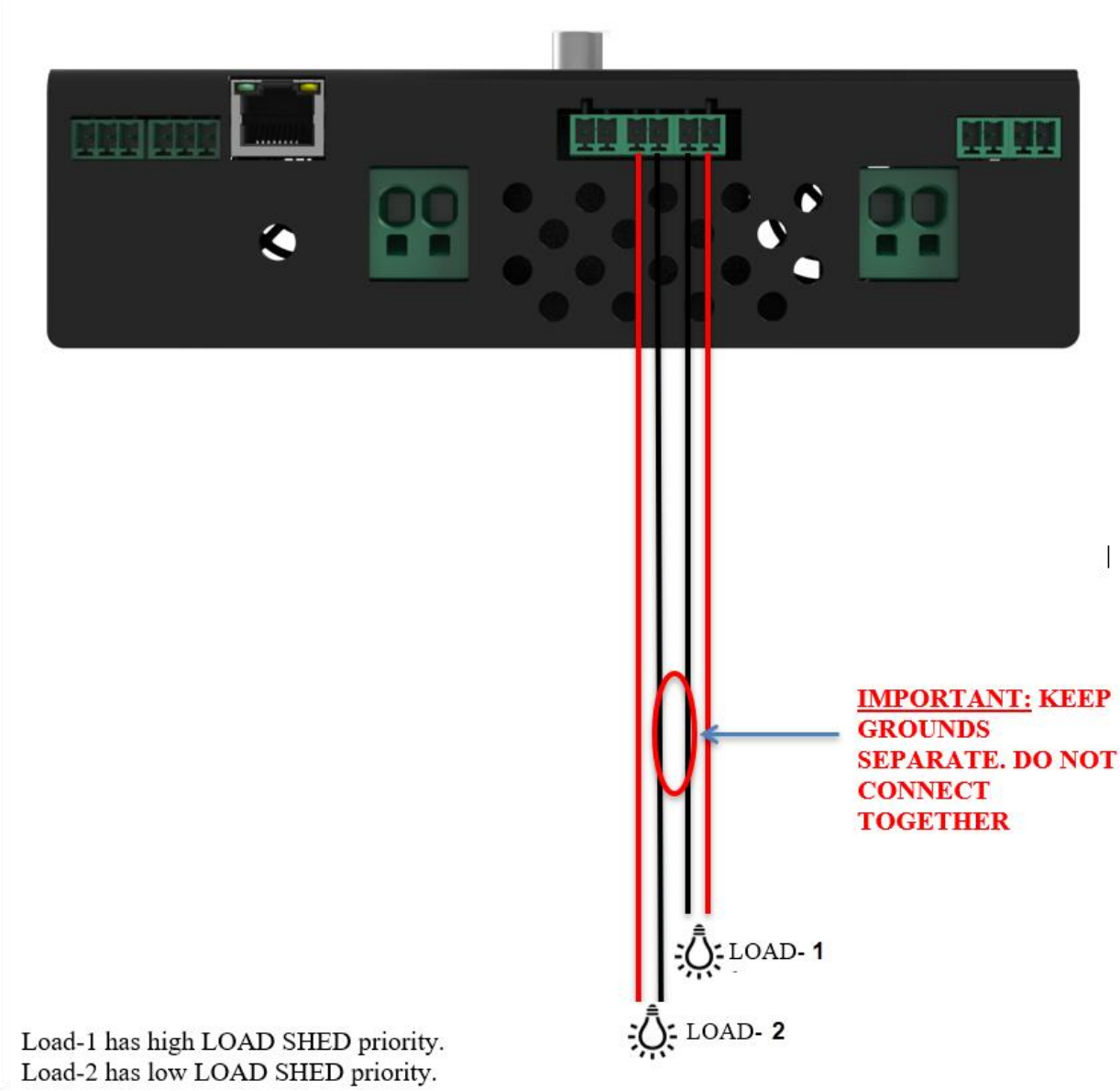


Figure 13- A typical load distribution connection scheme

Prioritized load demand

The system will prioritize based on the level of the battery voltage level. **LOAD-2 has the lowest priority** and will remain on until the battery voltage falls below 11.8 volts on a 12-volt system and 23.6 volts on a 24-volt system. LOAD-2 will remain OFF until the battery voltage rises above 12.2-volts on a 12-volt system and 24.4volts on a 24-volt system. When the battery reaches those levels, LOAD-2 will reapply power. It is recommended that any equipment attached to LOAD-2 **not** be required to notify a user or SCADA system of an issue. For example, if a telemetry radio or cellular router was used to send device data and LOAD-2 is disabled, the respective equipment there would have no way to notify the user of an issue until power was re-applied. Equipment connected to LOAD-2 is typically sensors, data loggers, process controllers, and so on.

LOAD-1 has top priority and will remain on until the battery voltage falls below 11.6 volts on a 12-volt system and 23.2 volts on a 24-volt system. LOAD-1 will remain OFF until the battery voltage rises above 12.2-volts on a 12-volt system and 24.4volts on a 24-volt system. It is recommended that any equipment attached to LOAD-1 be equipment required to notify a user or SCADA system of an issue. Equipment connected to LOAD-1 is typically any equipment in support of sending data or notification is a user or SCADA system.

When both loads are off, the battery does not have a discharge current applied. All equipment attached to LOAD-1 and LOAD-2 will not be powered. There may be exceptions if the cooling and exhaust fans are running.

In practice, the device attempts to extend the days of autonomy AND to make sure the battery voltage does not fall below an unsafe voltage discharge level. Many customers do not use load-shedding, causing the voltage to fall below a destructive level. Batteries will not recover from this state and will not retain a charge forcing the customer to replace the battery.

System over current protection

OVER CURRENT OR SHORT-CIRCUIT PROTECTION IS MANDATORY. DO NOT POWER EQUIPMENT WITHOUT PROPER CIRCUIT PROTECTION!

WARNING – EXPLOSION HAZARD. DO NOT REMOVE OR REPLACE FUSES WHEN DEVICE IS ENERGIZED.

An external 20A circuit breaker must be placed between the battery's **positive** post and the "**+**" connection of the MPPT 20A CONTROLLER WIRE-PUSH type connector labeled **BATTERY**. DO NOT operate or power up equipment without the proper short-circuit protection such as a circuit breaker, the risk of a fire is high.

An external 20A circuit breaker **must** be placed between the solar panel's **positive** lead and the "**+**" connection of the MPPT 20A CONTROLLER WIRE-PUSH type connector labeled **SOLAR PANEL**. DO

NOT operate or power up equipment without the proper short-circuit protection such as a circuit breaker, the risk of a fire is high.

The MPPT 20A CONTROLLER cannot protect the battery or solar panel from a direct short or over-current, which is why an external circuit breaker is mandatory.

The MPPT 20A CONTROLLER can supply and manage two independent power loads to supply power to system equipment such as telemetry radios, sensors, RTUs, PLCs, and so on. These connections are fused and protected by the MPPT 20A CONTROLLER. The independent power loads are labeled LOAD-1 and LOAD-2. Each load can supply 7.5-amps. EQUIPMENT ATTACHED TO RESPECTIVE LOAD CONNECTION MUST NOT EXCEED 7.5-amps. The MPPT 20A CONTROLLER will load-shed/disrupt power to the equipment attached if:

- the current exceeds more than 7.5-amps
- the battery voltage drops below limits
- a manual SCADA load-shed command is issued

(See Device load – Trigger level and timers)

Each load is load-managed separately.

There are three controlled load-shedding events that will occur:

- when the system detects respective loads above 7.5 amps
- when the system sees a low battery voltage threshold
- when a SCADA user forces a load-shed via Modbus. The only uncontrolled load-shedding event is when a fuse has opened due to a high current scenario.

The MPPT 20A CONTROLLER allows for manual LOAD disruptions/overrides using a Modbus 0X register 00026 and 00027. Forcing a respective register to a “1” causes the respective load to disrupt power for 30 seconds to all equipment attached to a respective load. Once the 30-second timer has expired, the load is returned to normal and power resumes. A “0” to a respective 00026 and 00027 register will automatically be written; there is no requirement to reset these registers. This function was designed to allow a SCADA supervisor to cycle power to any equipment that may require a power reset. Solar Supervisor is designed as a cost savings device. Giving the SCADA system the ability to remotely restart equipment prevents the need to send personnel out in the field, saving time and money.

- Modbus 1X (DI) registers 10006 and 10007 will indicate an active load-shed for a respective load. “1” indicates an active load-shed, “0” indicates no active load-shed.
- Modbus 3X (AI) registers 30085 and 30086 will display time remaining for a respective load-shed event. This is a countdown timer.
- Modbus 3X (AI) register 30087 and 30088 display total number of load-shed events.

- Depending on which load is in load-shed the respective LOAD1 or LOAD2 LED will remain on until the respective LOAD-SHED timer has expired and the error is resolved.
- After a load-shed event; it is possible for the LOAD-SHED indicator to indicate "0", the respective LOAD-SHED timer to show "0", and the respective load to remain off **UNTIL** the battery voltage rises above the 12.2/24.4-volt levels.

File logging

One of the unique features of the MPPT 20A CONTROLLER is a built-in data logger file system and creates and appends several files. The file name will depend on the serial number of your device and is unique for every MPPT 20A CONTROLLER. This data **IS NOT** available for download remotely.

Example file name	Start with and extension	Type
A8CDFFAU.TXT	"AXXXXXXU.TXT"	Audit file appended twice in a 24-hour period. Created based on the system clock at noon and midnight
D8CDFFAL.CSV	"DXXXXXXL.CSV"	Data-logger CSV file containing a timestamp of all system vital signs. Data-logging intervals are determined by user defined sample interval.
D010418Y.CSV	"DMMDDYYS.CSV"	Daily data logger CSV files. File is named by using the date: mm/dd/yy
S8CDFFAL.TXT	"SXXXXXXL.TXT"	System log (syslog) contains all events the MPPT 20A CONTROLLER may have detected.
T8CDFFAR.CSV	"TXXXXXXR.CSV"	Battery charging three-day trend logs.

Table 3 -File logging formats

Device system logging

Type	Example syslog event message
Battery 12V type	Syslog: 02/01/18 14:15:23 Supporting battery type to 12-volt
Battery 24V type	Syslog: 02/01/18 14:15:23 Supporting battery type to 24- volt
Unknown type, default	Syslog: 02/01/18 14:15:23 Changed battery type to 12- volt (default)
Load-1 shed or trip	Syslog: 02/01/18 14:15:23 load1 trip [15] 12.54 volts 1.20 amps autonomy: 15
Load-2 shed or trip	Syslog: 02/01/18 14:15:23 load2 trip [0] 12.54 volts 0.60 amps autonomy: 15
Load-1 shed or trip reset	Syslog: 02/01/18 14:15:23 load1 reset [15] 12.54 volts 0.70 amps

Type	Example syslog event message
Load-2 shed or trip reset	Syslog: 02/01/18 14:15:23 load2 Reset [15] 12.54 volts 0.70 amps
Trending is less than float voltage setting	Syslog: 02/01/18 14:15:23 three days of battery charge is < VCHARGE set point
Resetting values at midnight	Syslog: 02/01/18 14:15:23 mid-reset values 11.89 volts -1.34 amps
Invalid system serial number detected	Syslog: 02/01/18 14:15:23 Invalid serial#
New production device – New system initialize	Syslog: 02/01/18 14:15:23 New production INIT
High enclosure temp. fan-1 is on	Syslog: 02/01/18 14:15:23 High temp alert 141.3F] 120.00F], FAN-1 ON
High enclosure temp reset. fan-1 is on six events	Syslog: 02/01/18 14:15:23 High temp alert reset [90.0F] [102.3F], FAN-1 OFF: 6
High enclosure temp. fan-2 is on	Syslog: 02/01/18 14:15:23 High temp alert 150.0F] 140.01F], FAN-2 ON
High enclosure temp reset. fan-2 is on 1 event	Syslog: 02/01/18 14:15:23 High temp alert reset [90.0F] [102.3F], FAN-2 OFF: 1
No deep cycle battery discharges over month period	Syslog: 02/01/18 14:15:23 No deep cycle in a month
Battery reached deep cycle six times. Total of 378 SEC	Syslog: 02/01/18 14:15:23 Deep cycle [count: 6] [Time: 378]
Battery reached deep cycle reset seven times. Total of 490 SEC	Syslog: 02/01/18 14:15:23 Deep cycle reset [count: 7] [Time: 490]
System never made >14V a total of five days	Syslog: 02/01/18 14:15:23 Never made PEAK CHR: 13.15V/0.12A DAY: 5
System parameters cleared	Syslog: 02/01/18 14:15:23 Cleared system parameters
Charging hardware (HW) forced to restart via MODBUS CMD	Syslog: 02/01/18 14:15:23 INIT INV HW via MODBUS
LOAD1 forced to cycle via MODBUS CMD	Syslog: 02/01/18 14:15:23 LOAD-1 PWR CYCLE via MODBUS
LOAD2 forced to cycle via MODBUS CMD	Syslog: 02/01/18 14:15:23 LOAD-2 PWR CYCLE via MODBUS
System parameters cleared via MODBUS CMD	Syslog: 02/01/18 14:15:23 Cleared vital via MODBUS
MPPT 20A CONTROLLER forced to restart via MODBUS CMD	Syslog: 02/01/18 14:15:23 System restart/reset via MODBUS

Type	Example syslog event message
Changed MODBUS holding register FLOAT #	Syslog: 02/01/18 14:15:23 Remote MODBUS CMD - HOLDING FLOAT
Changed MODBUS holding register 16-bit #	Syslog: 02/01/18 14:15:23 Remote MODBUS CMD - HOLDING 16-bit
Real time clock failed to restart	Syslog: 02/01/18 14:15:23 RTC Failed, Attempted Restart
No MODBUS communication in two hours. Restart MPPT 20A CONTROLLER	Syslog: 02/01/18 14:15:23 NO MODBUS COMM in 7200 SECs
System detected a battery charge fault, 12th one	Syslog: 02/01/18 14:15:23 BATT Charge fault: 12
Battery fully charged 320 times	Syslog: 02/01/18 14:15:23 BATT fully charged: 320
System restarted two times	Syslog: 02/01/18 14:15:23 System power up [2]
On of the MENU switches is stuck or not working	Syslog: 02/01/18 14:15:23 Menu SW failure
Battery life is < 44%. May need to be changed	Syslog: 02/01/18 14:15:23 BATT life health is low 45% 1155 2100
Unknown battery charger restart	Syslog: 02/01/18 14:15:23 Unexpected INV restart
Battery floating voltage out of user defined SPEC	Syslog: 02/01/18 14:15:23 VCharge restart

Table 4 – Example syslog event messages

Audit file

The MPPT 20A CONTROLLER will create then append, for the life of the MPPT 20A CONTROLLER, a system audit file. This file is updated twice in a 24-hour period: at midnight and noon. The audit file is a comprehensive vital signs, analysis and system data file containing system performance information and is used in the event an issue arises or you wish to look at the system performance. Do not remove the SD card from the MPPT 20A CONTROLLER and make sure your device has an SD card inserted. Removal of the SD should only be performed when there is a desire to copy files from the SD card to a PC then return the SD card to the MPPT 20A CONTROLLER. Failure to return the SD card to the MPPT 20A CONTROLLER will void the warranty. The following is an actual audit file.

See the Appendices for details.

Example audit file

```
>> Audit Report <<                          Up Time (sec): 8247
06/15/20 12:00:00                           Product Model Code: 201
Serial#: 0028CEC2340B0000B4                 Firmware Rev: 742
```

Hardware Rev: 702

System is in warranty. 99.97% Remaining

** Solar Info **

Solar Voltage: 40.58

Solar Current: 2.02

Solar Watts: 82.08

** BATT Info **

BATT Voltage: 13.95

Battery Charge Current: 3.96

Battery Watts: 55.32

Battery is 97.24% Full

BATT VDC MIN: 12.54

BATT VDC MAX: 14.00

BATT AMPS MIN: -1.48

BATT AMPS MAX: 13.63

BATT Compensation Temp: 85.49f

** Fan Info **

Fan1 total on Time 8149

EXT Fan total on Time: 0

Fan1 on Time last 24hrs: 8149

EXT Fan on Time last 24hrs: 0

** General Info **

Life charge Time: 0:2:15:28

Life Discharge Time: 0:0:0:47

Percent Charging 24HRS: 99.4%

Percent Discharging 24HRS: 0.5%

CPU Board power-up cycles: 0

Tamper Count: 1

Board TEMP: 92.41f

EXT TEMP: 85.29f

Deep Cycle Count/Time [Count:0] [Time:0]

Charging Cycles: 1

Full Charging Cycles: 0

BATT Maintenance ok, SCH: 1 of 30 Days

System Life Runtime: 8258 Seconds

Low Trend1: 0.00 Low Trend2: 0.00 Low Trend3: 0.00 [Day: 0]

High Trend1: 0.00 High Trend2: 0.00 High Trend3: 0.00 [Day: 0]

Total Missed 14/28vdc PEAK Count: 0

Last Contiguous missed days 14/28vdc PEAK Count: 0

** Charging Characteristics **

Total Time in Bulk: 49 SEC

Total Time in Absorb: 8105 SEC

Total Time in Float: 0 SEC

Total Time not Charging: 48 SEC

Total Time Sun Exposure: 8131 SEC 2 Hours last 24 hours

Peak/Actual Battery Amp Hours required/Installed: 600 AMPHRS 196 AMPHRS last 24 hours

Peak/Actual Solar Watts required/Installed: 1466 Watts 335 Watts last 24 hours

** Load Info **

Load 1: 1.40 Amps

Load 1: 19.58 Watts

Load 2: 0.00 Amps

Load 2: 0.00 Watts

Total Load Amps: 1.40

Total Load Watts: 19.58

Predicted Solar WATTS required based on total Load power demand: 228 Solar Watts

Predicted Battery Amp Hours required based on total Load power demand: 570 Battery Amp Hours

Load1 over-current count: 0

Load2 over-current count: 0

Did not Load-shed within the last 24HRS

**** System Analysis ****

Over the last 24 hours the system required 600 Battery Amp Hours to sustain 5 days of autonomy.

Currently have 196 Battery Amp Hours. Add 404 more Amp Hours to your system.

Over the last 24 hours the system required 1466 Solar Watts to sustain daily charging.

Solar Panel is 335 Watts. Add 1131 more Solar Watts

System maintained 2 hours of Sunshine [8131 SEC]

Predicted Number of Autonomy Days: [0 DAYS]

Predicted Number of Remaining Autonomy Days: [0 DAYS] Peak Solar Panel Watts: 217.36

No system sustainable FLAGS indicated

Data logger

The MPPT 20A CONTROLLER logs data for all system vital signs with a logging interval defined by the user. The default is 60 seconds. The logging interval may be adjusted via the LCD display or via Modbus by writing to **MODBUS AO register 40029**.

Data being logged includes the following (In order):

Logging element	Format	Notes
Real-time clock	MM/DD/YY HH:MM:SS	Time stamp
Solar voltage	Volts DC	Solar panel supply voltage
Solar current	DC amps	Solar panel supply current
Battery voltage	Volts DC	Output voltage to the battery
Battery charge current	DC amps	Output current to the battery and equipment loads
Current consumed on Load-1	DC amps	Current being consumed from equipment attached to load 1
Current consumed on Load-2	DC amps	Current being consumed from equipment attached to load 2
Enclosure temperature	-67°F to 257°F	Internal MPPT 20A CONTROLLER enclosure temperature
External temperature sensor	-67°F to 257°F	External temperature sensor probe. Typically used to measure and monitor outside ambient temperature
Battery temperature	-67°F to 257°F	Battery thermistor sensor must be secured to the battery/near the battery.
MPPT charging board temperature	-67°F to 257°F	MPPT charge controller temperature reading.
Battery rate of charge	0 – 100%	Determines how fast a battery is being discharged
Hours of sunshine last 24 hours	2-24	Hours of sun exposure onto panel in the last 24 hours
System solar watts required	0-1000	Predicted system solar watts required

Logging element	Format	Notes
Battery amp hours required for load	0-1000	Number of battery amp hours required to sustain the load
Predicted days of autonomy	0-30	Number of days the system will safely stay on without being charged.
Solar watts required on load	0-1000	Solar panel watts needed just to sustained load attached
System battery amp hours required	0-1000	Predicted system battery amps hours required
Battery temp too HOT to charge	0 / 1	Charger disabled due excessive heat
In Bulk mode	0 / 1	1 = In Bulk mode
In Absorb mode	0 / 1	1 = In Absorb mode
In Float mode	0 / 1	1 = In Float mode
Battery amps capacity real-time	0 / 1	1 = Failed battery amps capacity in real-time
Panel watts capacity sustained	0 / 1	1 = Failed panel watts capacity sustained over time

Table 5 -Example logged data

Introduction – Product anatomy – Front

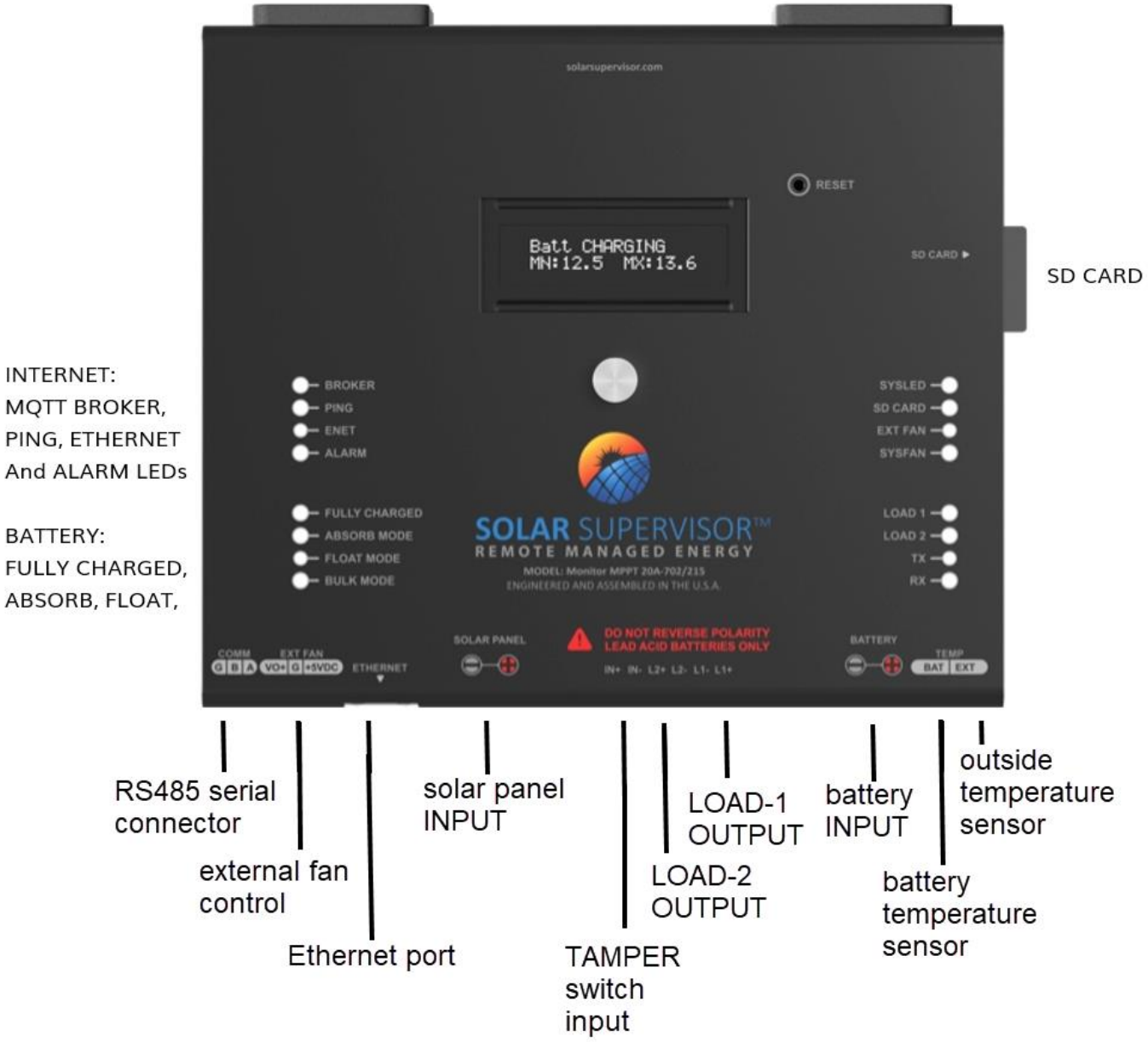


Figure 14 – Product anatomy - front

Introduction – Product anatomy – Bottom

IMPORTANT: KEEP GROUNDS SEPARATE. DO NOT CONNECT TOGETHER

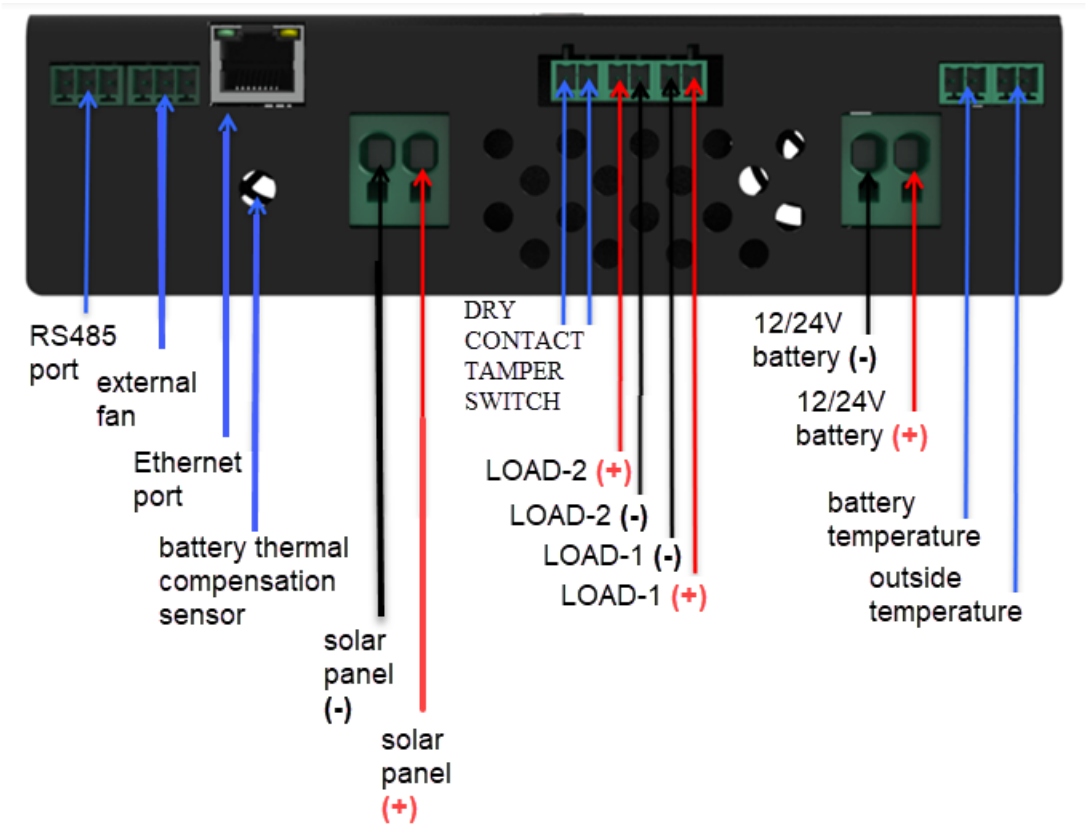


Figure 15 – product anatomy - bottom

Introduction – Product anatomy – Bottom

The MPPT 20A CONTROLLER is equipped with two 2-pin power connectors designed to accept solar panel and battery power. Use the proper gauge wire to insure the proper fit into the respective connector entry. Using the improper gauge wire may cause the wire to fall out or become loose and can reduce the performance of the system.

Removing the wire requires a small profile flathead screwdriver. Insert the screwdriver and press hard while gently pulling on the wire. This may require a significant amount of force and **care should be used to avoid slipping and causing injuries.**

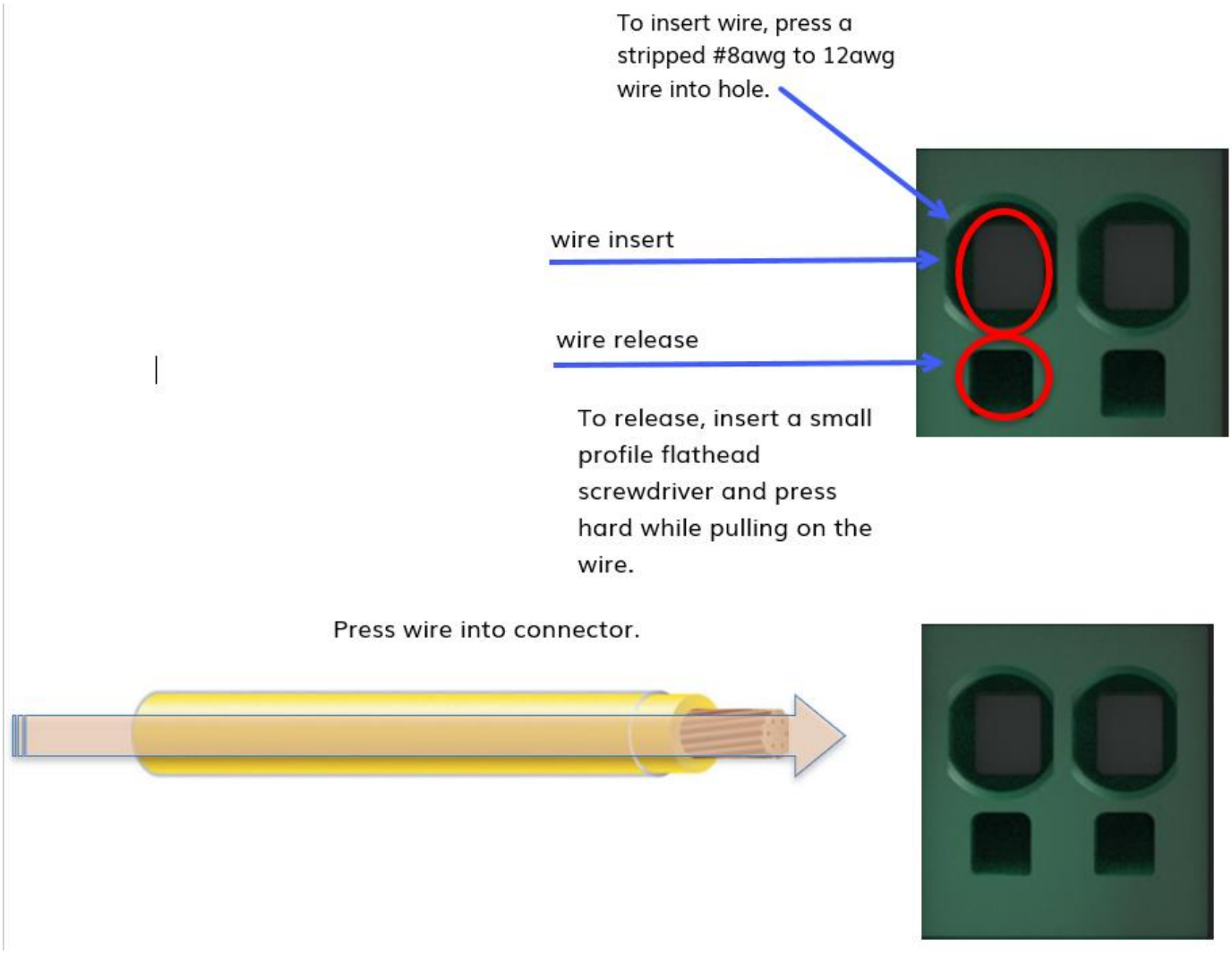


Figure 16 – Wire insertion and removal

Introduction – Product anatomy – Right side

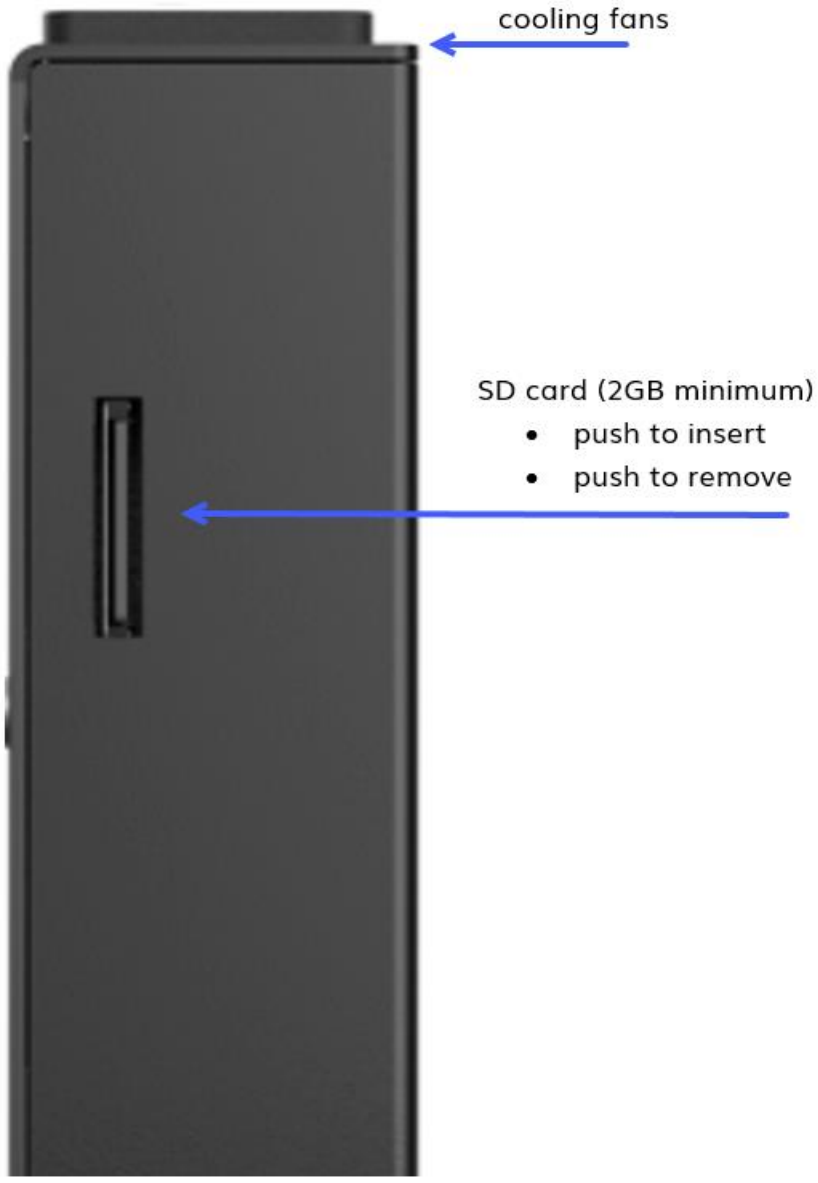


Figure 17 – Product anatomy, right side

Introduction – Product anatomy – Left side

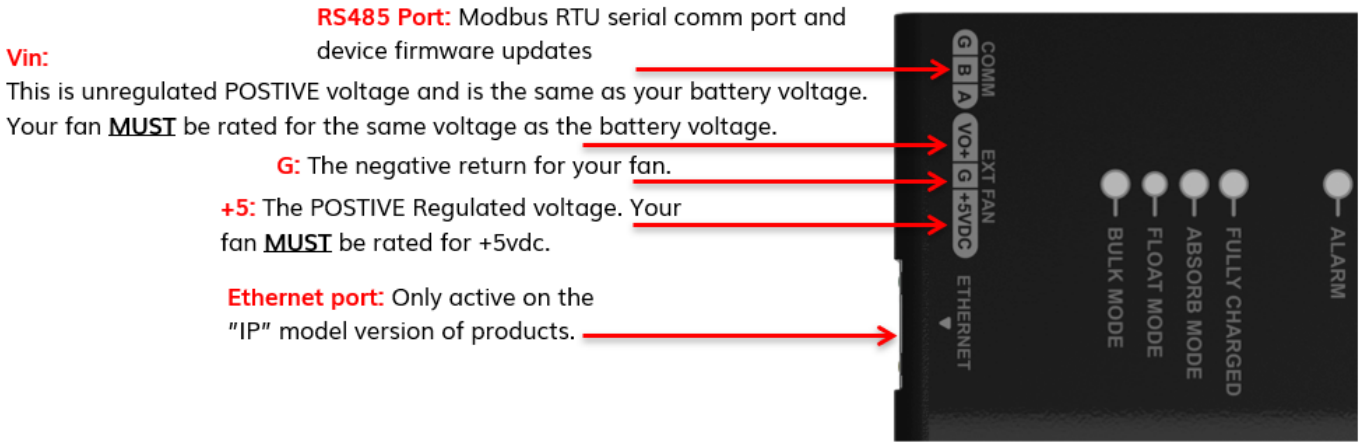


Figure 18 – Product anatomy – left side

Connectors

The MPPT 20A CONTROLLER is equipped with several types of connectors that allow for solar power input, battery power output, load connections, temperature sensors, serial communication, battery temperature and tamper switch. This section will describe each connector, its respective function and how to connect.

KEEP RESPECTIVE GROUNDS SEPARATE, DO NOT SHARE OR CONNECT GROUNDS TOGETHER

DO NOT MAKE CONNECTIONS WITH POWER APPLIED TO THE DEVICE. TURN OFF ALL CIRCUIT BREAKERS, MAKE CONNECTIONS THEN APPLY POWER.

Solar power input

The MPPT 20A CONTROLLER accepts most 12/24vdc solar panels with the MAX Vin/Voc <= 52vdc. Use a high-quality solar panel that meets your system needs when specifying your system.

It's important to use the proper size panel. Use the appropriate wattage for your application. Do not exceed 52vdc on the solar input, component damage will occur. ALWAYS USE A CIRCUIT BREAKER BETWEEN THE PLUS "+" LEAD OF THE SOLAR PANEL TO THE MPPT 20A CONTROLLER. FAILURE TO DO SO MAY LEAD TO DAMAGE OR FIRE. See the following figure.

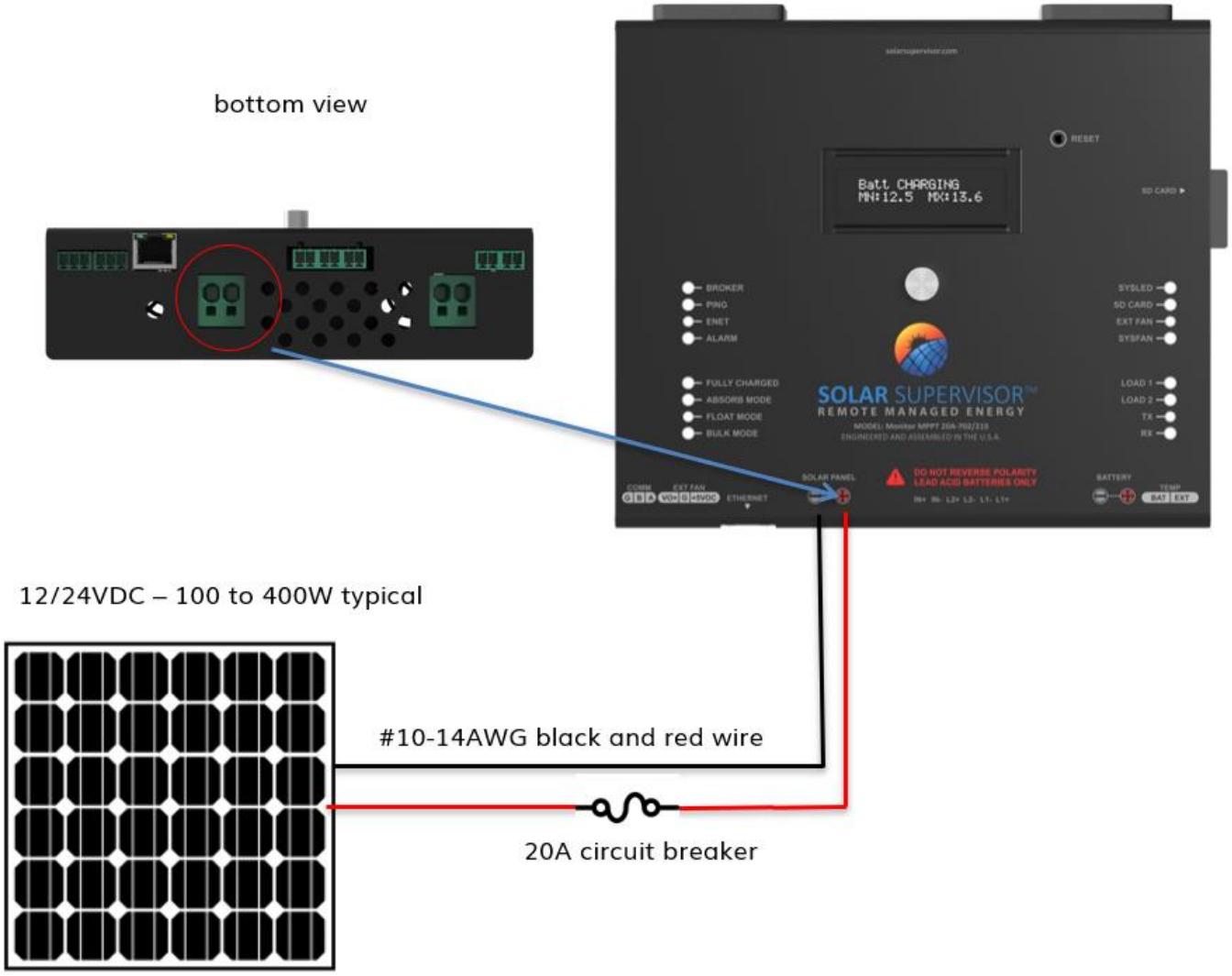


Figure 19 - Connectors

Typical solar specifications

The following are examples of typical solar panel specifications and definitions. Specifications will vary and may differ significantly from manufacture to manufacture.

Voltage at maximum power point (Vmpp) and Current at maximum power point (Impp) are the key numbers for any solar panel and define the electrical point at which the panel is operating at peak efficiency, the maximum power point. (Vmpp x Impp) should always give you Pmax (the maximum rated power output of a solar panel). When you wire different panels in parallel, you should try to match the Vmpp so that the panels work well together. And when you wire panels in series, try to match the Impp.

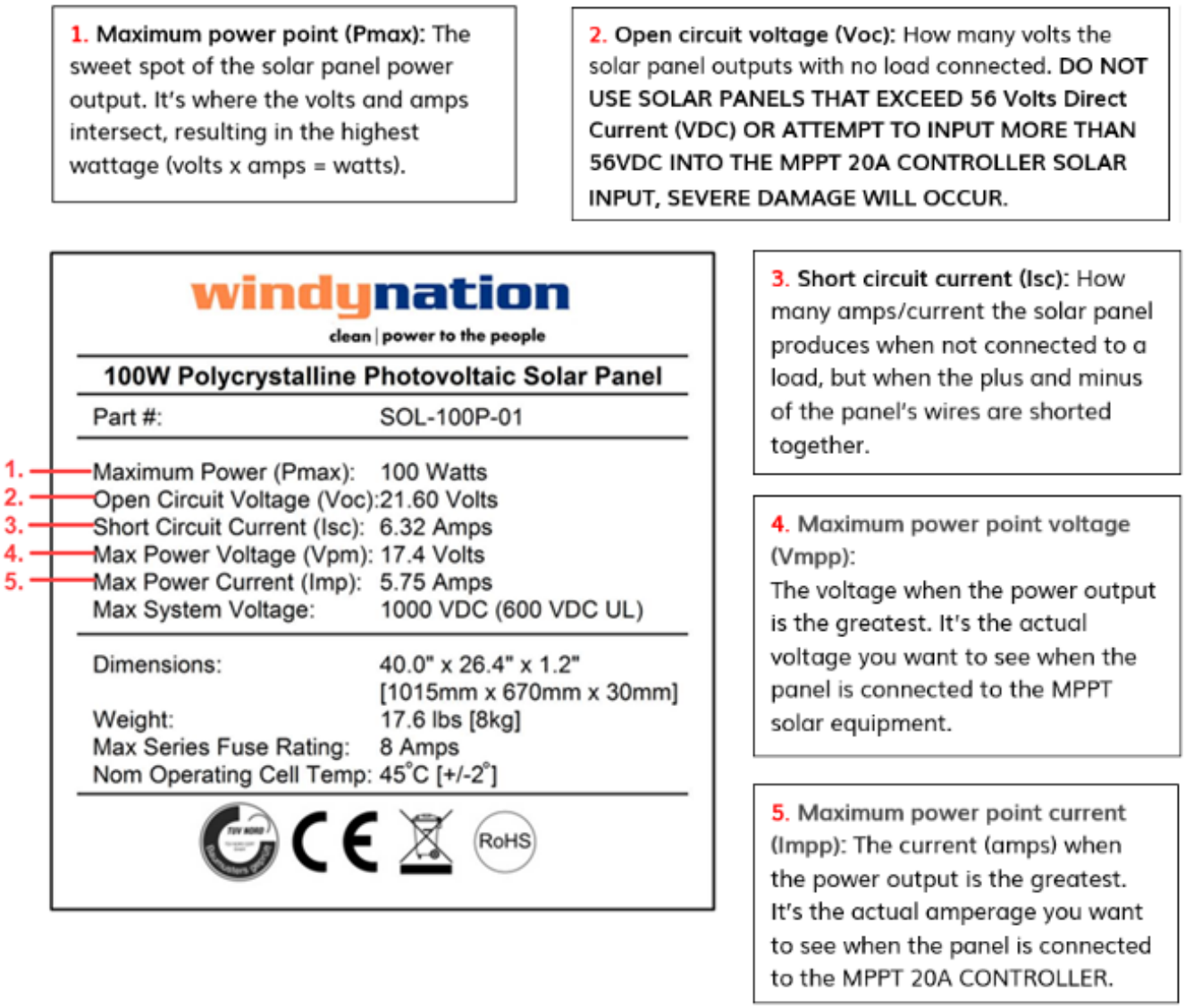


Figure 20 – An example of typical solar panel specifications

An example of a Pulse Width Modulation (PWM) controller

Technology	Panel voltage	Vmp	Panel supply amps	Battery absorb voltage	Max battery changing current
PWM	12V	18V	8A	14.0	8A
MPPT	20V	32V	9A	14.0	20A

Table 6 – PWM vs. MPPT controllers

The MPPT 20A CONTROLLER is designed with a highly efficient MPPT to match the solar panel output to the battery's needs. This type of technology is much different than the typical PWM type battery charger.

As outlined in the example above; MPPT more efficiently uses the power developed by the solar panel where the PWM technology cannot. An MPPT controller will provide an additional 20 to 25% of charging capability, when compared to standard PWM technology.

What is an MPPT charge controller?

The functioning principle of an MPPT solar charge controller is rather simple - due to the varying degree of sunlight or irradiance, landing on a solar panel throughout the day, the panel voltage and current continuously changes. To generate the most power, the maximum power point tracker sweeps through the panel voltage to find the 'sweet spot' or the best combination of voltage and current to produce the maximum power. The MPPT is designed to continually track and adjust the voltage to generate the most power, no matter what the time of day or weather conditions might be. (**Note:** only high-end MPPT controllers can detect partial shading or track multiple power points). Using MPPT technology, the solar panel efficiency increases, and the amount of energy generated is up to 30% more than a PWM solar charge controller.

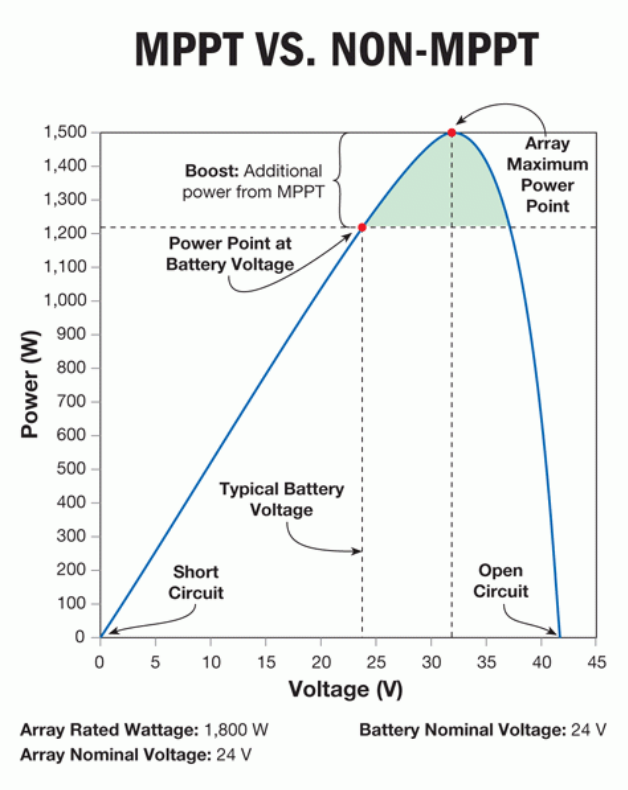


Figure 21 - MPPT vs. non-MPPT

Batteries charge only if the output voltage of the solar panel is greater than that of the batteries and facilitates a flow of current from the panel to the battery.

The output voltage of the panel depends on different factors, including the weather and the amount of sunlight on the panel (irradiance). On a sunny day the output voltage may be higher than the rated output voltage, while during a cloudy day the output voltage is probably less.

Normal charge controllers do not have the capacity to utilize this higher output voltage to deliver more power. However, MPPT charge controllers can adjust the voltage to get a boost of current during times of peak demand in such conditions.

MPPT delivers a higher than rated charge to the battery, because MPPT controllers can adjust the voltage to current ratio.

What do you mean by MPPT "optimize"?

Most PV panels are built to output a nominal 12 volts. The catch is "nominal". In fact, almost all "12-volt" solar panels are designed to output from 16 to 18 volts. The problem is that a nominal 12-volt battery is close to an actual 12 volts - 10.5 to 12.7 volts, depending on state of charge. While being charged, most batteries need from around 13.2 to 14.4 volts to fully charge - quite a bit different than what most panels are designed to produce.

MPPT optimization example 1

As an example of a solar panel rated at 7.39 amps at 17.6 volts or 7.39 amps X 17.6 volts produces 130 watts.

So, what happens when you connect the example 130-watt panel to your battery through a non-MPPT charge controller? Unfortunately, your system will not use the full 130 watts.

- Your panel outputs 7.4 amps.
- Your battery is sitting at 12 volts under charge: 7.4 amps times 12 volts = 88.8 watts.
- 88.8 – 130 = 41.2 watts, your system lost over 41 watts – but your panel is 130 watts.
- 41 watts will not be used. The 41 watts are not being produced because there is a poor match between the panel and the battery.
- With a very low battery; for example, 10.5 volts, the problem is even worse - you could lose as much as 35% (10.5 volts x 7.4 amps = 77.7 watts. Your system lost about 53 watts.
- The lost power is getting converted into heat. It's not actually missing; it's just not usable by the charge controller.

Other issues to consider are that the panels are rated at 130 watts at full sunlight at a particular temperature standard test conditions (STC). If the temperature of the solar panel is high, you don't get 17.4 volts. At the temperatures seen in many hot climate areas, you might get under 16 volts. If you start with a 15-volt panel (like some of the so-called "self-regulating" panels), you are in trouble, as you won't have enough voltage to develop a difference between the panel and battery to put a charge into the battery. Solar panels must have enough leeway built in to perform under the worst of conditions.

Using 12-volt batteries

When using **12V batteries** the panel voltage drop is not a big issue because most “12V” solar panels operate in the 18V to 22V range, which is much higher than the typical 12V battery charge voltage of 14.1V. “24V” solar panels are not a problem as they operate in the 30V to 40V range.

Using 24-volt batteries

When using **24V** batteries there is no problem when two or more solar panels are connected in series, but there is an issue when only one solar panel is used. Most common 25-volt solar panels have a Vmp of 30V to 34V. While this is higher than the battery charging voltage of around 28V, the problem arises when the panel temperature increases on a very hot day. The panel voltage can drop by up to 6V and end up well below the 28V battery charge voltage, preventing it from fully charging.

MPPT optimization example 2

- Panel maximum power current (Imp) = 5.0A

- Panel maximum power voltage (Vmp) = 18vdc
- Battery voltage = 13vdc (battery voltage can vary between say 10.8vdc fully discharged and 14.4Vdc during absorption charge mode).

PWM vs. MPPT

At 13Vdc the panel amps will be slightly higher than the maximum power amps – for example, 5.2A.

With a PWM controller the power drawn from the panel is 5.2A * 13V = 67.6 watts.

This amount of power will be drawn regardless of the temperature of the panel if the solar panel voltage is sustained above the battery voltage.

With MPPT, the power from the panel is 5.0A * 18V = 90 watts, i.e., 25% higher.

However, this is overly optimistic, as the voltage drops and as the temperature increases. Assuming the panel temperature rises to say 30°C above the standard test conditions (STC) temperature of 25°C and the voltage drops by 4% for every 10°C (a total of 12%), then the power drawn by the MPPT will be 5A * 15.84V = 79.2W, 17.2% more power than the PWM controller. There is an increase in energy production with MPPT, but the percentage increase in production varies significantly over the course of a day.

Solar panel VMP and where MPPT is most effective

This section gives some guidance on the panel size to select to get the most from MPPT.

Battery system voltage	Panel VMP	MPPT effectiveness
12	Greater Than 19.0Vdc	Highest
24	Greater Than 34.0Vdc	Highest
12	Within 17Vdc to 19Vdc	Moderate
24	Within 30Vdc to 35Vdc	Moderate
12	Less Than 13.0Vdc	Boost required
24	Less Than 26.0Vdc	Boost required

Table 7 – Solar panel VMP and where MPT is most effective

The Solar Supervisor series controllers use MPPT Buck/Boost and will work well in all regions.

Something to consider when using 24-volt batteries

Engineers will often use two 12-volt batteries to produce 24-volts. The thinking is that this is more efficient, or that equipment attached has a 24-volts DC input requirement. If equipment attached to a

load consumes an amp of current at 12-volts and ½ amp at 24-volts, this does not make the system more efficient. Watts are watts, and nothing can change that fact.

Let's look at the math. 12-volts @ 1 AMP = 12watts, 24-volts @ ½ amp = 12watts. If the goal is to design a system that can sustain itself in bad conditions, using the same two 12-volt batteries placed in series and connecting them in parallel to create 12-volts at double the AMP HOURS would almost double the hours of autonomy. Then, using a DC-to-DC converter to convert the 12-volts to 24-volts for equipment that require 24-volts would create a system that increases the discharge time of batteries.

Charging voltage above 2.15 volts per cell will charge a lead acid battery. 12-volt batteries have six-cells, and 24-volt batteries have 12-cells. This also means that nothing below 2.15 volts per cell will do any charging (12.9V for a 12V battery). However, a higher voltage is often used because it forces the charging reaction at a higher rate. Charging at the minimum voltage takes a long time to complete a full charge. As you increase the voltage to get faster charging, the voltage to avoid is the gassing voltage, which limits how high the voltage can go before undesirable chemical reactions take place. The typical charging voltage is between 2.15 volts per cell (12.9 volts for a 12V 6 cell battery) and 2.35 volts per cell (14.1 volts for a 12V 6 cell battery). These voltages are appropriate to apply to a fully charged battery without overcharging or damage. If the battery is not fully charged you can use much higher voltages without damage because the charging reaction takes precedence over any over-charge chemical reactions until the battery is fully charged. This is why a battery charger can operate at 14.4 to 15 volts during the bulk-charge phase of the charge cycle.

MPPT 20A CONTROLLER charging specs

Charging mode	Voltage target/limit – 12V system	Voltage target/limit – 24V system	Time
Bulk	14.28vdc	28.56vdc	Varies
Absorb	14.28vdc	28.56vdc	four hours
FLOAT	13.65vdc	27.30vdc	Remains through night discharge

Table 8 – MPPT 20A CONTROLLER charging specs

The following table shows the average effective output expected per day from summer to winter, with older technology PWM controllers, and newer MPPT (Maximum Power Point Tracking) technologies. While in good solar conditions the difference is not so great. In winter and marginal light, the MPPT controllers can produce between 20- to 30% more from the same solar source.

True production of solar panel production – usable daily average								
Solar panel watts	Season							
	SUMMER				WINTER			
	PWM		MPPT		PWM		MPPT	
90 W	18Ahr	252W	20Ahr	280W	10Ahr	140W	13.5Ahr	189W
120 W	29Ahr	406W	32Ahr	448W	16Ahr	224W	21.6Ahr	302W
140 W	34Ahr	476W	38Ahr	532W	21Ahr	294W	28.7Ahr	402W
190 W	45.5Ahr	637W	50Ahr	700W	25Ahr	350W	33.8Ahr	473W

Table 9 - True production of solar panel production – usable daily average

Battery output

The MPPT 20A CONTROLLER accepts most 12/24vdc lead acid batteries. Use high quality batteries that meet your requirements and are sized correctly. Total AMP HOURS must be configured/entered into the MPPT 20A CONTROLLER. This can be accomplished by using the LCD/Menu PAGE-24 or via MODBUS holding register 40026. MODBUS holding register 40026 is a 16-bit integer. For example, if you connected two 98 AMP HOURS batteries in parallel the total system AMP HOURS is now 196 AMP HOURS. "196" must be entered into MPPT 20A CONTROLLERs via MODBUS holding register 40026 OR via the LCD PAGE 24.

Located on the bottom side of the enclosure are 2 x two-pin connectors used to connect the battery and external temperature sensors.

DO NOT OPERATE OR ATTEMT TO USE LITHUM TYPE BATTERIES WITH THIS DEVICE. RISK OF FIRE OR DAMAGE MAY OCCUR.

THE TOTAL BATTERY VOLTAGE CONFIGURATION CANNOT EXCEED A TOTAL 24 VDC. DAMAGE WILL OCCUR IF MORE THAN TWO 12-VOLT BATTERIES ARE PLACED IN SERIES.

DO NOT MAKE CONNECTIONS WITH POWER APPLIED TO THE DEVICE. TURN OFF CIRCUIT BREAKER BEFORE APPLYING BATTERY POWER.

ALWAYS USE A CIRCUIT BREAKER BETWEEN THE PLUS "+" LEAD OF THE BATTERY TO THE MPPT 20A CONTROLLER. FAILURE TO DO SO MAY LEAD TO DAMAGE OR FIRE.

See the following diagram.

Battery output overview

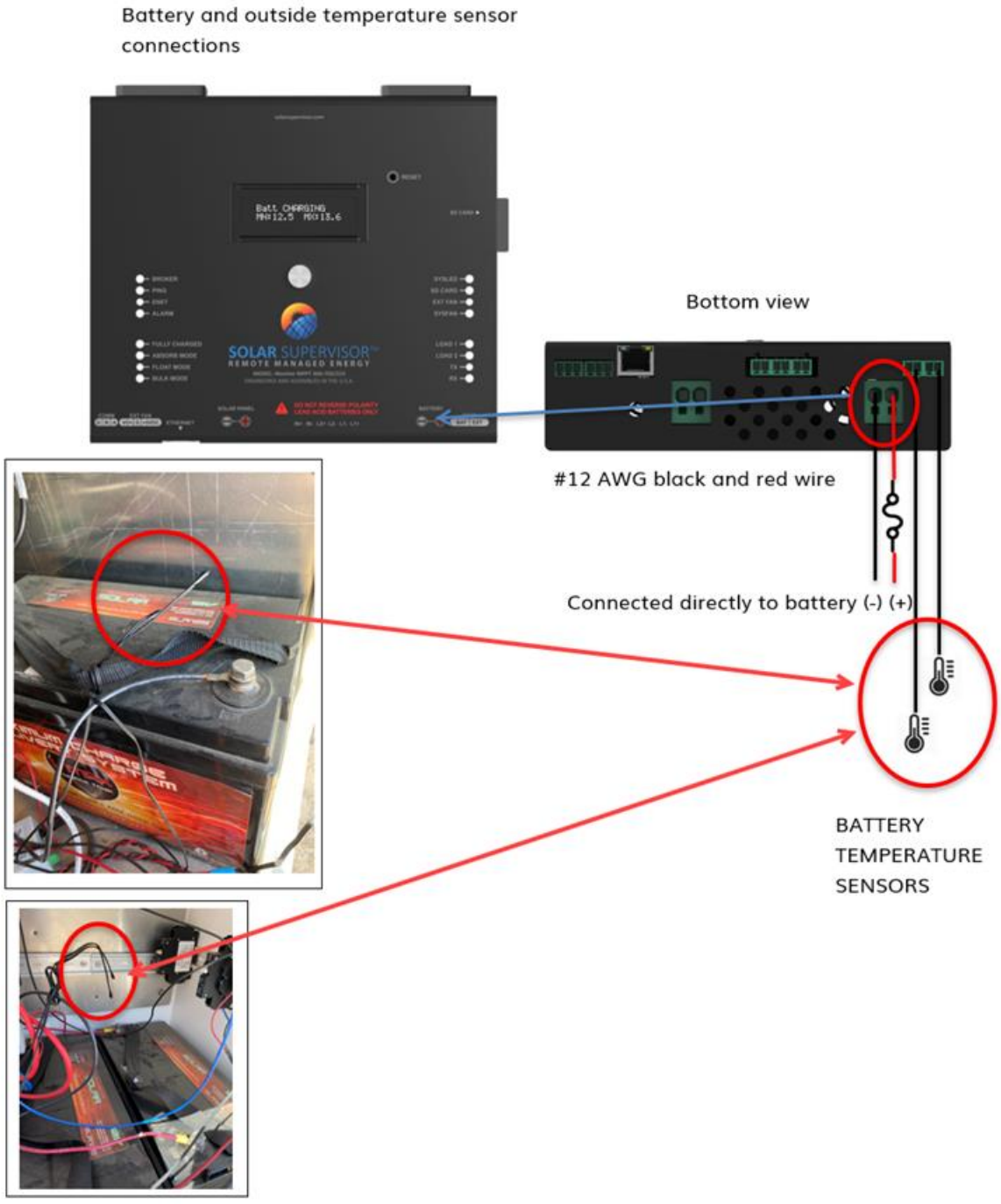


Figure 22 – Battery and outside temperature sensor connections

Battery output types

There are several ways to increase battery supply voltage or amp-hours or both.

Connecting two or more of the same battery type in parallel will increase system current/AMP-HOUR capacity whereas connecting the same battery type in series will increase the system voltage.

THE TOTAL BATTERY VOLTAGE CONFIGURATION CANNOT EXCEED A TOTAL OF 31 VDC. DAMAGE WILL OCCUR IF MORE THAN TWO 12-VOLT BATTERIES ARE PLACED IN SERIES.

Always use the same type/model number, voltage, and Amp-Hour rating of battery.

Battery output types – parallel connection

The following example demonstrates a typical method of increasing the system Amp-Hours (AHR). This type of configuration is used to double current capacity and hours of autonomy. The following figure shows two 12V lead-acid batteries rated at 99AHR each. By connecting the (+) battery post from both batteries together and connecting the (-) posts together as shown will increase the system amp-hour capacity and hours of autonomy. This type of configuration increases the time that the batteries can supply current to the loads. Amp-hours add, if the system had two 99AHR batteries @ 12V each, the system rating would be 12V @ 198AHR. **DO NOT CONNECT THE (+) POST TO THE (-) POST OF THE BATTERIES. FIRE WILL OCCUR.**

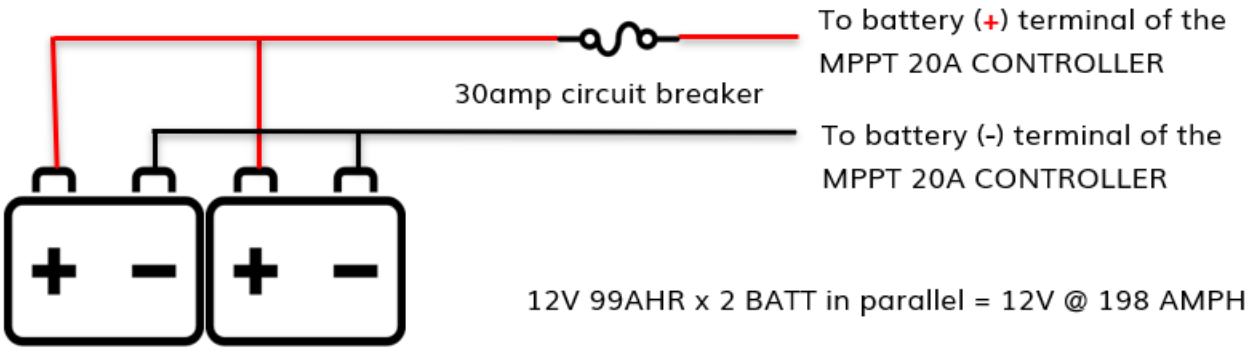


Figure 23 - A typical method of increasing the system amp-hours (AHR).

12 volt charging characteristics								
Typical voltage	*Absorption voltage peak	*FLOAT voltage	Load-1 low/reset shed voltage limits		Load-2 low/reset shed voltage limits		Deep cycle limit/reset	
12.5vdc	14.2vdc	13.6	11.6vdc	12.2vdc	11.8vdc	12.2vdc	<11.5vdc	>12.3vdc

Table 10 – 12 volt charging characteristics

Battery output types – Series connection

The following example shows a typical method of increasing the system operating voltage. This type of configuration is used to increase voltage capacity by connecting the (+) battery post from ONE Battery and the (-) post of the second battery, as shown below will increase the system voltage. The AHR's will remain as spec'd on each battery. **NOTE:** +24~30.5V system battery voltage will appear on the LOAD-1 and LOAD-2 Outputs. Be sure the equipment being attached to a respective LOAD output is rated for +24VDC. Damage will most likely occur if the equipment being attached is not rated for > 24VDC.

THE TOTAL BATTERY VOLTAGE CONFIGURATION CANNOT EXCEED A TOTAL 31 VDC. DAMAGE WILL OCCUR IF MORE THAN TWO 12-VOLT BATTERIES ARE PLACED IN SERIES.

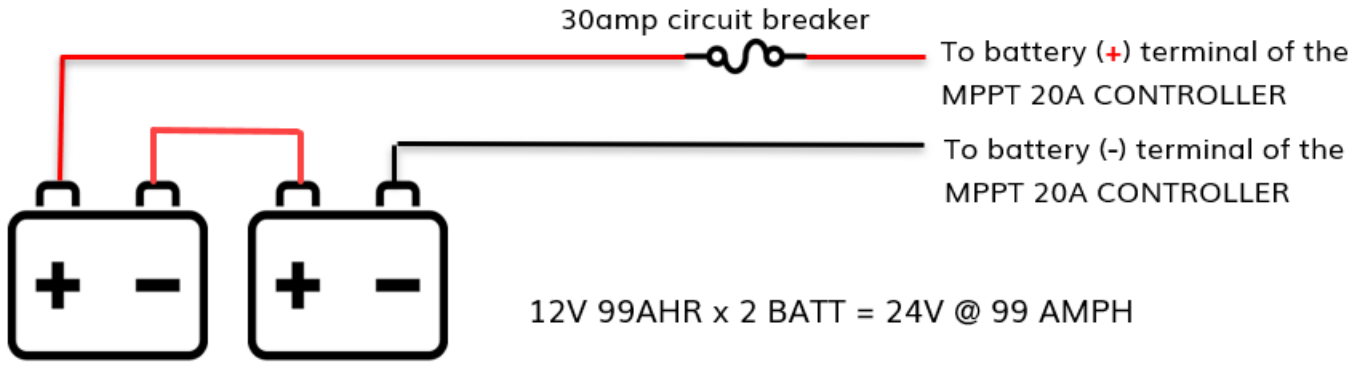


Figure 23 - A typical method of increasing the system operating voltage

24 volt charging characteristics								
Typical voltage	Absorption voltage peak	FLOAT voltage	Load-1 low/reset shed voltage limits		Load-2 low/reset shed voltage limits		Deep cycle limit/reset	
25.0vdc	28.4vdc	27.40	23.2vdc	24.4vdc	23.6vdc	24.4vdc	<23.0vdc	>24.6vdc

Table 11 – 24 volt charging characteristics

WARNING: IT IS POSSIBLE FOR VOLTAGES TO BE UNEVEN ACROSS THE TWO SERIES BATTERIES. THIS IS AN INHERENT RISK IN CONNECTING TWO UNBALANCED BATTERIES IN SERIES. THIS ISSUE BECOMES WORSE AS BATTERIES AGE.

FOR EXAMPLE, THE SYSTEM INDICATEs THE BATTERIES ARE BEING CHARGED AT 28.2 VOLTS, BUT IN REALITY, ONE BATTERY IS BEING CHARGED AT 15.4 VOLTS AND THE OTHER BATTERY IS BEING CHARGED AT 12.8 VOLTS. THIS IS CAUSED BY TWO UNBALLANCED BATTERIES.

DO NOT ALLOW BATTERIES TO BE OVER CHARGED. THIS IS A FIRE HAZARD.

Battery voltage levels vs. % full

Charge	12-V battery	24-V battery
100%	12.7	25.44
90%	12.5	25.0
80%	12.42	24.84
70%	12.32	24.64
60%	12.2	24.4
60%	12.20 LOAD 1&2 RESET	24.40 LOAD 1&2 RESET
50%	12.06	24.12
40%	11.9	23.8
32%	11.80 LOAD-2 SHED	23.60 LOAD-2 SHED
30%	11.75	23.5
23%	11.60 LOAD-1 SHED	23.20 LOAD-1 SHED
20%	11.58	23.16
10%	11.31	22.62
0%	10.5	21.00

Table 12 – Battery voltage levels vs. % full

Load output

The MPPT 20A CONTROLLER has two independent outputs to supply power to third-party equipment. As indicated in prior sections of this manual: if your system is configured to support 24Vdc, 24-to-30.4 vdc may appear as the supply voltage to all devices connected to LOAD-1 and LOAD-2. Damage may occur if any product connected to LOAD-1 or LOAD-2 does not support voltages in this range. Verify voltage INPUT specifications BEFORE connecting devices to any load outputs.

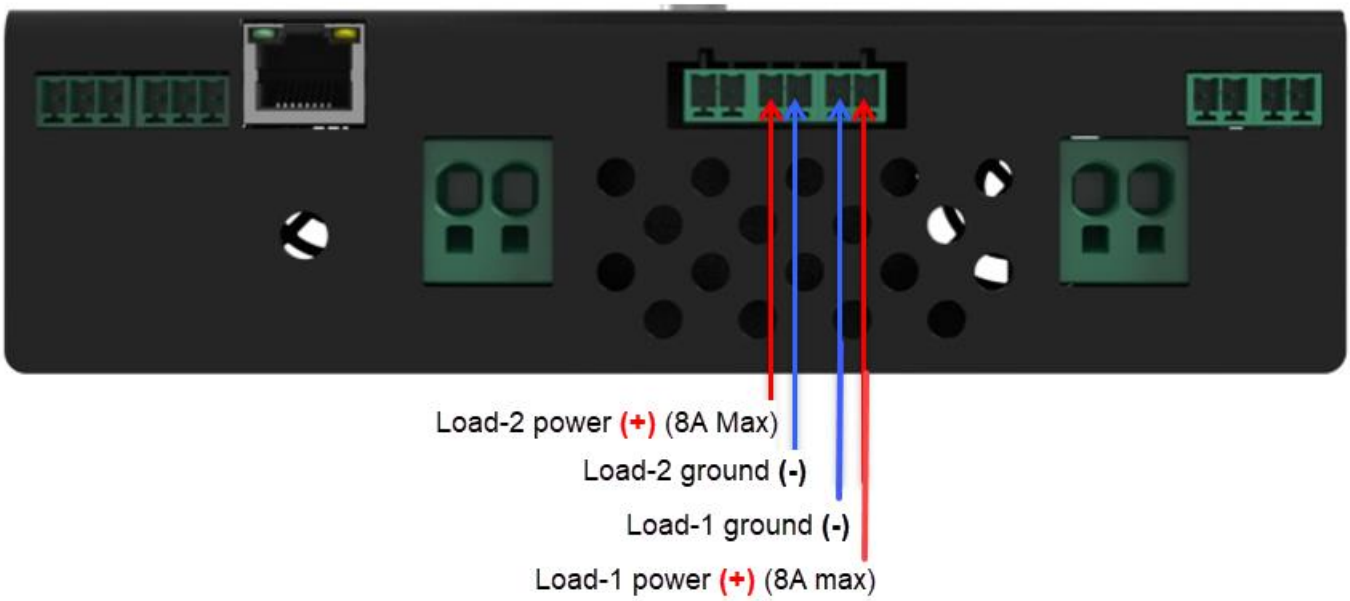
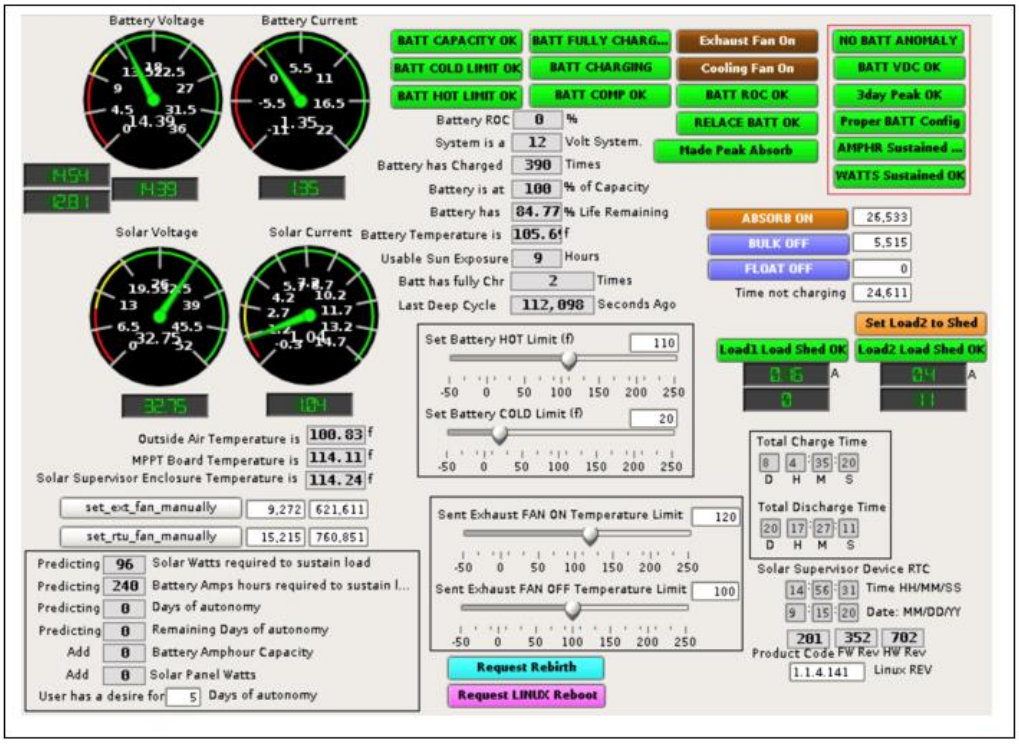


Figure 24 – Load output

Introduction – Sample SCADA system

The following figure is an example of a SCADA system displaying some of the critical measurements.

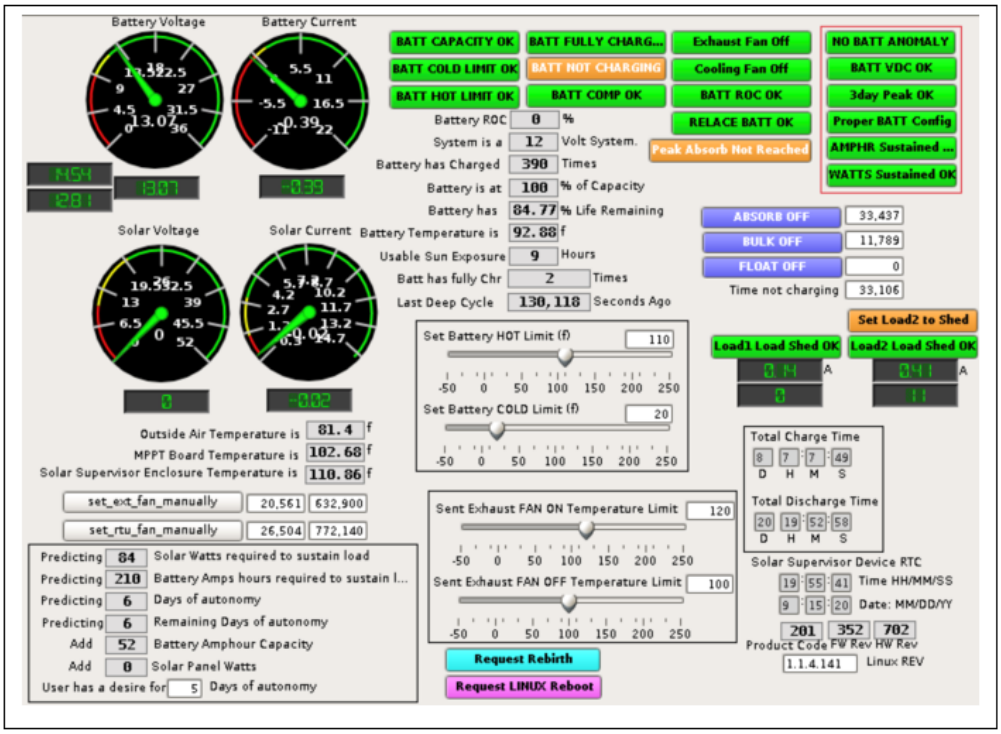
Day/nighttime system charging SCADA



Example showing solar site system under proper charge. This SCADA system is showing a normal operating system:

- DAY CONDITIONS
- COOLING FAN ON
- EXHAUST FAN ON
- IN ABSORB MODE
- NO LOAD SHED
- 5 DAYS OF DESIRED AUTONOMY

Figure 25 – A solar site system under proper change



Example showing solar site system under discharge conditions. This SCADA system is showing a normal operating system:

- NIGHT CONDITIONS
- BATT NOT CHARGING
- COOLING FAN OFF
- EXHAUST FAN OFF
- NO LOAD SHED
- 5 DAYS OF DESIRED AUTONOMY
- 6 DAYS OF CALCULATED DAYS OF AUTONOMY

Figure 26 – A solar site system under discharge conditions

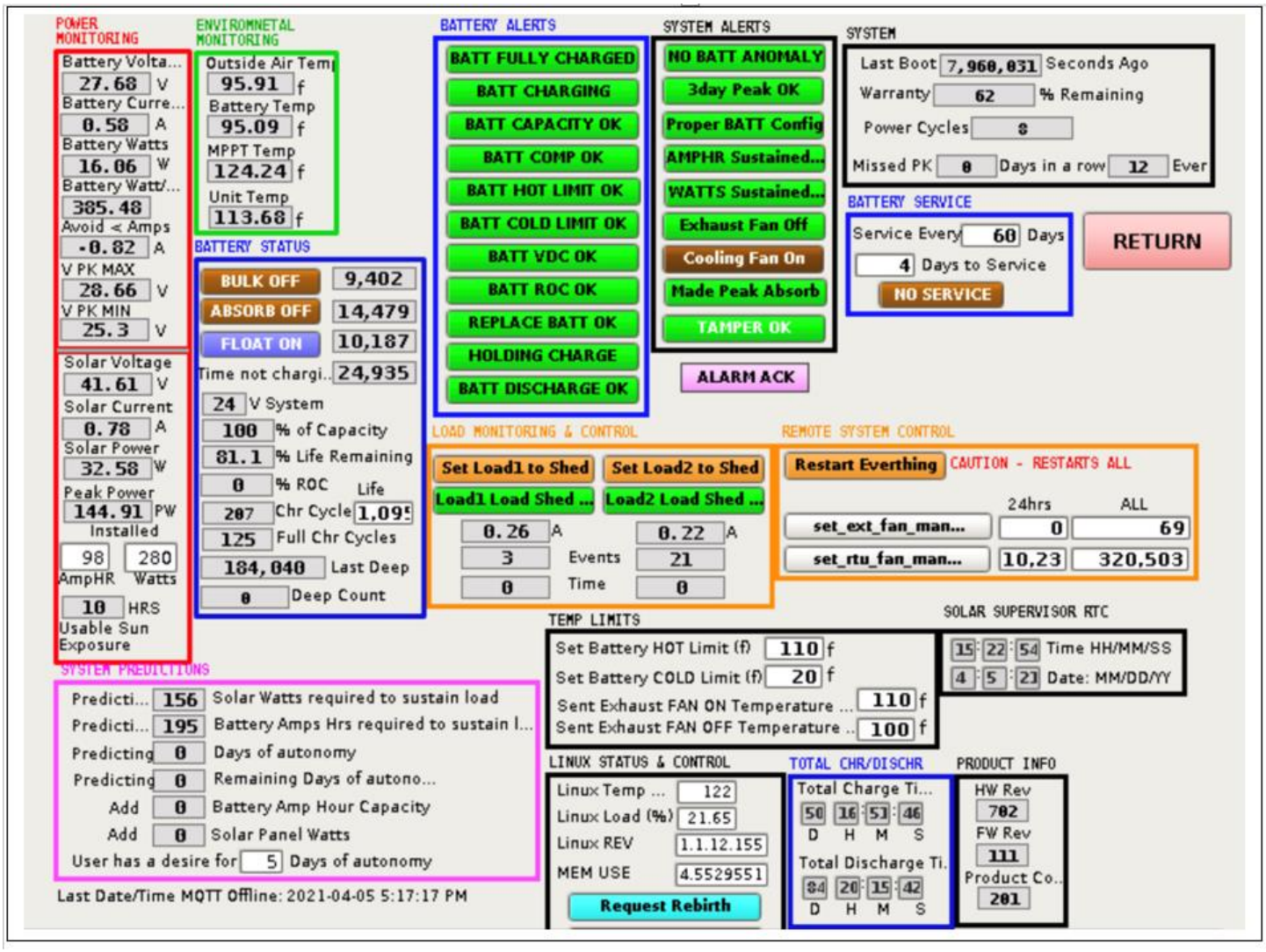


Figure 27 – A sample SCADA system

Introduction – Sample SCADA system – Power monitoring

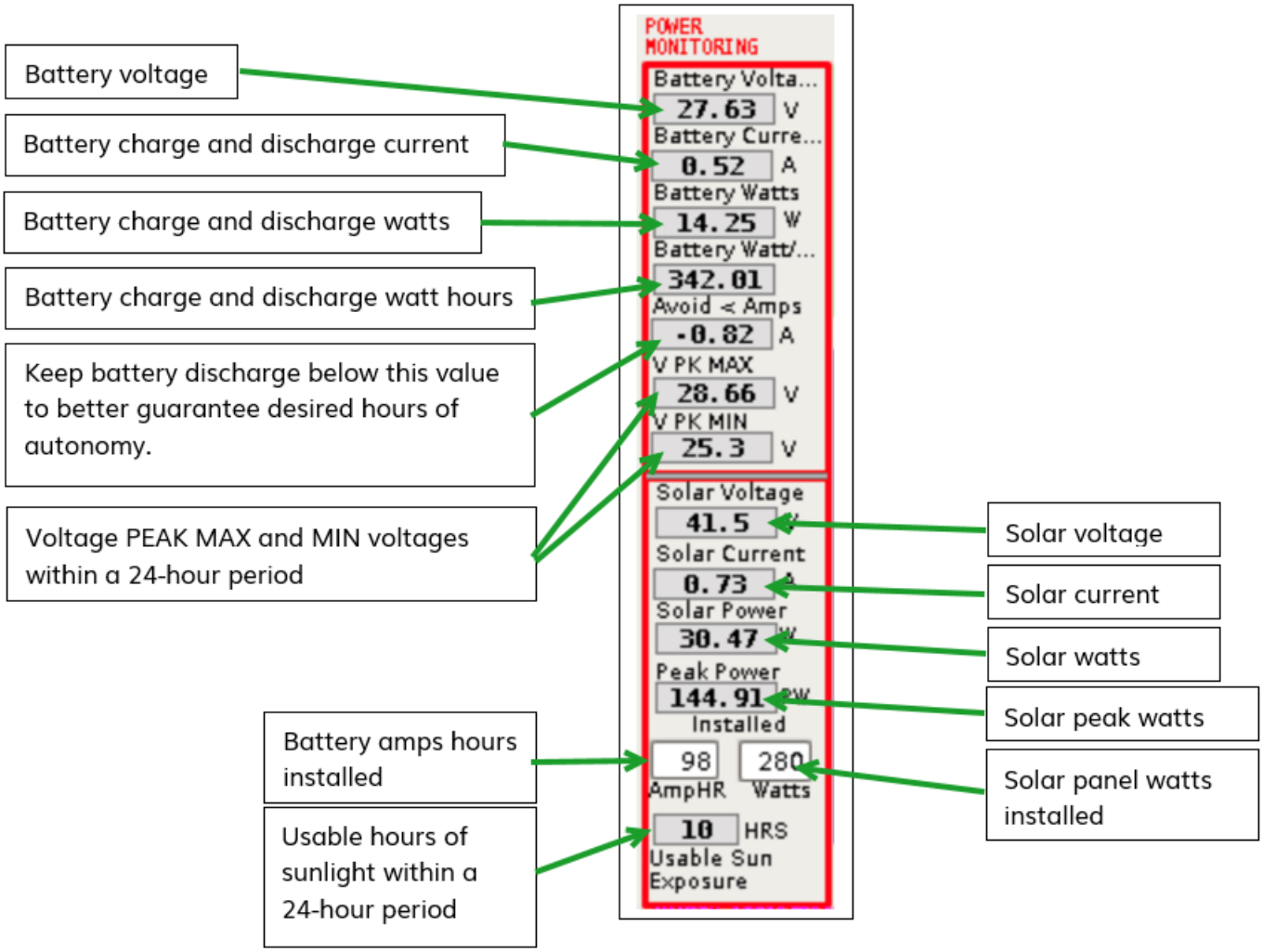


Figure 28 – A sample SCADA system: power monitoring

Introduction – Sample SCADA system – Environmental monitoring

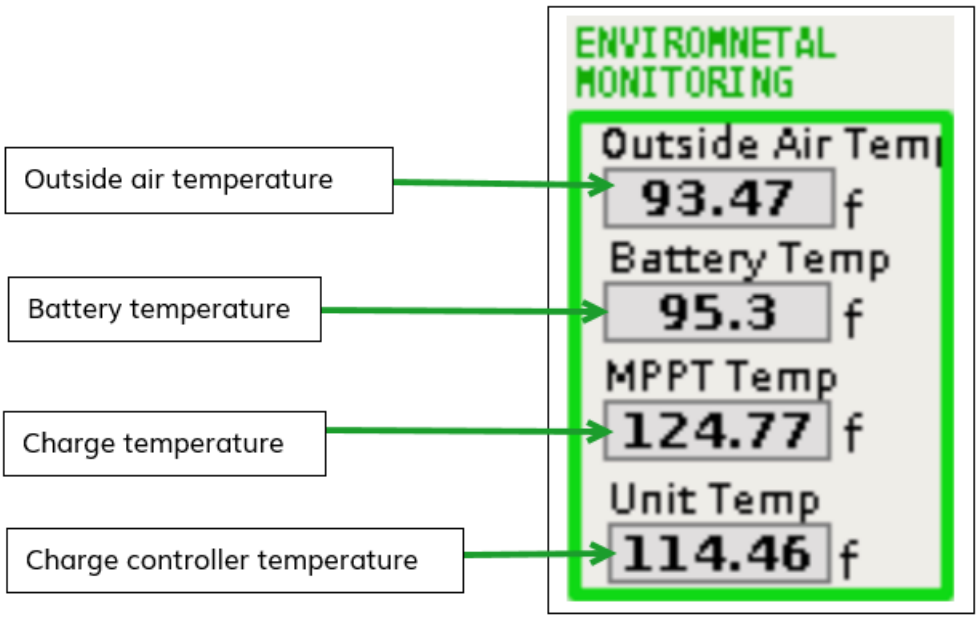


Figure 29 – A sample SCADA system: environmental monitoring

Introduction – Sample SCADA system – Charging status

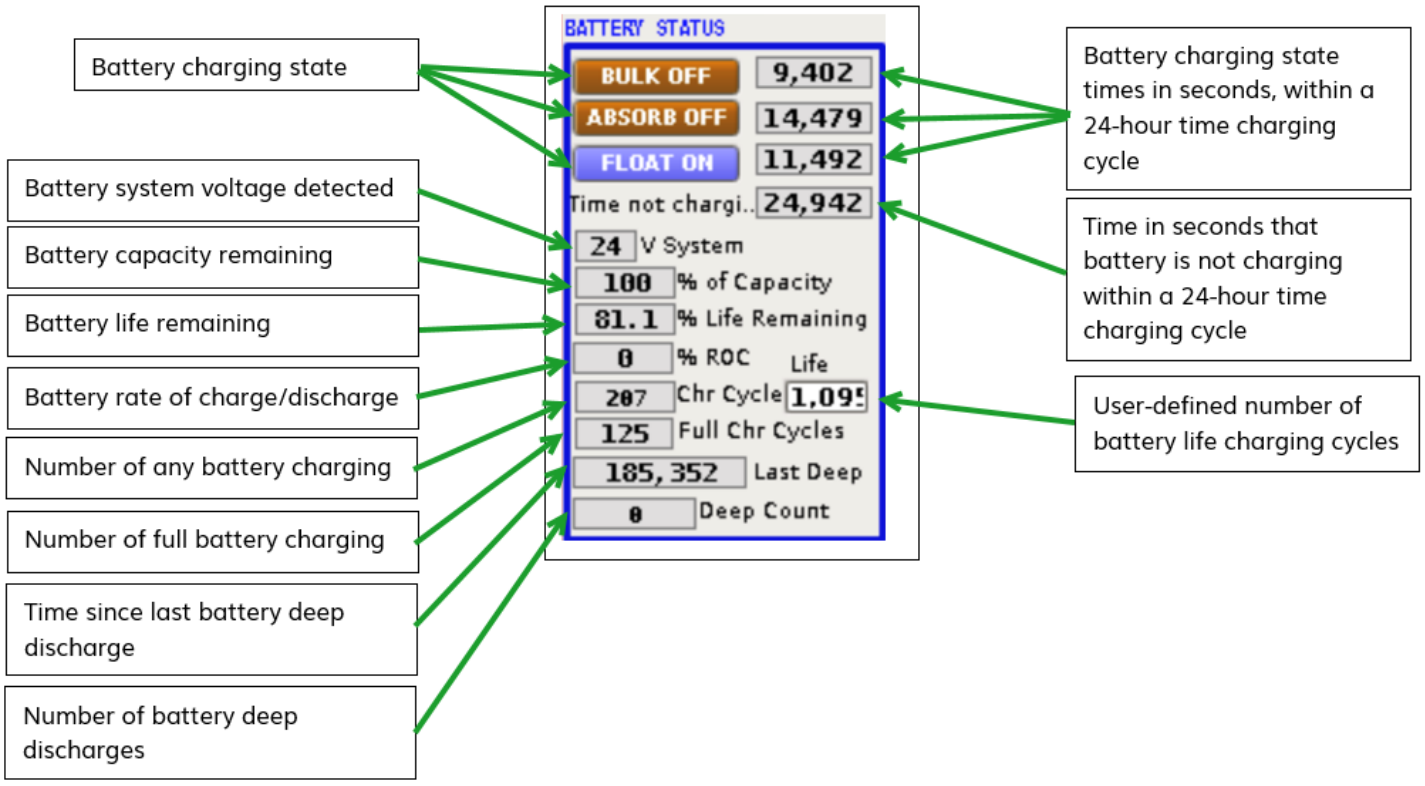


Figure 30 – A sample SCADA system: changing status

Introduction – Sample SCADA system – Load stats

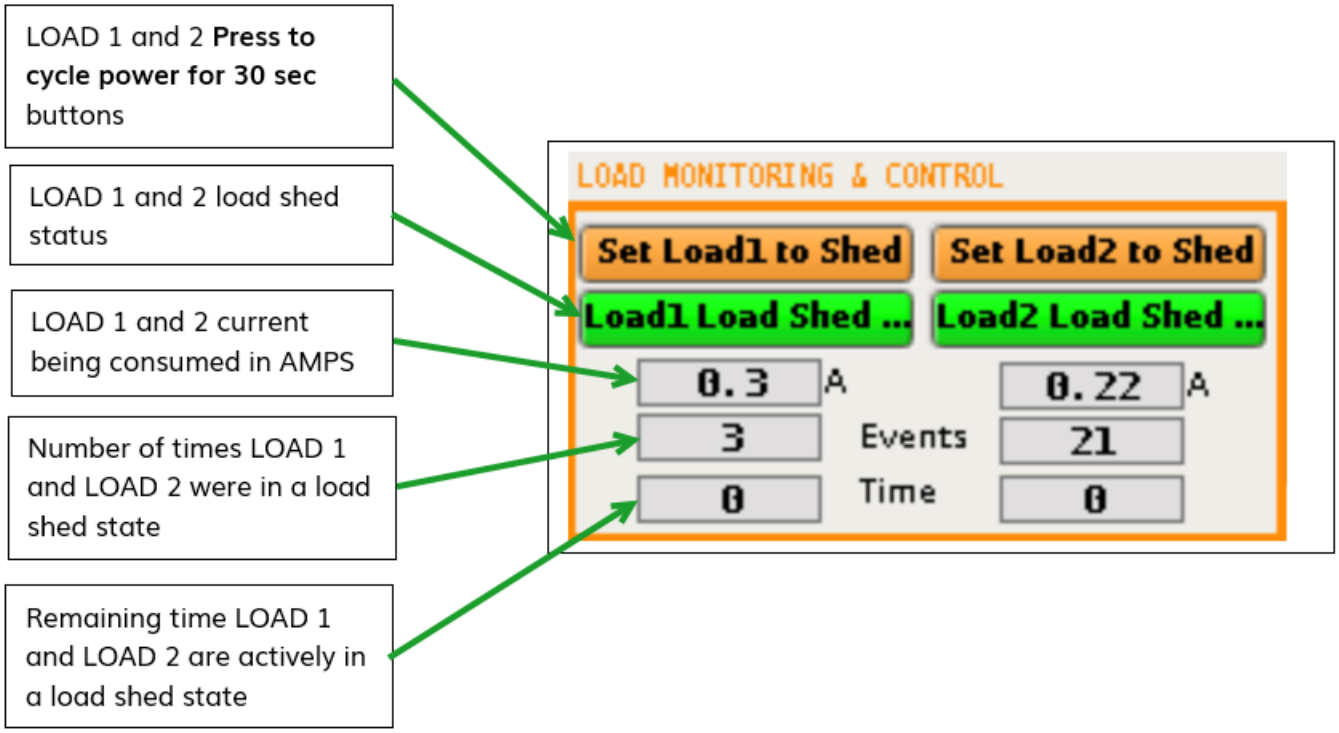


Figure 31 – A sample SCADA system: load stats

Introduction – Sample SCADA system – Alerts

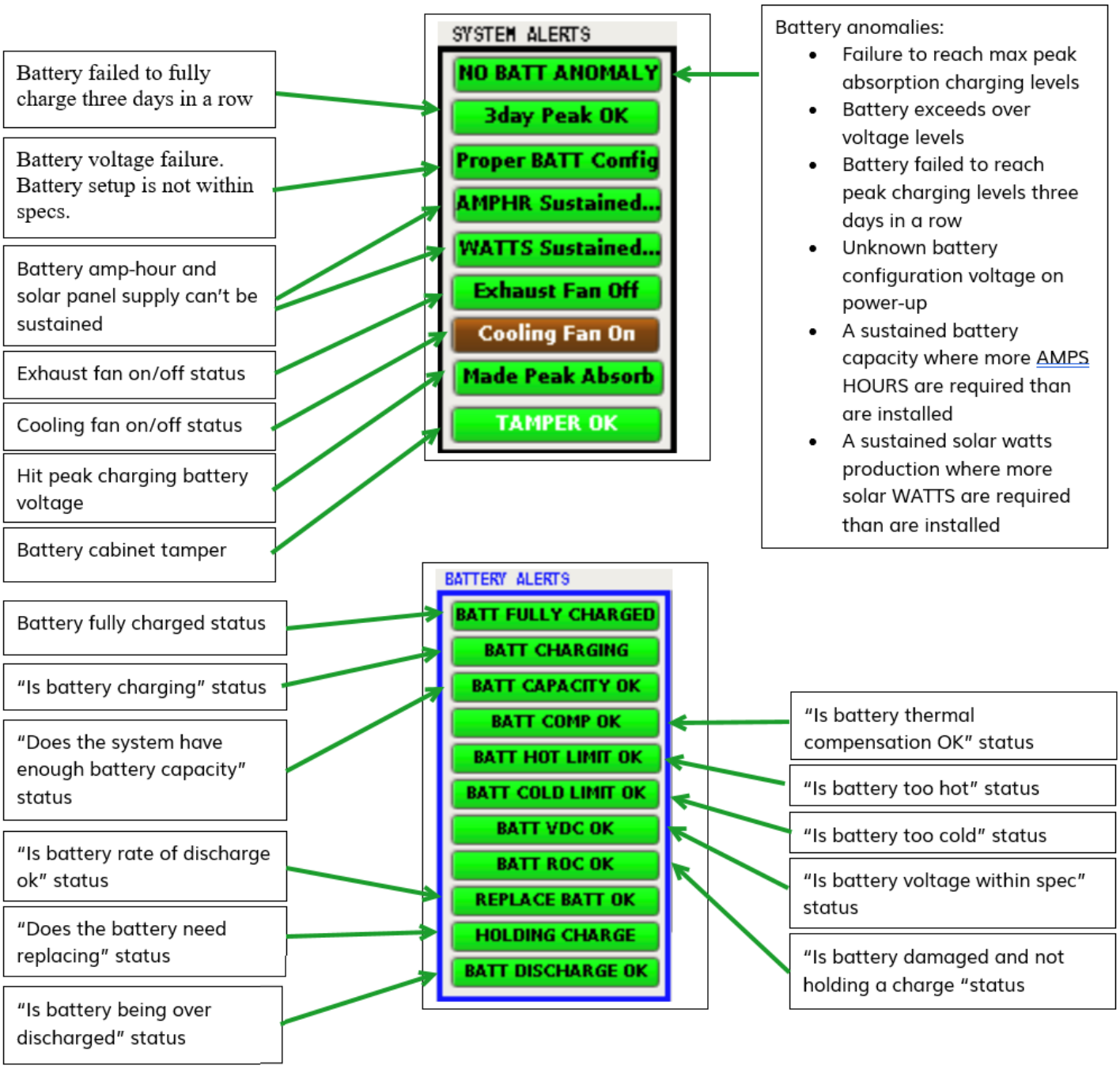


Figure 32 – A sample SCADA system: alerts

Introduction – Sample SCADA system – Predictions

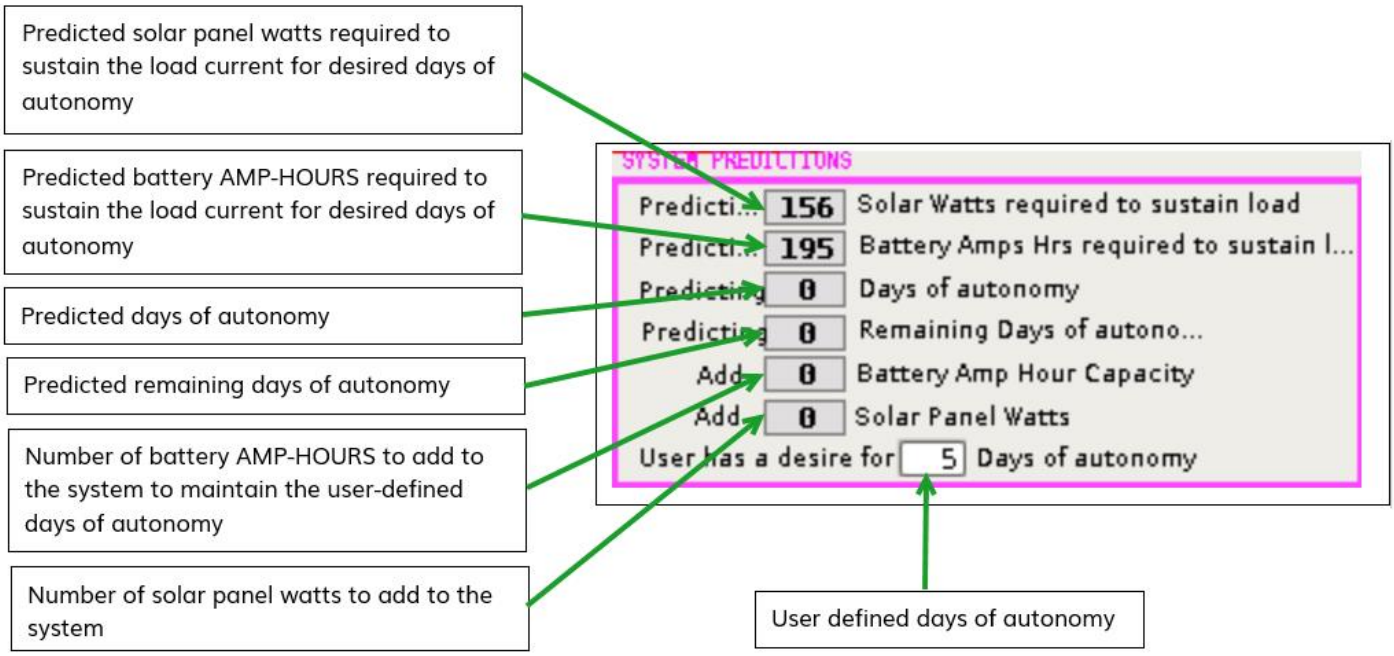


Figure 33 – A sample SCADA system: predictions

Introduction – LED status indications

LED STATUS		LED LABEL	DESCRIPTION
Active	Not Active		
		Broker	LED ON = Connected to MQTT broker
		Ping	LED ON = Can ping the internet
		Enet	LED ON = Ethernet cable plugged into Ethernet port
		Alarm	LED ON = Alarm is active
		Alarm	Blinking = Alarm has been acknowledged and no other alarms are active
		Fully Charged	LED ON = Battery is fully charged and hit peak absorb voltage
		Fully Charged	Blinking = Battery is fully charged but missed peak absorb voltage
		Absorb Mode	LED ON = In Absorb Charging mode
		Absorb Mode	Blinking = In Absorb Charging mode but missed peak absorb voltage
		FLOAT Mode	LED ON = In FLOAT Charging mode
		Bulk Mode	LED ON = In Bulk Charging mode
		Bulk Mode	Blinking = Battery temperature limits violated
		SYSLED	Blinking 1/sec = System is working
		SYSLED	Blinking in Concert with RX LED = MODBUS data is meant for this device
		SD CARD	Random Blinking = data activity being written to SD card
		EXT FAN	LED ON = Fan is on
		SYSFAN	LED ON = Fan is on
		LOAD-1	LED ON = Load-1 is disabled and equipment attached to LOAD- is off
		LOAD-2	LED ON = Load-2 is disabled and equipment attached to LOAD-2 is off
		TX	Random blinking = data activity being transmitted via a RS485 port
		RX	Random blinking = data activity being received via a RS485 port

Ledged

 LED blinking

 LED steady on

 LED off

Table 13 – LED status indications

Introduction – Product anatomy description

Listed within this section are descriptions of each "user-facing" indicator or device such as LEDs, sensors, cooling fans, LCD display, WIRE-PUSH type terminals, menu rotary, menu knob, and so on. Also listed are any respective Modbus registers that may be supported by the respective user-facing system. This section does not cover all Modbus functions/registers; more detailed information on Modbus is listed in other sections of this manual.

Solar Supervisor's cooling fan		
MODBUS Register - DI		Description
FAN status	10004	MPPT 20A CONTROLLER is equipped with two cooling fans. These fans will begin to circulate air when: 1) The enclosure air temperature reaches120F OR 2) The battery temperature sensor reaches 110F OR 3) The battery charging current exceeds 7.50 amps The FAN will continue running until 1) The enclosure air temperature falls below 110F AND 2) The battery temperature falls below 100F AND 3) The battery charging current falls below 7.50 Amps The cooling fans will be disabled if the MPPT 20A CONTROLLER's LOAD-1 AND LOAD-2 are both in an active load-shed. The purpose is to keep the battery from deep discharging damaging the battery or batteries.
Manually set fan ON	00011	Manual control of the cooling fan is possible by setting MODBUS COILS Register 11 to "1". The fan will remain on no matter the above conditions and until this register is set to "0".

Table 14 – Indicators – cooling fan

Battery fully charged LED		
MODBUS Register-DI		**Description**
Battery fully charged	10000	Flashes green when the battery has not reached the PEAK absorb voltage but is greater than 99% battery capacity. Solid green when fully charged; the battery has reached the PEAK absorb voltage and is greater than 99% battery capacity. The Modbus Digital Input register will indicate "1" with the BATT is fully charged and "0" when the BATT is not fully charged. While in a temperature fault the "FULLY CHARGED" and "BULK" LEDs will flash in concert.

Table 14 – Indicators – "Battery fully charged" LED

Bulk state LED		
MODBUS Register-DI		Description
Battery in Bulk Mode	10001	Flashes yellow if the system detects a battery temperature above 122.00f (Compensation Failure). Solid yellow when the system is in BULK charging mode. Modbus Digital Input register will indicate "1" when in BULK mode and "0" when not in BULK mode. While in a temperature fault, the "FULLY CHARGED" and "BULK" LEDs will flash in concert.

Table 15 – Indicators – Bulk state LED

Absorb state LED		
MODBUS Register-DI		Description
Battery in Absorb Mode	10043	Flashes yellow when in absorb mode but has not hit the peak absorb voltage. Modbus Digital Input register will indicate "1" when in ABSORB mode and "0" when not in ABSORB mode. Solid yellow when in Absorb mode and has hit the peakAabsorb voltage.

Table 16 – Indicators – Absorb state LED

Charge fault LED		
MODBUS Register - DI		**Description**
Digital Input	10003	Remains solid RED LED when a charge anomaly has occurred. Anomalies include: • NEVER MADE PEAK ABSORB VOLTAGE • BATTERY VDC TO HIGH • FAILED TO REACH PEAK ABSORB VOLTAGE THREE DAYS IN A ROW • UNKNOWN BATTERY VOLTAGE CONFIG • A SUSTAINED NEED FOR MORE SOLAR CAPACITY • A SUSTAINED NEED FOR MORE BATTERY CAPACITY The charge fault indication is reset at midnight.

Table 17 – Indicators – Change fault LED

FLOAT state LED		
MODBUS Register -DI		**Description**
Battery in FLOAT mode	10002	Solid yellow when in float mode. The Modbus Digital Input register will indicate “1” when in FLOAT mode and “0” when not in FLOAT mode. Off when not in float mode. It is possible the system never enters FLOAT mode; some of the causes are higher battery temperatures and time charging in absorb mode.

Table 18 – Indicators – FLOAT state LED

2x16 LCD display	
MODBUS register	**Description**
NONE/Does not apply	The LCD display shows system information such as battery voltage, battery current, solar voltage, solar current, and so on., as well as giving the user the ability to configure some parameters such as the Modbus slave address, system amp hours, and so on. More information about all displayed data and configuration is listed in this manual.

Table 19 – Indicators – 2 x 16 LCD display

Menu knob encoder	
MODBUS register	**Description**
NONE/Does not apply	The **Menu** knob allows the user to advance the display, to show system measurements as well as charging/system status. The **Menu** knob rotates LEFT and RIGHT by 360° as well as pressing as a select button when making configuration changes.

Table 20 – Indicators – 2 x 16 LCD display

System reset		
MODBUS Register - DO		Description
Remote system reset/restart	00028	To reset the MPPT 20A CONTROLLER, use a small paper clip type object to press the reset button. Do not use objects that may fall into the enclosure. The MPPT 20A CONTROLLER can be remotely reset via Modbus commands. This causes the charging process to stop, and all equipment on LOAD-1 and LOAD-2 is powered down for approximately one minute before powering up again. Reset the MPPT 20A CONTROLLER only as a last resort.
		Writing a "1" to MODBUS HOLDING register 00028 DO location remotely forces the MPPT 20A CONTROLLER to restart. Once a "1" is written to MODBUS register 00028, the MPPT 20A CONTROLLER stops communications for approximately two minutes, and the MPPT 20A CONTROLLE restarts and begins to communicate.

Table 21 – Indicators – System reset

System OK LED	
MODBUS Register	Description
NONE/Does not apply	The System OK LED (SYSLED) has a dual purpose: • A sanity indicator • A Modbus ID active indicator There may be times when the MPPT 20A CONTROLLER appears to have no activity. The SYSLED indicator flashes once a second to give you an indication the controller is functioning. If the "SYSLED" LED fails to flash, the MPPT 20A CONTROLLER is potentially damaged. The MPPT 20A CONTROLLER is equipped with a WDT with a timeout of 128 seconds and will automatically restart if the device is locked up.
	The "SYSLED" LED will BLINK in concert with the MODBUS RX LED **IF** valid Modbus data is received **AND** the data being received is for the respective device. This is a great troubleshooting tool when troubleshooting SCADA issues.

Table 22 – Indicators – System OK LED

MODBUS TX LED	
MODBUS register	Description
NONE/Does not apply	Blinks when the MPPT 20A CONTROLLER is sending data

Table 23 – Indicators – MODBUS TX LED

MODBUS RX LED	
MODBUS Register	**Description**
NONE/Does not apply	Blinks when the MPPT 20A CONTROLLER is receiving data

Table 23 – Indicators – MODBUS RX LED

External temperature sensor port		
MODBUS Register -AI		Description
External temperature sensor	30030-31 floating point	The external temperature sensor is designed to monitor external temperature, such as outside ambient temperature. The proper cable gland must be used to penetrate the equipment cabinet to allow the temperature sensor to be mounted outside the equipment cabinet. The external temperature measurement is displayed on the LCD display as well as a MODBUS register and MQTT TAG. The temperature range is –55°C to +125°C or -67°F to +257°F.

Table 23 – Indicators – External temperature sensor port

Introduction – Product anatomy – Right side

SD card data LED		
MODBUS Register - DI		Description
SD card inserted	10027	The SD DATA LED blinks anytime data is being written to the SD card. The SD DATA LED will not blink if the SD card is not installed. MODBUS DI register 10027 will indicate a “1” if the SD card is installed and a “0” if the SD card is not installed or not seated correctly. Do not operate the MPPT 20A CONTROLLER without an SD card installed. Equipment warranty will be void. Use a FAT32 formatted SD cards with no less than 2GB memory space.

Table 23 – Product anatomy – right side – SD card data LED

Introduction – Product anatomy – Bottom

RS-485 communications port
Description
The RS-485 interface is used to communicate with a MODBUS RTU SCADA system. Valid serial port data speeds are: 4800, 9600, 119200, 38400, 57600 and 115200. Data rates can only be configured via the MPPT 20A CONTROLLER menu switches. Fixed serial port settings are "N,8,1". Default settings are 9600, N, 8, 1.

Table 23 – Product anatomy – bottom – RS-485 communications port

Battery temperature sensor port		
MODBUS Register –AI/DO		**Description**
Battery temperature	30026-27 Floating point	Use only the temperature sensor provided. Do not replace it with a third-party temperature sensor. The battery temperature is displayed in actual temperature in Fahrenheit and is available on the LCD display as well as a MODBUS register and MQTT TAG. This is not the thermal compensation temperature sensor but reflects the actual battery temperature.

Table 24 – Product anatomy – bottom – Battery temperature sensor port

External fan OUTPUT and LED		
MODBUS registers		**Description**
Ext Fan On/Off (DI)	10005	If the battery temperature exceeds the HIGH temperature setting in **MODBUS HOLDING REGISTER 40000-01** the external exhaust-cooling fan comes on and remains on until the temperature falls below the LOW temperature setting in **MODBUS HOLDING REGISTER 40002-03**. The external exhaust cooling fan is not included and is sold separately. The fan may be remotely forced ON by writing a "1" to **MODBUS HOLDING register 00010 and** will remain on regardless of other conditions until a "0" is written to **MODBUS HOLDING register 00010**. The external fan is disabled if the MPPT 20A CONTROLLER's LOAD-1 AND LOAD-2 are both in an active load-shed. The purpose is to keep the battery from deep discharging, which would damage the battery or batteries.
EFAN HI Limit (AO)	40000-01	
EFAN LO Limit (AO)	40002-03	
Set exhaust manually ON (DO)	00010	
Exhaust fan ON time last 24hrs (AI)	30093	

Table 25 – Product anatomy – bottom – External fan OUTPUT and LED

Voltage output to battery		
MODBUS register - AI		**Description**
Battery voltage	30000-01 Floating point	A series of WIRE-PUSH type wire connections as well as connector type connections are located on the bottom of the MPPT 20A CONTROLLER. The right series of WIRE-PUSH connections labeled "BATTERY" are the voltage output connections used to directly connect the system's battery to the MPPT 20A CONTROLLER. Make sure to use a circuit breaker. Do not exceed 31VDC. **DO NOT REVERSE POLARITY. DAMAGE WILL OCCUR.**

Table 26 – Product anatomy – bottom – Voltage output to battery

Voltage input from solar panel		
MODBUS register - AI		**Description**
Solar panel voltage	30016-17 Floating point	A series of WIRE-PUSH type wire terminal connections and removable type connections are located on the bottom of the MPPT 20A CONTROLLER. The left two connections labeled "SOLAR PANEL" are the solar panel voltage input connections used to connect the systems solar power to the MPPT 20A CONTROLLER. Make sure to use a circuit breaker Do not exceed 52VDC. **DO NOT REVERSE POLARITY. DAMAGE WILL OCCUR.**

Table 27 – Product anatomy – bottom – Voltage input from solar panel

LOAD1 and LOAD2 shed and LEDs		
MODBUS Register – DI/DO		**Description**
LOAD -1 load-shed	10006	LOAD1 and LOAD2 LEDs show a solid YELLOW when LOAD-1 or LOAD-2 is in an active load-shed. *Load-shed* is when power is removed by the controller from the loads connected to LOAD-1 or LOAD-2 for a period of time. Current measurements for LOAD-1 and LOAD-2 are independent. The purpose of Load-shedding is to keep from damaging the battery. Draining the battery of capacity below 11.5VDC may permanently damage the battery. Excessive load-sheds are an indicator of an under-designed system, bad battery, or bad solar panel. This is designed to allow the battery some time to recuperate. Over-current faults cause a ten-minute delay before attempting to re-power a load. Low voltage faults are delayed for 20 minutes before attempting to re-power a respective load output AND the battery voltage MUST be greater than 12.2VDC for 12V systems and 24.4V for 24V systems. **LOAD-2 SPECS:** The MPPT 20A CONTROLLER sheds LOAD-2 first if the battery voltage drops below **11.8 VDC** for 12V systems and **23.6 VDC** for 24V systems OR if the current draw on LOAD-2 exceeds 7.5 AMPS. The system sheds lower priority devices/equipment first. It is recommended that you place devices and equipment on LOAD-2 that are not as critical as those on LOAD-1. Types of equipment connected to LOAD-2 may include sensors, RTUs, and so on. **LOAD-1 SPECS:** The MPPT 20A CONTROLLER sheds LOAD-1 as a lower priority than LOAD-2 if the battery voltage drops below **11.6 VDC** for 12V systems and **23.2 VDC** for 24V systems OR if the current draw on LOAD-1 exceeds 7.5 AMPS. The system sheds higher priority devices and equipment as a last resort. It is recommended that you place devices and equipment on LOAD-1 that are more critical than those on LOAD-2. Types of equipment connected to LOAD-1 may include telemetry radios, cellular radios, and devices connecting the MPPT 20A CONTROLLER to your SCADA system.
LOAD-1 RQST on	10033	
LOAD-2 RQST on	10034	
NO current det-1	10031	
NO current det-2	10032	
LOAD-1-shorted	10013	
LOAD-2-shorted	10018	
LOAD 1 cycle (DO)	00026	You may force one or both loads to cycle power via Modbus commands. This may help in the event a power-cycle is needed on the equipment attached to a respective load. Writing a "1" to MODBUS DO register 00026 with cycle power on LOAD-1 for 30 seconds. There is no need to reset this register - a "0" is automatically written. The same process applies for LOAD-2 except for the MODBUS DO register. DO register 00027 applies to LOAD-2.
LOAD 2 cycle (DO)	00027	

Table 28 – Product anatomy – bottom – LOAD1 and LOAD2 shed and LEDs

Three-stage charging process

Designed into the MPPT 20A CONTROLLER is a three-stage BUCK/BOOST, constant current constant voltage (CC/CV), MPPT smart charge controller. A regulated current raises the terminal voltage until the upper charge voltage limit is reached, at which point the current drops due to saturation. The charge time is 12 to 16 hours, and up to 36 to 48 hours for large stationary batteries. With higher charge currents and multi-stage charge methods, the charge time can be reduced to 8–10 hours; however, without achieving the full topping charge. Lead acid batteries can behave sluggishly and cannot be charged as quickly as other battery systems.

Data taken from an actual MPPT 20A CONTROLLER's Audit file shows time for each charging phas:.

Total Time in Bulk: 18225 SEC (Bulk Charge) // 5.06 Hours in Bulk Charge

Total Time in Absorb: 4475 SEC (Absorption Charge) // 1.24 Hours in Absorption Charge

Total Time in Float: 24160 SEC (Float Charge) // 6.8 Hours in Float Charge

Total Time not Charging: 33850 SEC (Discharge) // 9.4 Hours spent discharging

Lead acid batteries should be charged in three stages:

1. Constant-current charge (Bulk Charge)
2. Topping charge (Absorption Charge)
3. FLOAT Charge

The constant-current charge applies the bulk of the charge and takes up roughly half of the required charge time. The topping charge continues at a lower charge current and provides saturation. The float charge compensates for the loss caused by self-discharge.

According to batteryuniversity.com, during the constant-current charge, the battery charges to about 70 percent in 5–8 hours; the remaining 30 percent is filled with the slower topping charge that lasts another 7–10 hours. The topping charge is essential for the wellbeing of the battery and can be compared to a little rest after a good meal. If continually deprived, the battery will eventually lose the ability to accept a full charge and the performance will decrease due to sulfation. The float charge in the third stage maintains the battery at full charge. See Typical charging curve for an illustration of the MPPT 20A CONTROLLER three-stage charging curve.

Bulk charging mode

When the sun's light initially strikes the solar panel connected to the MPPT 20A CONTROLLER, it begins a charge algorithm based on the third-party charge controller you installed. Most commonly, In the first stage of the process, current is supplied by the solar panel, monitored by the MPPT 20A

CONTROLLER, and sent to the battery via the third-party charge controller at the maximum safe rate the battery will accept until voltage is brought up to nearly 80-90 percent of full charge. During bulk-charge the "**ABSORB**" LED will blink until the charging voltage has reached >14.0VDC on a 12-volt system and >28.0VDC on a 24-volt system, at which point it will remain on solid. You may also notice the "**CHARGED**" LED blink or remain on. The "**CHARGED"** LED blinks if the battery has been charging for at least 1.8 hours AND a positive current is being absorbed by the battery. The "**CHARGED"** LED remains on, indicating the battery is fully charged, if the battery has been charging for more than 2.5 hours.

Absorption charging mode

In the second charging stage, voltage peaks and stabilizes and current begins to taper off as internal battery resistance rises. The "**ABSORB**" LED blinks if the battery voltage is < 14.00vdc for 12vdc systems or < 28.00vdc for 24vdc systems and remains solid when the battery voltage is greater than the respective voltages. Once the system completes the absorption cycle, the "**ABSORB**" LED remains off and the MPPT 20A CONTROLLER enters the FLOAT charging mode. The absorption process may take many hours.

The MPPT 20A CONTROLLER logs system CHARGE STATUS and timestamps the start and end of the absorption charge cycle.

Note: all the times described below are available in Modbus RTU format.

Examples of SYSLOG absorption status messages:

Syslog: 02/01/14 05:26:56 CHARGE STATE: Charge in ABSORB.

Syslog: 02/01/14 12:23:16 CHARGE STATE: Charging not in ABSORB.

The audit report gives more detailed information about the absorption charging cycle such as total time to absorption and total time in absorption. All times are in seconds.

Examples of AUDIT file absorption time messages:

Total Time to Absorb: 17461 SEC

Total Time in Absorb: 5615 SEC

FLOAT charging mode

The final charging stage is the FLOAT stage. At this point the charge on the battery is maintained at an optimal level also known as a FLOAT charge. The voltage is reduced to lower levels to reduce gassing and extend battery life.

The audit report gives more detailed information about the float charging cycle such as total time in a float cycle. All times are in seconds.

Examples of SYSLOG FLOAT status messages:

Syslog: 06/09/15 12:22:13 CHARGE STATE: Battery in CCCV/FLOAT.

Syslog: 06/09/15 18:14:54 CHARGE STATUS: Constant Voltage Not Active.

Typical charging curve

The following graph shows a typical MPPT 20A CONTROLLER 12-volt charging cycle. The 24-volt cycle would show a similar profile except for battery voltage levels. The data-logger data on the SD card was used to create the following graph,

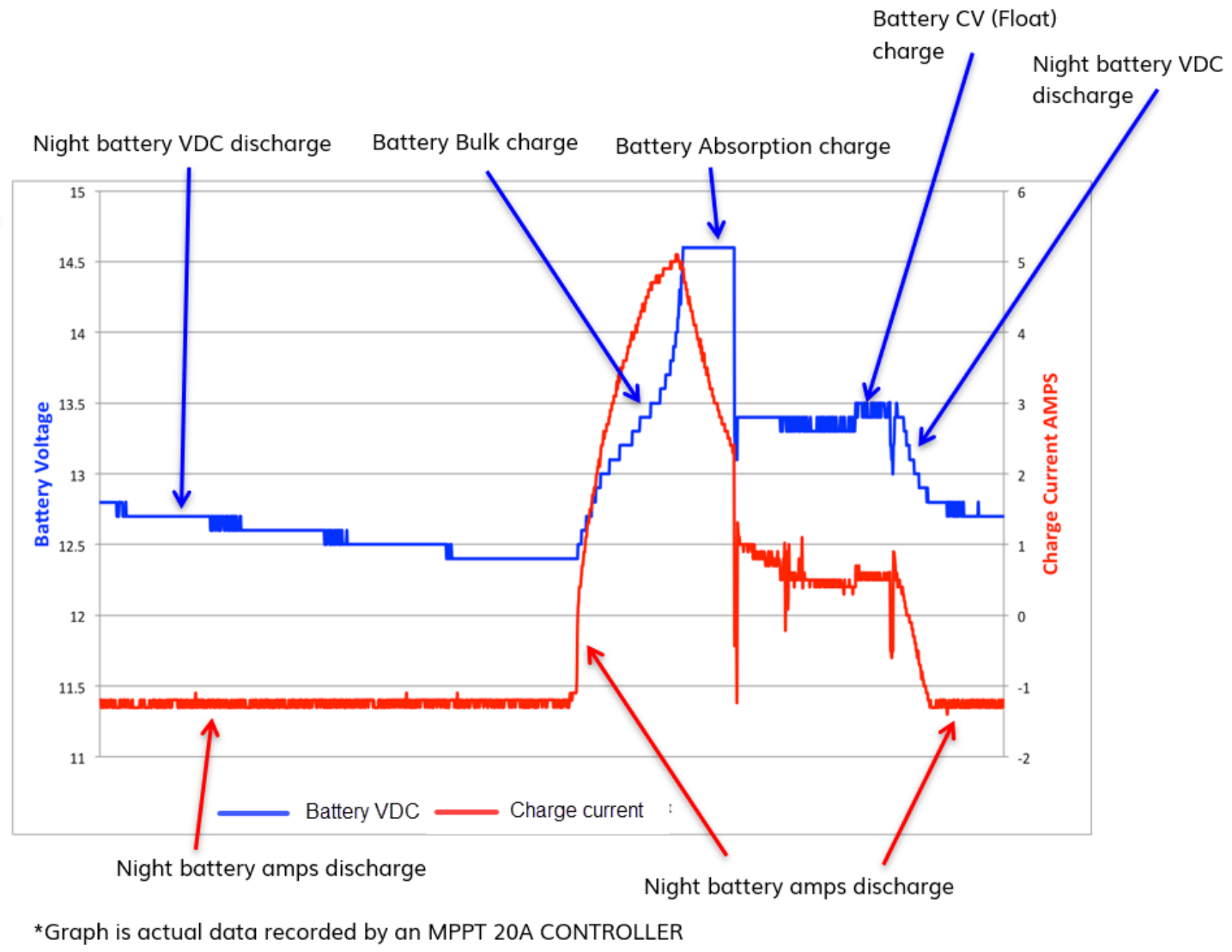


Figure 34 – A typical MPPT 20A CONTROLLER 12-volt charging cycle

Battery-specific specification

Although many of the following parameters may be mentioned throughout this manual, there are a few configurable parameters that require knowing battery factory specifications. This may require contacting the factory directly to collect the specifications. It's a good idea to use the same battery manufacture and model number when designing your sites, because this balances differences with Battery Series Resistance (BSR), battery characteristics, and so on.

Battery HOT limits

Modbus register	Type		Range
30026-27	FLOAT input	BATT TEMP	-67f to 257f
40004-05	FLOAT output	BATT HOT Temp Limit	-67f to 257f
10009	Digital input	ALRM: Battery Hot Limit Alarm	0=OK, 1=Failed. Exceeds High Temp Limit

Table 29 – Related Modbus functions and parameter

Batteries operate over a wide temperature range. This should not be confused with charging batteries in extreme hot or cold conditions. The charging process is more critical and delicate than discharging, and special care must be taken. Extreme cold and high heat reduce charge acceptance, so the battery must be brought to a moderate temperature before charging.

Thermal compensation makes automatic adjustments to the charging characteristics. If the BATT TEMP reading is higher than the BATT High TEMP limit, a SYSLOG event is logged and Modbus Digital input register 10009 indicates a "1". The BATT TEMP reading is required to fall 10°f below the user high limit to clear the alarm. **DO NOT set the "Battery HOT limit" within 10°f of the Battery cold limits.**

During extreme hot and cold temperatures (above 122°f and below -4°f), the battery thermal compensation functions cause the MPPT to stop charging until the battery temperature returns to normal temperatures.

`<-4°f Cold Fault (Charging Disabled)` `>5°f Return to normal (Charging Enabled)`

`> 122°f Hot Fault (Charging Disabled)` `< 113°f return to normal (Charging Enabled)`

Battery COLD limits

If the BATT TEMP reading is lower than the BATT low TEMP limits, a SYSLOG event is logged and

Modbus Digital input register 10008 indicates a "1". The BATT TEMP reading is required to rise 10°f above the user low limit to clear the alarm. **DO NOT set the "Battery COLD limit" within 10°f of the Battery HOT limits.**

Modbus register	Type		Range
30026-27	FLOAT input	BATT TEMP	-67°f to 257°f
40006-07	FLOAT output	BATT COLD Temp Limit	-67°f to 257°f
10008	Digital input	ALARM: Battery Cold Limit Alarm	0=OK, 1=Failed. Exceeds Cold Temp Limit

Table 30 – Battery hot and cold limits

MQTT

One of the protocols supported by the MPPT 20A CONTROLLER is MQTT and MQTT SparkPlug B. MQTT is a transport protocol used with SCADA platforms and other IoT/IIoT ecosystems.

A sample of MQTT:

```
SolarMonitor/683522613184549545/batt_fully_charged_flag = true
```

LCD display

The MPPT 20A CONTROLLER is equipped with a 2x16 LCD display and shows system status and information such as battery voltage, charging status, errors, faults, measurements, and so on. The display, in conjunction with the menu rotary knob, allows for system configuration where applicable and displays system information. Rotating the menu knob left and right forwards or reverses the display pages, and the display remains on a single page for 20 seconds unless the rotary knob is rotated again.

After an expired display time, the MPPT 20A CONTROLLER automatically advances the first 12 pages, which are the most critical system measurements.

This section outlines each display page, its content, and its function. Also outlined are supported Modbus registers.

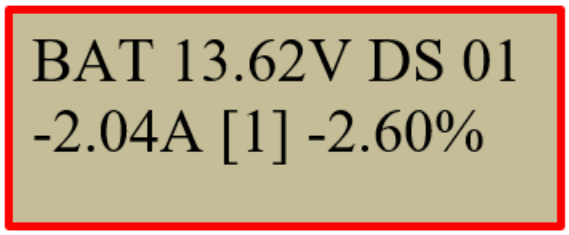
Note: All voltages, currents, and other data shown below are examples. Data changes based on the type of system support, such as 12vdc VS 24vdc battery system configuration.

Each page displays a page number at the top-right corner of the display.

Battery status – Charge Status LCD PAGE 01

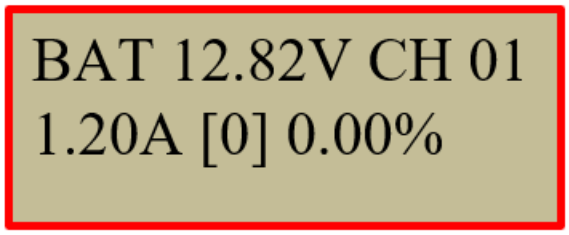
The Battery status indicates the measured battery voltage and the charge or discharge current. Negative amps indicate the battery is being discharged and positive amps indicate the battery is being charged. The display shows "CH" when the battery is being charged and "DS" when the battery is discharging. Also shown is the battery rate of charge/discharge rate (ROC) and the number of times the battery did not hit the peak charging voltage noted by **[X]** in the center of the bottom line of the display.

Pressing the **Menu** knob while viewing this menu auto-calibrates the system voltage and current measurements. This temporally disables all loads and charging functions and powers OFF all equipment attached to the respective loads. This process takes approximately 15 seconds. Once completed, the system automatically enables and powers up all loads and charging controllers.



Modbus register	Type	Range
30000-01	Battery voltage	6-36 VDC
30002-03	Battery current	-11.0 to 22.0 Amps
30004-05	Battery watts	(BAT V * BAT I)
30074-75	Absorb miss	32-bit

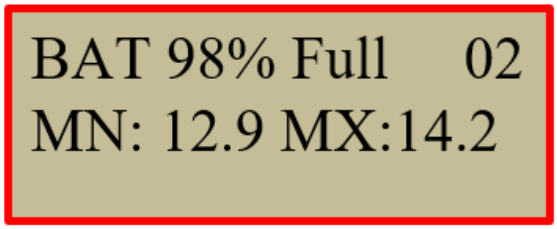
Display showing battery discharging



Display showing battery charging

Battery status – Percent Full Min/Max – LCD PAGE 02

The Percent Full Min/Max page shows the battery capacity, the minimum valley the battery voltage has reached, and the maximum peak the battery has reached within a 24-hour window. These values are reset at midnight. The minimum voltage value is typically how far the voltage reached at night or when the solar panel is not illuminated. The maximum peak is typically the peak bulk or absorption charge.



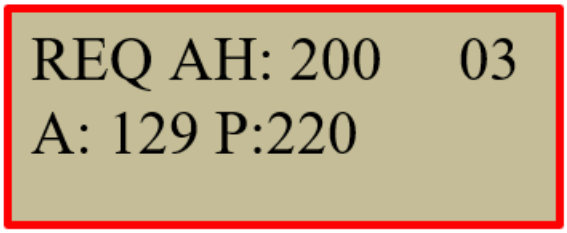
Modbus register	Type	Range
30006-07	Battery % capacity	0-100 %
30010-11	BATT Peak MIN	0-36vdc
30012-13	BATT Peak MAX	0-36vdc

Display showing:

- Battery is 98.6% full
- Battery reached a minimum of 12.9 volts
- Battery reached a maximum of 14.2 volts

Required amps hours – ADD and PEAK Amp Hour Values LCD PAGE 03

Displays the AMP hours required in real time. "A:" is the amp hours to ADD and "P:" is the peak amp hours the system required at any instance. Keep in mind; this is a SYSTEM prediction and accounts for items such as the battery charging current requirements. This value is an instantaneous, real-time demand measurement and may indicate a higher value than is really required during battery charging phases when large current is placed into the battery. Pressing the rotary knob resets the PEAK value. Writing a "1" to MODBUS Holding DO register 00018 resets the Peak Amps.



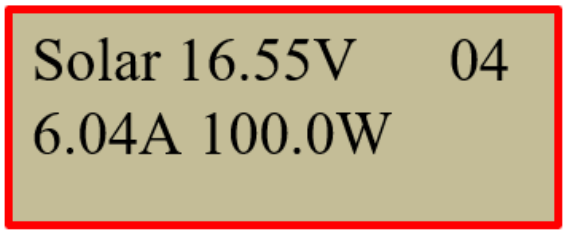
Modbus register	Type	Range
30113	Required AMP Hours	0-1000
30109	Add Amp Hours	0-1000
30115	Peak Amp Hours	0-1000
00018	Reset Peak Amp Hours	1=Reset

Display showing:

- Real-time amp hours required: 200
- Battery amp hours to add: 129
- Peak amp hours system required: 220

Solar panel – Power measurements – LCD PAGE 04

The solar panel power measurements consist of the solar panel voltage and current being generated. The solar panel is limited by specifications on the total power being generated; for example, a 100W solar panel can generate only 100 watts. The Solar Panel Power measurement page displays the solar voltage, current, and power being produced.

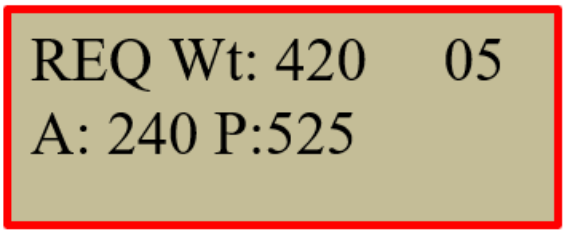


Modbus register	Type	Range
30016-17	Solar voltage	0-36 VDC
30018-19	Solar current	0 to 25 amps
30020-21	Solar watts	(Solar V * Solar I)

Display showing a solar panel generating 16.55 volts at 6.04 amps, or 100 watts of power.

Required solar power/watts – ADD and PEAK Watts Values – LCD PAGE 05

Displays the solar watts required in real time, "A:" is the solar watts to ADD and "P:" is the Peak Solar Watts the system required at any instance. This value is an instantaneous, real-time demand measurement and may indicate a higher value than is really required during battery charging phases when large current is placed into the battery. Pressing the rotary knob resets the PEAK value. Writing a "1" to MODBUS Holding DO register 00017 resets the Peak Watts.



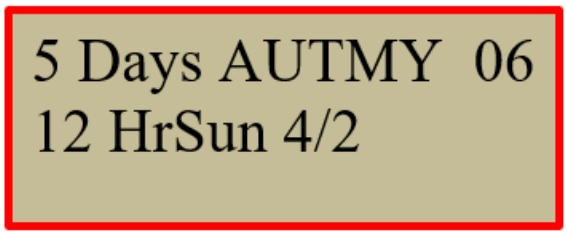
Modbus register	Type	Range
30112	Required panel WATTS	0-1000
30110	Add panel WATTS	0-1000
30114	Peak Panel WATTS	0-1000
00017	Reset Peak Panel WATTS	1=Reset

Display showing:

- Real-time solar watts required: 420
- Solar watts hours to add: 2
- Peak solar watts system required: 525

Desired Days of Autonomy – Hours of Light – Predicted Days of Autonomy/Remaining LCD PAGE 06

Displays the desired hours of autonomy. This is the desired time in days you would like the system to safely sustain power to the loads. This page also displays the amount of SUNLIGHT exposure on the panel in hours and the predicted hours of autonomy/remaining hours of autonomy. The desired hours of autonomy is not a value that forces the system to maintain the hours of autonomy. Pressing the rotary knob allows you to set the desired hours of autonomy.



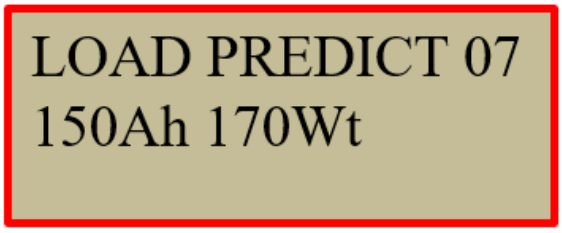
Modbus register	Type	Range
40019	Desired AMP hours	0-30
30111	Hours of sunlight	0-24
30119	Predicted days	0-30
30090	Remaining days	0-30

Display showing:

- Desired days of autonomy: 5 (MODBUS REG 40019)
- Sunlight exposure on the panel: 12 hours (MODBUS REG 30111)
- Predicted days of autonomy/remaining days of autonomy: 4/2 (MODBUS REG 30119 and 30090)

Predicted amp hours and solar watts required based on load current – LCD PAGE 07

Displays the predicted required System amp hours and predicted required System Solar Watts to maintain only the load. These predictions filter out other demands that may cause dynamic swings and bring better accuracy to the system demands. Other system demands, such as battery charging current, can create significant demands.



Modbus register	Type	Range
30118	Predicted amps hours	0-1000
30117	Predicted solar watts	0-1000

Display showing:

- Predicted amp hours to sustain load only: 150
- Predicted solar watts to sustain load only: 170

Device load – Power measurements PAGE 08 and LCD PAGE 09

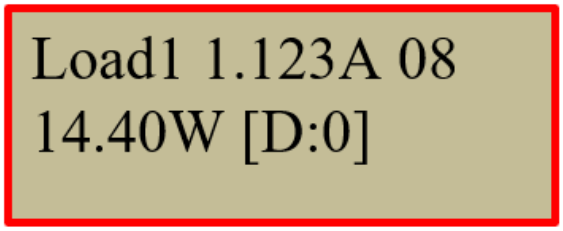
The MPPT 20A CONTROLLER is equipped with two separate load outputs. Each load output can supply 7.5 amps of current. LOAD-1 output will load-shed and be disabled if the power drawn by the load is greater than 7.5 amps OR if the battery voltage drops below 11.60 volts in a 12-volt system or 23.20 volts in a 24-volt system. LOAD-1 typically supports critical equipment such as telemetry radios and so on.

Load-shedding is prioritized; LOAD-2 is the first load to load-shed. LOAD-1 is the last load to load-shed and has the highest priority.

LOAD-2 trips if the power drawn by the load is greater than 7.50 amps OR if the battery voltage drops below 11.80 volts in a 12-volt system or 23.6-volts in a 24-volt system. If load-shedding was triggered by a low battery voltage event, all loads are re-enabled when the battery voltage reaches levels greater than 12.2vdc in a 12-volt system or 24.4vdc in a 24-volt system.

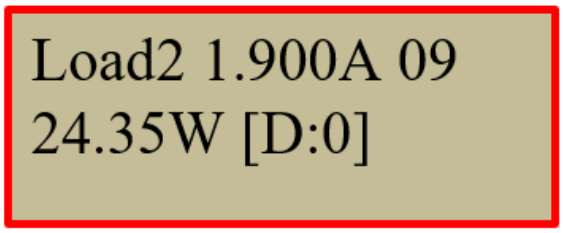
This page also shows any load-shed delay during a load-shed trip. "**[D:0]**" displays the number of seconds before the load is allowed to be re-enabled. The timer counts down from several seconds to several minutes depending on the trigger type. It's possible for a load-shed event to occur, the timing process to start and expire, and the respective LOAD to remain off IF the battery voltage is below the reset value.

Pressing the menu knob while viewing LOAD-1 or LOAD-2 menu forces the respective load-shed timer to 15-seconds IF the respective LOAD output is already in load-shed and the load-shed timer is greater than 150-set. The purpose of this function is to accelerate the load-shed timeout during events where the time could exceed 20 20 minutes.



Modbus register	Type	Range
30022-23	Load-1 Current	0-8.00 Amps
30024-25	Load-2 Current	
30085	Load-1 Shed Timer	0-900 sec
30086	Load-2 Shed Timer	0-900 sec

Display showing equipment connected to LOAD-1 drawing 1.123 amps of current, 14.40 watts



Display showing equipment connected to LOAD-2 drawing 1.900 amps of current, 24.358 watts

Device load – Trigger level and timers

The MPPT 20A CONTROLLER attempts to maintain power to external loads attached. The MPPT 20A CONTROLLER manages LOAD-1 and LOAD -2 by monitoring independent load currents and the battery voltage, but not to a point where the battery will be permanently damaged by depleting the battery. Critical equipment such as telemetry radios and SCADA-related equipment should be connected to LOAD -1 (L1). LOAD -1 remains on until the battery falls below 11.60vdc on a 12v system and below 23.20vdc on a 24v system. This is done to extend hours of autonomy and extend the power-on time of equipment attached to LOAD -1, and still maintain the ability to notify the SCADA operator of an appending complete LOAD shutdown.

Load timers are activated during a load-shed event and may be caused by an over-current/over-power, under-voltage or Modbus request event. When the device is in an active load-shed event, the respective "LOAD1" and/or "LOAD2" LEDs remain on during the duration. The SYSLOG ***"snnnnnnl.txt"*** file contains all load-shed events in the form of a timestamp record; for example, ***"Syslog: 02/01/18 14:15:23 load1 trip [15] 11.80 Volts 2.61Amps"***. The load-shed record contains the total current being drawn by the equipment, on a respective load output, at the time of the event and the total number of events. In the example given, LOAD-1 tripped at 2.62 amps. The battery voltage was at 11.80vdc at the time of the event, and a total of 15 load-shed events occurred to date.

If a load-shed event occurred within a 24-hour period, the audit report ***"annnnnnu.txt"*** file notes the event with an entry of "***Did Load-shed within the last 24HRS***". if a load-shed did not occur within a 24-hour period, an entry of "***Did not Load-shed within the last 24HRS***" is recorded. Triggers are reset at midnight based on the system's real-time clock.

12 V system load-shed triggers and times

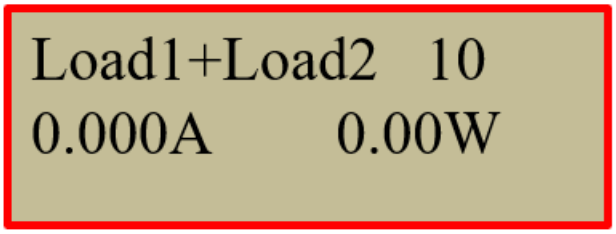
Load	Low voltage trigger	Off time (sec)	Low voltage reset	High amps limits	Off time (seconds)	Modbus command Delay time (seconds)
L1	<11.6 V	900 (15M)	>12.2 V	> 7.00	300 (5)	300 (5)
L2	<11.8 V	900 (15M)	>12.2 V	> 7.00	300 (5)	300 (5)

24 V system load-shed triggers and times

Load	Low voltage trigger	Off time (seconds)	Low voltage reset	High amps limits	Off time (seconds)	Modbus command Delay time (seconds)
L1	<23.2 V	900 (15M)	>24.4V	> 7.00	300 (5)	300 (5)
L2	<23.6 V	900 (15M)	>24.4V	> 7.00	300 (5)	300 (5)

Load 1 + 2 amps/watts – LCD PAGE 10

For convenience, the LCD displays total amps consumed by LOAD-1 + LOAD-2. The LOAD TOTAL amps value is not reflected in the Modbus table.



System date/time – LCD PAGE 11

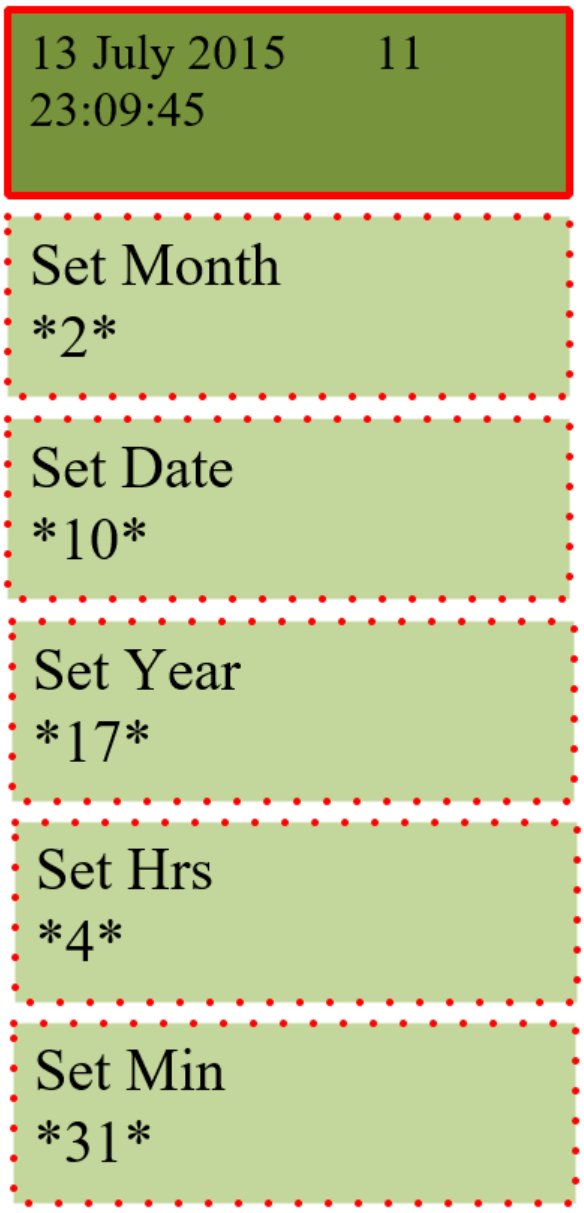
The MPPT 20A CONTROLLER has a real-time clock (RTC) to maintain a system clock. The RTC maintains time even with the power removed. Pressing the menu knob IN while the time/date is displayed lets you set the time and date. The time and date may also be set via Modbus commands. The first menu allows you to set the month.

Rotating the menu knob advances to the DATE and continues to advance to YEAR, HOURS, MIN, and so on. When the display shows the date/time attribute you want to change, press the menu knob IN to change the respective attribute.

Enclosure-internal/MPPT temperatures – LCD PAGE 12

The MPPT 20A CONTROLLER monitors several temperature sensors which include the Solar Supervisor enclosure internal temperature and the MPPT process temperature. The enclosure internal temperature is monitored to give an indication of how hot the system may be getting and the MPPT temperature indicates the heat being generated during the charging process. If the internal temperature rises to a temperature >120.00°f the MPPT 20A CONTROLLER will turn on the dual cooling FANs located on the top of the enclosure. The enclosure must return to <110.00°f before the fans stop operating. The FANS are also affected by battery temperature sensor. If the Battery temperature is >110.00°f and may remain on even if the enclosure internal temperature returns too normal.

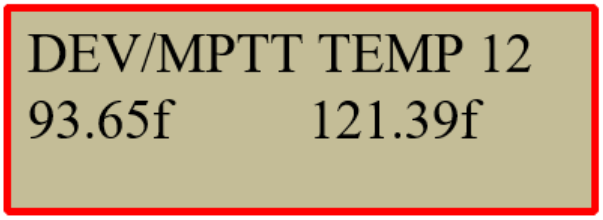
Enclosure temperature is also available as a Modbus floating-point value in Modbus INPUT register 30028-29 and the MPPT Temperature is available as a Modbus floating-point value in Modbus INPUT register 30036-37



Modbus register	Type	Range
30094	RTC Hour	0-23
30095	RTC Min	0 - 59
30096	RTC Sec	0 - 59
30097	RTC Month	1 - 12
30098	RTC Date	1-31
30099	RTC Year	2000-2099

R/W Modbus registers: Allows SCADA to set RTC

Modbus register	Type	Range
40021	RTC Hour	0-23
40022	RTC Min	0 - 59
40023	RTC Month	1 - 12
40024	RTC Date	1-31
40025	RTC Year	2000-2099

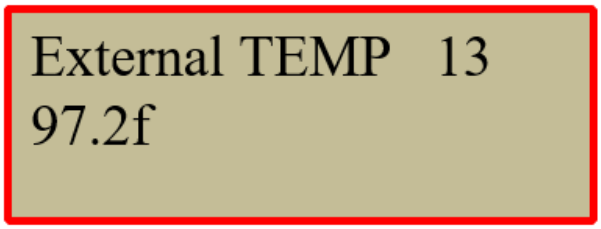


Modbus Register	Type	Range
30028-29	Enclosure Temp	-67°f to 257°f
30036-37	MPPT Temp	-67°f to 257°f

External and outside air temperatures – LCD PAGE 13

The MPPT 20A CONTROLLER monitors an external temperature sensor to allow for ambient temperature monitoring.

External temperatures are also available as a Modbus floating-point value in MODBUS INPUT register 30030-31.



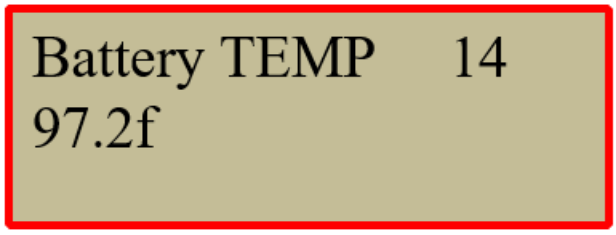
Modbus register	Type	Range
30030-31	External Temp	-67°f to 257°f

Battery temperature – LCD PAGE 14

Temperature can dramatically change how your battery is charged. Typically, batteries that get too hot or too cold do not charge correctly if the charging voltages are not adjusted. (See your battery manufacturer for proper temperature charging specifications.)

The MPPT 20A CONTROLLER uses an external battery temperature sensor to display the battery temperature. Using the same voltage and current charging curves on a hot battery as a cold battery may cause damage to your battery. The MPPT 20A CONTROLLER battery compensation temperature thermistor is monitored separately using the temperature compensation sensor located below the Ethernet port.

Battery temperature LCD reading



Modbus register	Type	Range
30026-27	Battery temp	-67f to 257f

Alarms – LCD PAGE 15

There are several parameters that cause an alarm. Alarms are simply notification of a potential issue, and not all alarms are critical. Listed below are the alarm types and a description of each. The MPPT 20A CONTROLLER displays all active alarms on the bottom line of the display and rotates to display all alarms. Any alarm causes the “ALARM” LED to display RED. Pressing the rotary knob resets all alarms. If all alarms remain reset the top line of the display reads “ALARM ACK'ed”, and the “ALARM” LED begins to flash. The LED resets itself at midnight. All alarms remain displayed even if the

respective alarm is no longer in alarm. The only way to attempt to reset the actively displayed alarms is to press the rotary knob while displaying page 15, or to reset via Modbus DO register 00022.

Alarms listed:

Modbus register	Type	Range
30108	Bit-map alarms	See list
00022	Reset alarms	See list

ALARM Faults 15
No Alarms

Display showing no active alarms

ALARM Faults 15
SUSTAINABILITY

Display showing system sustainability issues

ALARM Faults 15
NO FLOAT 3days

Display showing ABSORBS voltage not reaching peak three days in a row

ALARM Faults 15
AMP HRS REQ SUST

Display showing system AMP HOUR requirements in real-time, sustained needs.

ALARM Faults 15
AMP HRS REQ NOW

Display showing system AMP HOUR requirements in real-time, instantaneous needs.

ALARM Faults 15
AMP HRS REQ SUST

Display showing system AMP HOUR requirements in real-time, sustained needs.

ALARM Faults 15 AMP HRS REQ NOW	Display showing system AMP HOUR requirements in real-time, instantaneous needs.
ALARM Faults 15 SOL WAT REQ SUST	Display showing system SOLAR POWER requirements in real-time, sustained needs.
ALARM Faults 15 SOL WAT REQ NOW	Display showing system SOLAR POWER requirements in real-time, instantaneous
ALARM Faults 15 Critical VDC	CRITICAL: Display showing a critical internal power issue.
ALARM Faults 15 SOLAR VDC HIGH	CRITICAL: Display showing a HIGH solar panel voltage input.
ALARM Faults 15 LOAD2 SHORTED	CRITICAL: Display showing LOAD-2 is shorted

Charge failures – LCD PAGE 16

There are several parameters that cause charging failures. Not all failures are critical. Listed below are the charge failure types and description of each, and the respective Modbus register is any. The

MPPT 20A CONTROLLER displays all active failures on the bottom line if the display and can rotate to display all failures.

Charge faults listed

CHARGE Fault 16
No Alarms

Display showing no active alarms

CHARGE Fault 16
<PEAK CHAR 24hr

Missed absorb peak charging level in last 24-hour cycle

CHARGE Fault 16
BATT VDC to HIGH

Modbus register	Type	Range
10015	BATT V TOO HIGH	1-High

CHARGE Fault 16
PEAK FAIL >3days

Modbus register	Type	Range
10028	Absorb peak fail	1-Fail

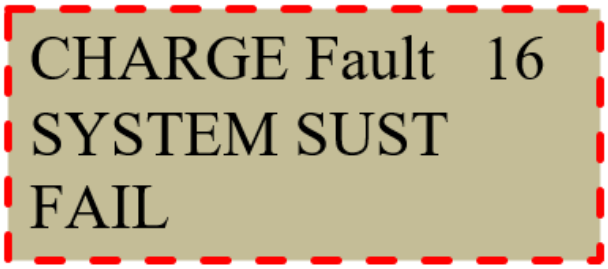
CHARGE Fault 16
BATT TYPE FAIL

Modbus register	Type	Range
10035	Not 12 or 24 V battery system	1-Fail

CHARGE Fault 16
AMPHR SUST FAIL

Modbus register	Type	Range
10044	Amp hours sustain fail	1-Fail

Modbus register	Type	Range
10038	Solar power sustain fail	1-Fail

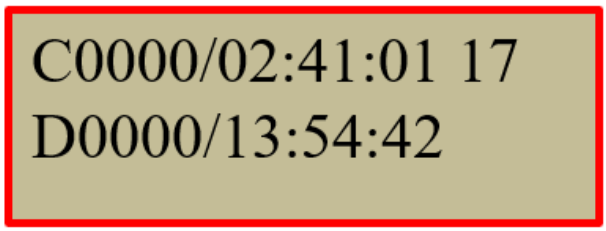


Modbus register	Type	Range
10045	System sustain fail	1-Fail

No charge failures

System charging/discharging hours - LCD PAGE 17

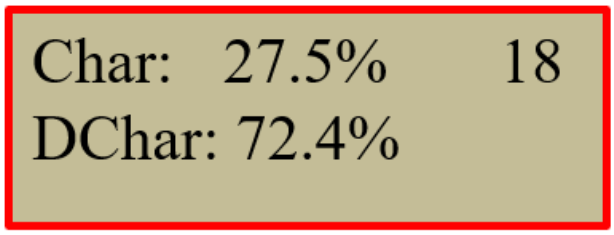
System life Charge/Discharge keeps track of the number of DAYS/MONTHS/MIN/SEC the system has charged and discharged. The total number of respective DAYS is 65535 days or 180 years.



Modbus register	Type	Range
30100	Life Lapse Charge Days	0-65535
30101	Life Lapse Charge Hours	0-23
30102	Life Lapse Charge Min	0-59
30103	Life Lapse Charge Sec	0-59
30104	Life Lapse Discharge Days	0-65535
30105	Life Lapse Discharge Hours	0-23
30106	Life Lapse Discharge Min	0-59
30107	Life Lapse Discharge Sec	0-59

System % 24-hours charging/discharging – LCD Page 18

The "System % 24-hour" timer keeps track of time percentage of battery charge vs. discharge within a 24-hour period.



Modbus register	Type	Range
30032-33	Total chr+dischr time SEC	
30034-35	Charge % time	0-100%

Board serial number - LCD Page 19

Each MPPT 20A CONTROLLER is embedded with a unique serial number. The serial number is used for purposes of warranty, RMA, remote Internet capabilities, MQTT publication, and so on.

MODBUS registers 40010-11 contain the high order 4-bytes and 40012-13 low order 4-bytes.

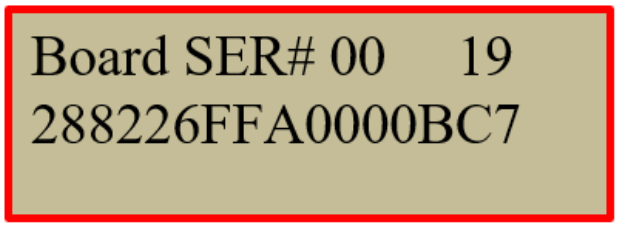
For the following serial number: "288226FFA0000BC7", the high order bytes would reflect "288226FF" the low order bytes would reflect "A0000BC7". Depending on your system, your SCADA system may display the serial number in a 32-bit number format; for example, High Order: "679618303", Low Order: "2684357575". The entire serial number in decimal would be: 2918938387832376263

288226FF converts to 679618303A0000BC7 converts to 2684357575

288226FFA0000BC7 converts to 2918938387832376263

Take note that when using MQTT this serial number is converted to decimal.

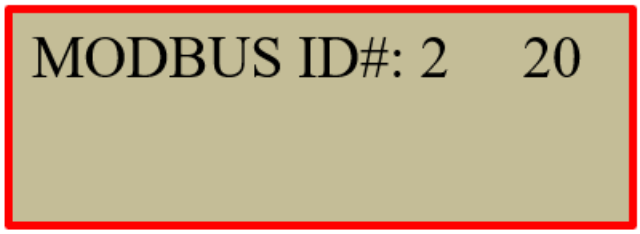
Example: SolarMonitor/**684638772184549556**/batt_vdc



Modbus register	Type	Range
40010-11	Serial Number HIGH Order	0-4294967294
40012-13	Serial Number LOW Order	0-4294967294

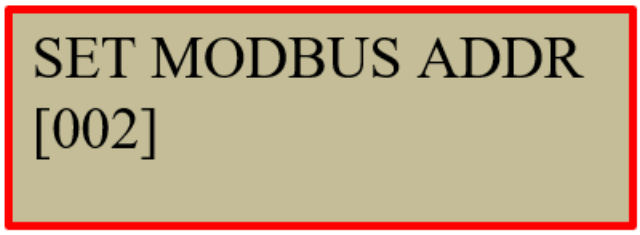
Modbus slave address – LCD Page 20

If your MPPT 20A CONTROLLER is the RTU version, it is designed to be used with a Modbus-RTU SCADA system. The device will need a unique Modbus slave address. The slave Modbus address can only be configured via the MPPT 20A CONTROLLER menu knob. Pressing the rotary knob lets you set the Modbus Slave address.



System configured for MODBUS Slave address 2

While displaying the Modbus address on the LCD display,
Press the rotary knob.



- ✓ Rotate the menu knob until the desired Modbus Slave Address is displayed.
- ✓ Press the rotary knob to save the new Modbus Slave address.
- ✓ If the device does not detect any menu key activity, it will automatically time out and save the last address displayed on the LCD display.
- ✓ Confirm the correct slave address is shown on the display.

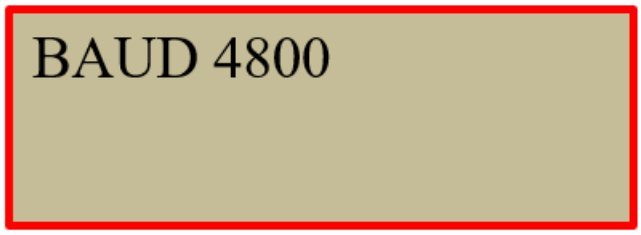
Modbus communications BAUD speed – LCD PAGE 21

If the MPPT 20A CONTROLLER has six serial communication speeds to select from: 4800, 9600, 19200, 38400, 57600 and 115200. The communications port is factory default to N,8,1.

The communications serial speeds can only be configured via the MPPT 20A CONTROLLER menu knob.

While the communications BAUD speed is on the LCD display:

- ✓ Press the rotary knob
- ✓ The LCD display will show:



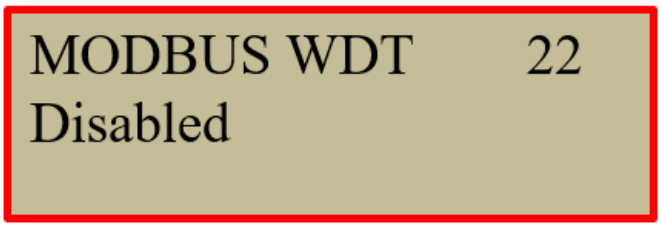
- ✓ Rotate the menu knob until the desired Modbus communication BAUD RATE displays.
- ✓ Once the desired data rate is displayed, press the rotary knob to save the new Modbus BAUD rate.
- ✓ If the device does not detect any menu key activity, it will automatically time out and save the last serial data rate shown on the LCD display.
- ✓ Confirm the correct serial data rate is shown on the display.

Modbus communications Watchdog Timer (WDT) – LCD PAGE 22

As described within this manual, the goal of installing the MPPT 20A CONTROLLER is to reduce callouts. The Modbus COMM WDT is designed to restart the MPPT 20A CONTROLLER if it does not detect a valid Modbus command to itself. This means that any respective MPPT 20A CONTROLLER that has communications enabled and has not received valid communications within a user-defined time window will attempt to restart itself, as well as any equipment attached. Once a WDT failure has occurred, it takes a few minutes to reboot and re-enable/power the equipment attached.

The device menu knob only supports the ability to enable or disable. Pressing the menu knob will toggle the ENABLE/DISABLE WDT parameter.

The timeout timer must be configured via Modbus (see the following).



Modbus register	Type	Range
00000	WDT enable/disable	0 - 1

The user-defined timeout timer must be configured via 32-bit MODBUS register 40008-09. The MAX setting is 432000 (five days). This timer is in seconds.

Modbus register	Type	Range
40008-09	COMM WDT Setting	0-432000
00000	WDT Enable/Disable	0 - 1

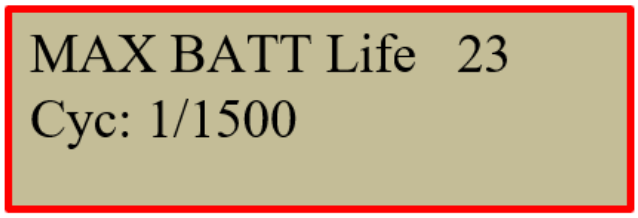
If the COMM WDT is enabled and a valid packet of data is received, the "SYSLED" LED blinks in sync with the RX LED and the WDT timer is reset back to the number set in MODBUS REG 40008-09. The WDT timer counts down to "0" while detecting a lack of communications for the unit. Once the WDT timer hits "0" the MPPT 20A CONTROLLER begins its re-booting/restart sequence.

Be sure to set the WDT timer to a reasonable value. Keep in mind; your SCADA system may have inherent polling delays due to many other Modbus devices it may need to poll.

Battery life charging cycles – LCD PAGE 23

The MPPT 20A CONTROLLER keeps track of the number of charging cycles. Every battery manufacturer has a MAX numbers of charging cycles for a battery make/model. Contact the battery manufacturer for specifications.

The MPPT 20A CONTROLLER uses the user settings and the number of cycles counted to determine the % of life remaining. If the life remaining is <40% AND the MPPT 20A CONTROLLER indicates a "Replace Battery" status. It's recommended to replace the battery on a single event such as Replace Battery = "1".

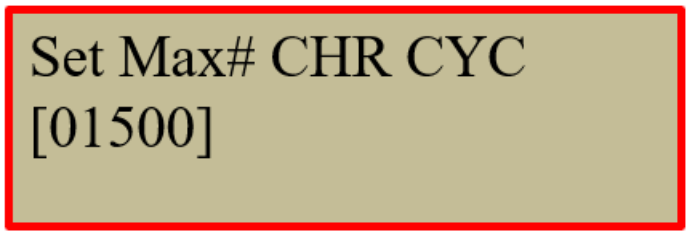


Display indicates one charge cycle out of 1500 life charging cycles.

Modbus register	Type	Range
40028	MAX Battery Life Count	0-10000
30076	Battery Charge Count	0- MAX Battery Life Count
30008-09	% BATT Life Remaining	0-100%
10016	Battery Capacity Low <45%	0=ok, 1=LOW
10017	Battery Life Low <40%	0=ok, 1=Replace

While displaying MAX BATT Life settings on the LCD display:

- ✓ Press the rotary knob.
- ✓ The LCD display shows:



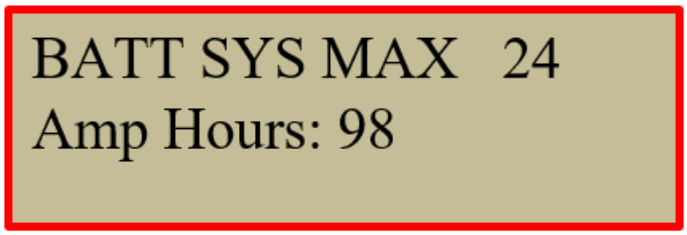
- ✓ Rotate the Menu Knob to increment and decrement the MAX number of battery charging life cycles.
- ✓ Once the desired MAX number of battery charging life cycles displays, press the menu knob to set the MAX number of battery charging life cycles.
- ✓ If the device does not detect any menu key activity it will automatically time out and save the last MAX number of battery charging life cycles displayed on the LCD display.
- ✓ Confirm the correct MAX number of battery charging life cycles is shown on the display.

Battery amps hour capacity – LCD PAGE 24

The system batteries are rated for a specific AMP HOUR rating, the MPPT 20A CONTROLLER requires you to enter the total AMP HOUR capacity of your system. As an example: If you have one 12 volt @ 98 Amp Hour, "98" is entered. If you have two 98-amp hour batteries in parallel, the amp hours added, and in this case, the total system AMP HOURS is 196, and "196" is entered.

This value may also be entered via Modbus.

This value is used to calculate several critical parameters and it is important it is accurate and entered.



Modbus register	Type	Range
40026	System amp hours	0-10000

Display indicates a 98 AMP HOUR battery installed in your system

While displaying BATT SYS MAX Life settings on the LCD display:

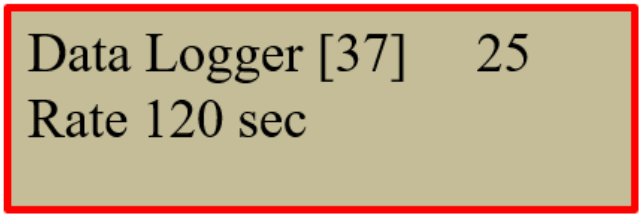
- ✓ Press the Rotary Knob.
- ✓ The LCD display shows:

- ✓ Rotate the menu knob to increment and decrement the system AMP HOURS.
- ✓ Once the desired system AMP HOURS is shown press the Menu Knob to set the system AMP HOURS.
- ✓ If the device does not detect any menu key activity it will automatically timeout and save the last system AMP HOURS displayed on the LCD display.
- ✓ Confirm the correct system AMP HOURS is shown on the display.

Data logger log sample interval – LCD PAGE 25

The MPPT 20A CONTROLLER is equipped with an embedded data logger. Data is collected and recorded on the inserted SD card. The rate at which the data is recorded is controlled by a user-defined sampling/logging rate.

If the MPPT 20A CONTROLLER does not have an SD card inserted or if it is inserted incorrectly, data will not be written to the SD card. The warranty requires an SD card to be properly placed into the MPPT 20A CONTROLLER.



Modbus Register	Type	Range
40029	Data Logger LOG time	10-65535
30089	Time to next log	10-65535

Display indicates lapsed time of 37 seconds with a logging rate of 120 seconds.

While displaying "SET LOGGER TIME" settings on the LCD display:

- ✓ Press the Menu Knob.
- ✓ The LCD display displays:

- ✓ Rotate the Menu Knob to increment and decrement the Once the desired Data logging sample time.
- ✓ Once the desired Data logging sample time is shown press the Menu Knob to set the value.
- ✓ If the device does not detect any menu key activity it will automatically timeout and save the last battery specified AMP HOURS displayed on the LCD display.
- ✓ Confirm the correct data logger sample time is shown on the display.

Battery life health – LCD PAGE 26

Battery health is calculated by using the user-defined battery specified MAX number of life charges and the number of actual charging cycles. The % remaining value is the battery life remaining. If the battery life is less than 40% a MODBUS DI REGISTER 10017 indicator will be set to "1", indicating the need to replace the battery.

Modbus register	Type	Range
30008-09	Battery health % remaining	100% – 0%
40028	MAX battery life count	0-10000
30076	Battery charge count	0- MAX battery life count
10017	Battery life low <40%	1= REPLACE BATTERY

System battery configuration – LCD PAGE 27

The MPPT 20A CONTROLLER will automatically detect and adjust for proper system voltage as part of the power-up cycle. DO NOT change the battery configuration or add or remove batteries with power ON to the MPPT 20A CONTROLLER. The MPPT 20A CONTROLLER automatically sets charging voltages, calculations, limits, predictions, and so on. based on the voltage detected.

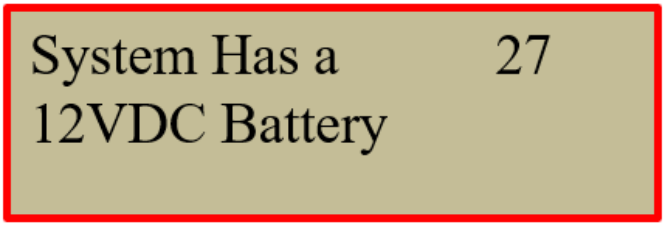
If the MPPT 20A CONTROLLER detects battery voltage of > 9.5vdc on power-up but < 15.5vdc the system is set to a 12 VOLT system.

If the MPPT 20A CONTROLLER detects voltage battery of > 15.5vdc but < 31.2vdc, the system is set to a 24 VOLT system.

Any other voltages detected cause the MPPT 20A CONTROLLER to completely disable ALL charging functions and report an “Unknown Battery Configuration type”, and the system sets to a “0” VOLT system.

The system battery configuration is placed into MODBUS register 30077 and is a 16-bit unsigned value.

Any battery voltages below 6vdc may cause the system to shut down and will most likely damage the battery beyond repair.

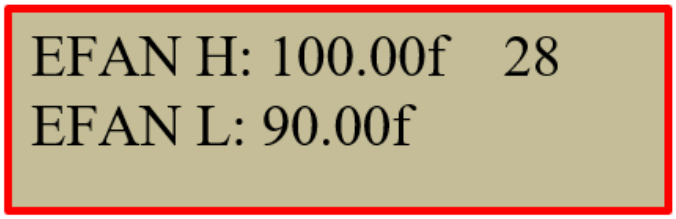


Modbus register	Type	Range
30077	System Battery Voltage Detected	12/24/0

External FAN High/Low Temperature Limits – LCD PAGE 28

The MPPT 20A CONTROLLER comes equipped with the ability to control an external exhaust fan. The BATTERY TEMPERATURE sensor is used to determine when to turn ON and OFF the external exhaust FAN.

This page displays the HIGH and LOW limits and does not currently allow for configuration. The Modbus registers must be used to make temperature limit changes.



Modbus register	Type	Range
40000-01	External Fan HIGH Temperature Limit	-67°f to 257°f
40002-03	External Fan Low Temperature Limit	-67°f to 257°f
10005	External Fan ON	1=ON

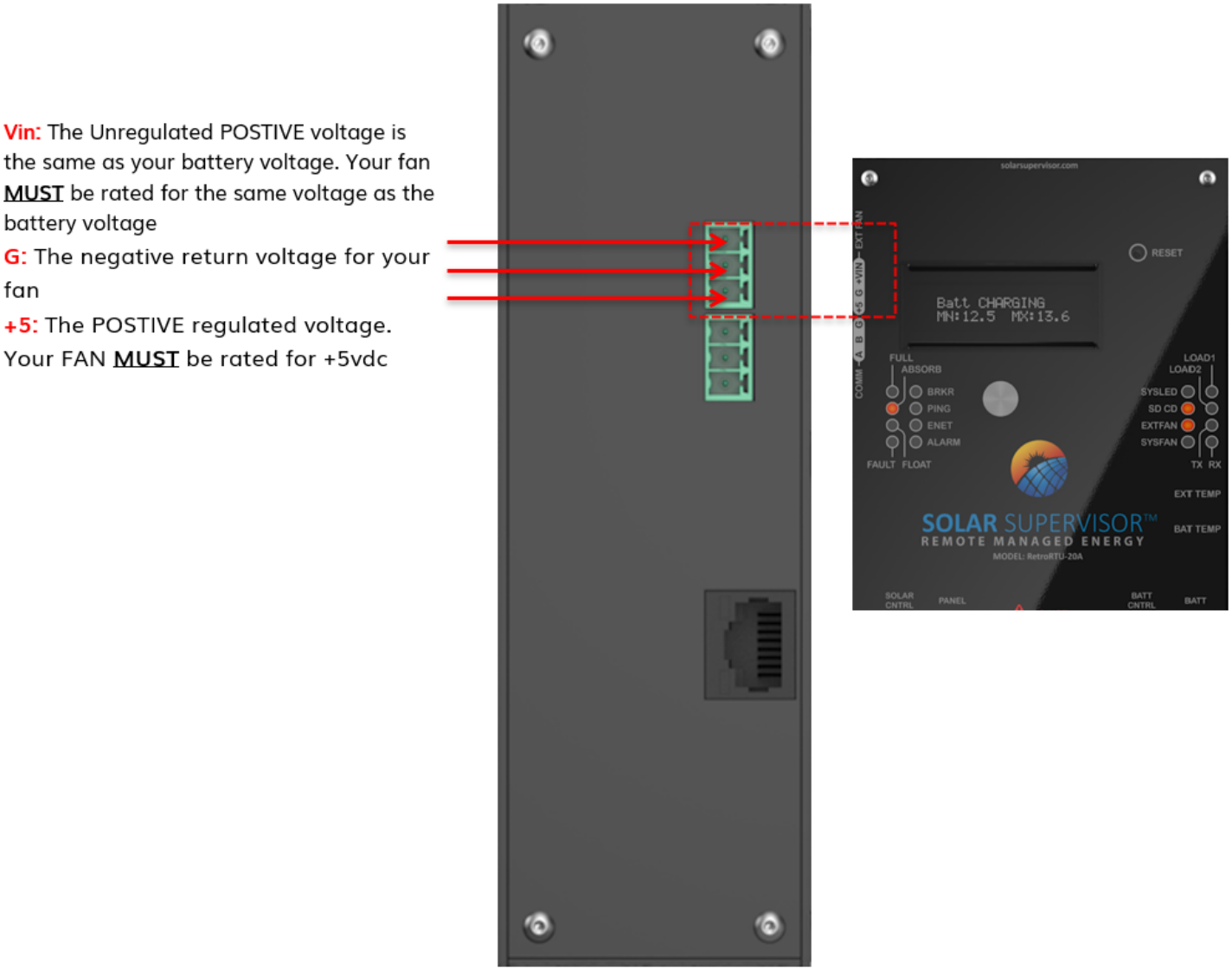


Figure 35 - Cabinet exhaust fan wiring connections

New battery installed date – LCD PAGE 29

The MPPT 20A CONTROLLER allows for a SCADA operator/system to be set when new batteries are installed. The purpose of this function is to allow an "Install Marker" and a note for when new batteries are installed. No other notification is given. To reset with a NEW DATE, the SCADA system must write a "1" to MODBUS DO registers 00023 and 00024 AT THE SAME TIME.

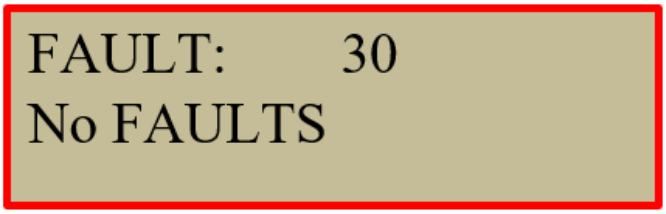
New MPPT 20A CONTROLLER may display "-1/-1/-1 -1:-1", once the function is reset. It captures the real-time Month/Day/Year and Hour/Minutes of the MPPT 20A CONTROLLER's real-time clock and

stores the values as the “Battery Install Date/Time”. Pressing the menu knob while displaying PAGE 29 also sets the “Battery Install Date/Time”.

Modbus register	Type	Range
30056-57	External Fan HIGH Temperature Limit	-67°f to 257°f
00023	New Battery Lock1	1=RESET AND
00024	New Battery Lock2	1=RESET

MPPT charging faults – LCD PAGE 30

Displays any MPPT charging faults. These faults directly relate to the MPPT charging process.

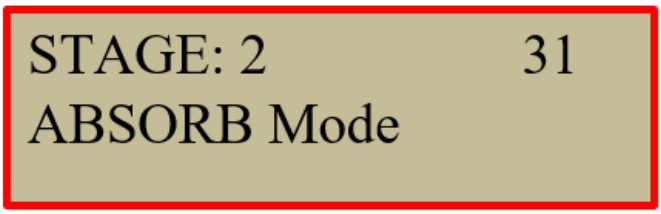


Modbus register	Type	Range
10048	Compensation Sensor Disconnected	1=Disconnected
10049	Invalid Temperature	1=Invalid
10050	Charging Timer Status	1=Failed
10051	Battery Under Voltage	1=Under VDC

Faults	Description
No FAULTS	No MPPT Faults Detected
TEMP DISCONNECT	Compensation Sensor disconnected
INVALID BATT TEMP	BATT Temp is <-4°f or >122°f
TIMER FAIL	Charging Timer failed
BATT UNDER VDC	Battery VDC below specs

MPPT charging status – LCD PAGE 31

Displays any MPPT charging Status. These statuses directly relate to the MPPT charging process.

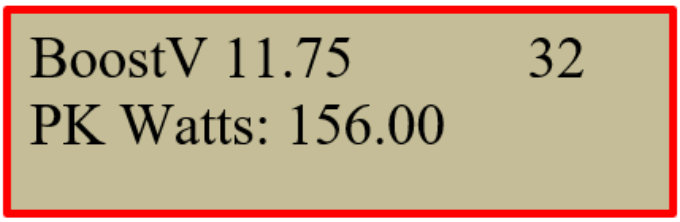


Modbus register	Type	Range
10001	Bulk Charging Mode	1=Bulk Charging
10002	Float Charging Mode	1=Float Charging
10030	Trickle Charging Mode	1=Trickle Charging
10043	Absorb Charging Mode	1=Absorb Charging

Status	Description
Trickle Charging	Trickle Charging mode
Bulk Charging	Bulk Charging mode
Absorb Charging	Absorb Charging mode
Float Charging	Float Charging mode
Not Sure	Unknown State
Charge Complete	Charging Complete
Not Charging	Not Charging

System critical power supply/PEAK solar power requirement in the last 24 hours – LCD PAGE 32

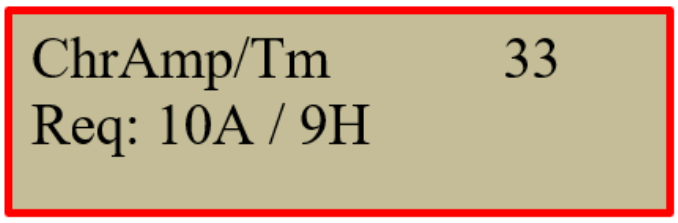
Displays the systems VBoost voltage that is critical for the system to operate. If the Vboost voltage is < 11.30 vdc, MODBUS DI Register 10042 is set to "1". If register 10042 is set to "1" the device must be returned to the factory for repair



Modbus register	Type	Range
10042	Vboost Power Supply	1=Fail
30040-41	Peak Solar Power	0-1000 watts

Rule of thumb charging current and charging times – LCD PAGE 33

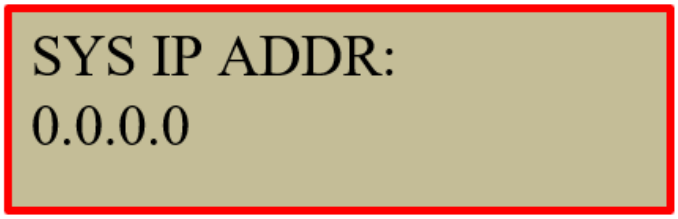
Displays a basic "rule-of-thumb" calculation of the number of amps and time in hours required to charge the battery. The calculation is based on the specified system battery amp hours installed by the user. These are general calculations and are NOT real-time.

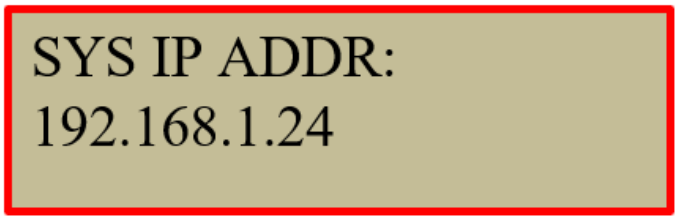


Modbus register	Type	Range
30120	Required AMPS	0-65535
30121	Required TIME (HRS)	0-65535

Device IP address – LCD PAGE 34

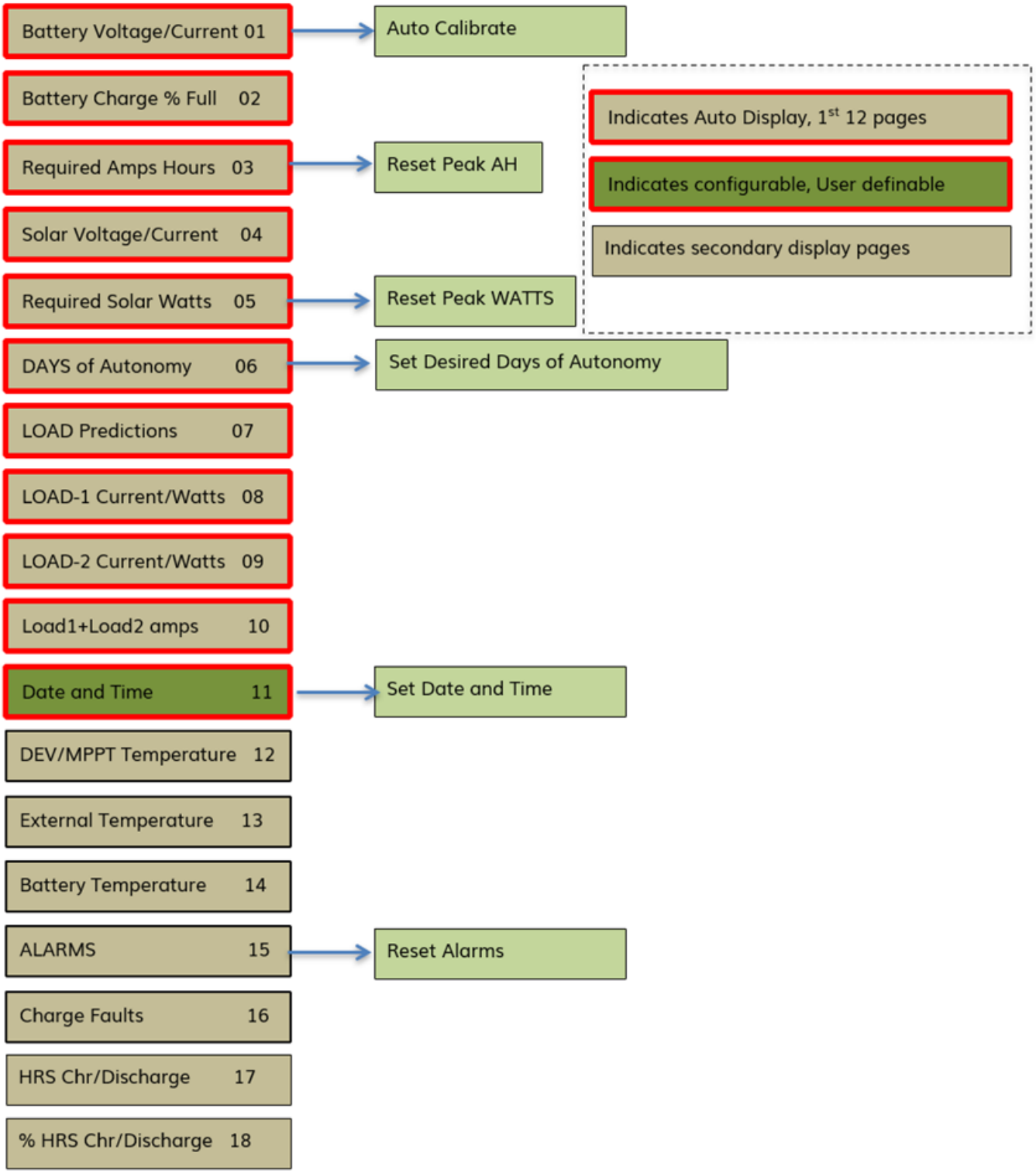
Displays the MPPT 20A CONTROLLER's IP address **IF** the MPPT 20A CONTROLLER is equipped with Modbus TCP, MQTT and embedded web page functionality. IP enabled units must be ordered from the factory.

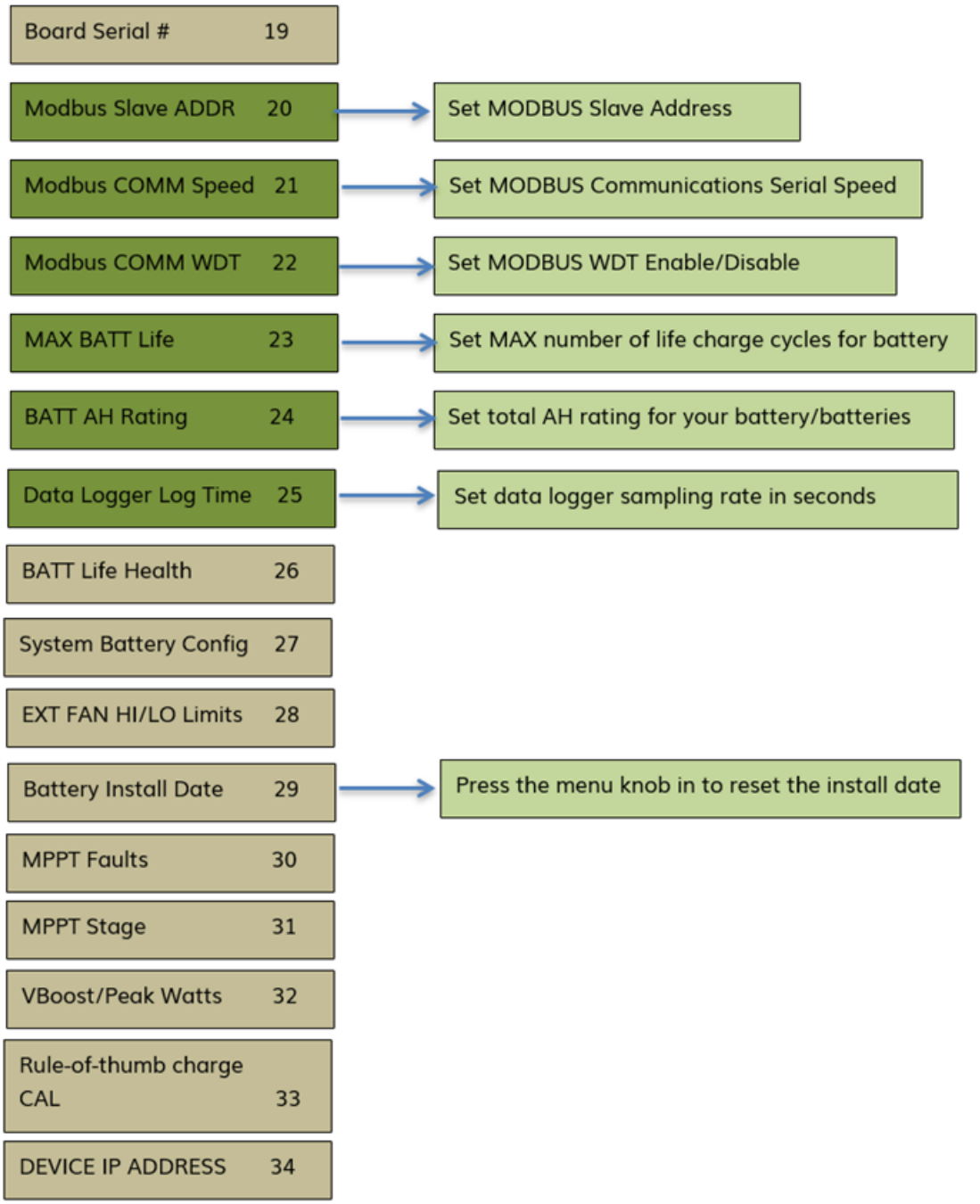




Modbus register	Type	Range
40032	IP HI ORDER	0-65535
40033	IP LOW ORDER	0-65535

LCD display map





Functions and data point measurements

This section outlines and explains all system vital signs and measurements.

Some functions are also explained. All functions and measurements are calculated and returned in real-time. There are many co-dependent, co-related functions and data points. This section does not

attempt to outline how other parameters affect respective sections; rather, each section stands on its own for the purpose of simplicity.

3000X – Analog input registers

Battery voltage measurement

Measures the battery voltage from 8 to 52vdc range. The value is a floating-point number. This value is a direct reflection of the battery voltage. The MPPT 20A CONTROLLER automatically detects and adjusts for proper system voltage as part of the power up cycle. DO NOT change the battery configuration or add or remove batteries with power ON to the MPPT 20A CONTROLLER. The MPPT 20A CONTROLLER automatically sets charging voltages, calculations, limits, predictions, and so on. based on the voltage detected.

On power-up, If the MPPT 20A CONTROLLER detects a battery voltage of > 9.5vdc but < 15.5vdc, the system is set to a 12 volt system.

If the MPPT 20A CONTROLLER detects a voltage battery of > 15.5vdc but < 31.2vdc, the system is set to a 24 volt system.

Any other voltages detected cause the MPPT 20A CONTROLLER to completely disable ALL charging functions and loads and report an “Unknown Battery Configuration type”, and the system is set to a “0” VOLT system.

The system battery configuration is placed into MODBUS register 30077 and is a 16-bit unsigned value.

Any battery voltages below 6vdc may cause the system to shut down and will damage the battery beyond repair. Once the MPPT 20A CONTROLLER has determined a system voltage, it will monitor the battery system for over and under voltage limits. As an example, System detects a 12-volt battery system, then later measures a voltage level of 15vdc; the MPPT 20A CONTROLLER disables the charge controller, disable the loads, and issues an alarm.

Modbus register	Alias name	Range/units	Type
30000-01	Battery Voltage	8-52 VDC	FLOAT
30077	System Battery Voltage Detected	12/24/0	16-bit

Battery current measurement

Measures the battery current in charge and discharge states from -11.00 amps to +23.0 amps range. T floating-point number. When the value being measured is positive the battery is being charged, when t negative the battery is being discharged. The charging current is the actual current charging or discharging the batter no matter the load current.

Modbus register	Alias name	Range/units	Type
30002-03	Battery Charge/Discharge Current	- 11.0 to 23.0 Amps	FLOAT

Battery watts (power) measurement

Measures the battery power in watts for the charge and discharge states from -264 watts to +552 watts range. The value is a floating-point number. This value is calculated by Battery (Voltage * Battery Charge/Discharge Current). The range is not an indication of system performance specifications; obviously, the system will not support a 552-watt power rating. Some of the specifications are based on absolute max rating to include measurement overhead to detect issues.

Modbus register	Alias name	Range/units	Type
30004-05	Battery watts	-264 to 552 watts	FLOAT

Battery capacity % full measurement

Measures the capacity level of the battery or how full the battery is. This measurement considers the battery voltage level, how long the battery has been continuously charging, and at what current rate. Once the battery is completely full **DI MODBUS REGISTER 10000** will be set to "1". A battery level indication of "100%" does not necessarily mean the battery is completely charged. Other factors are used to determine when the battery is completely charged.

Modbus register	Alias name	Range/units	Type
30006-07	Battery capacity % Full	0-100%	FLOAT
10000	Battery Fully Charged	1=Fully Charged	Digital IN

Battery health - percent remaining

The battery health value is a measurement of how many charge cycles are remaining of the factory number of life cycles. Every battery has a specified number of life charging cycles. The MPPT 20A CONTROLLER keeps track of the number of completed charging cycles and other system and environmental measurements and calculates the remaining life. **Modbus holding register 40016** allows a user to set the estimated number of charges already completed, as an example; this may be a battery already installed for several months or years. The user can simply estimate the days the battery has been in use and set register 40016 to the estimated number of days.

Modbus holding register 40028 is the manufacture's estimated number of total charges for the battery's life. This is also a settable Modbus register, and the user can configure the proper max life charging cycles.

The system will indicate poor battery health if the life is less than 40% and when to replace the respective battery.

Modbus register	Alias name	Range/units	Type
30008-09	Battery Health % Remaining	0-100%	FLOAT
40016	Set de-rated charging cycles	0-1825 (5 Years)	16-bit
40028	Set battery life charge	0-1825 (5 Years)	16-bit
10016	Battery Capacity LOW	1= < 45% Capacity	DI
10017	Replace Battery	1= Replace BATT	DI

Peak MIN battery voltage

The MPPT 20A CONTROLLER will keep track of the minimum peak voltage within a 24-hour charging window. This will display the MIN peak voltage level the battery was charged to. Peak battery voltage is reset at midnight. This measurement may be used to determine the bottom voltage peak during a 24-hour charging cycle.

Modbus register	Alias name	Range/units	Type
30010-11	Peak MIN Battery Voltage	8-52 VDC	FLOAT

Peak MAX battery voltage

The MPPT 20A CONTROLLER keeps track of the maximum peak voltage within a 24-hour charging window. This displays the maximum peak voltage level the battery was charged to. The peak voltage level depends on many things such as weather, battery, and loading. This measurement may be used to determine the top voltage peak during a 24-hour charging cycle. Peak battery voltage is reset at midnight.

Modbus register	Alias name	Range/units	Type
30012-13	Peak MAX Battery Voltage	8-52 VDC	FLOAT

Battery watt hours being produced

Calculation of the watt-hours being produced or consumed. Positive Watt/Hours is an indication the batteries are being charged, and negative Watt/Hours is an indication the batteries are being discharged.

Modbus register	Alias name	Range/units	Type
30014-15	Battery Watt/HRs	- / +Watt/Hours	FLOAT

Solar voltage measurement

Measures and reports the voltage produced by the solar panel. Review the Solar power input and Typical solar specification for detailed information, specifications, and warnings. **WARNING: DO NOT EXCEED 52VDC. DO NOT USE A SOLAR PANEL WITH A Voc THAT EXCEEDS 52vdc, DAMAGE MAY OCCUR.**

Modbus register	Alias name	Range/units	Type
30016-17	Solar Voltage	0-52 VDC	FLOAT

Solar current measurement

Solar current measurements reflect how much current the solar panel is producing. Refer to Typical solar specification.

Modbus register	Alias name	Range/units	Type
30018-19	Solar Current	0-13.00 Amps	FLOAT

Solar watts (power) measurement

Measures the solar power in watts for the charge and discharge states, from 0 watts to +1000 watts range. The value is a floating-point number. This value is calculated as (Solar Voltage * Solar) current being supplied. The range is not an indication of system performance specifications; obviously the system will not support a 1000watt power specification. Some of the specifications are based on absolute maximum rating to include measurement overhead to detect issues.

Modbus register	Alias name	Range/units	Type
30020-21	Solar Watts	0 - 1000 Watts	FLOAT

LOAD-1 current measurement

The MPPT 20A CONTROLLER will monitor the independent current being consumed by equipment attached to LOAD-1. Exceeding 7.50 amps will disrupt and remove power to all equipment attached to LOAD-1 for a defined period. See Device load – Power measurements. LOAD-1 may also be disrupted if the battery falls below an unsafe level.

Critical equipment such as telemetry radios and PLCs should be attached to LOAD-1. LOAD-1 has a higher priory than LOAD-2.

LOAD-1 may also be manually cycled for 30 seconds by setting **DO Modbus register 00026** to "1". The Modbus register and power to LOAD-1 automatically resets after 30 seconds.

This function allows a SCADA operator to remotely power cycle all equipment attached to LOAD-1 eliminating having to send a technician to the field to cycle power on third-party equipment.

NOTE: If the battery is below the "battery load-shed reset voltage" and a manual power cycle for either load is sent, the loads may remain OFF until the battery voltage rises above the "battery load-shed reset voltage".

There are several other measurements associated with LOAD-1 to include:

- **Load-1 Shed Timer:** Seconds remaining in load-shed **16-bit MODBUS REGISTER 30085**
- **Load-1 Shed Trip Count:** Number of load-sheds **16-bit MODBUS REGISTER 30087**
- **Load-1 Shed Active:** Load-Shed State DI MODBUS REGISTER 10006, 1= In Load-Shed
- **Load-1 Output Shorted:** Load-shed State DI MODBUS REGISTER 10013, 1= Output Shorted
- **Load-1 Current Detect:** No Current Detected **DI MODBUS REGISTER 10031, 1= No Current**
- **Load-1 Output Request ON:** System request Load to be ON DI MODBUS REGISTER 10033, 1= Controller is requesting Load-1 to be on

NOTE: If the battery voltages are lower than the minimum for LOAD-1, it is possible for this load to remain OFF until the battery voltage is above reset limits and any equipment used to send data to include data being sent form the MPPT 20A CONTROLLER will be disrupted.

See section Device load – Trigger level and timers for a detailed list of events that will affect disruptions on LOAD-1

Modbus register	Alias name	Range/units	Type
30022-23	Load-1 Current	0- 7.50 Amps	FLOAT
00026	Manual Cycle OFF for 30 seconds	1=Cycle Power	DO
30085	Load-1 Timer	900 to 0	16-bit
30087	Load-1 Trip Count	0 to 65535	16-bit
10006	Load-1 Load-Shed Active	1= In load-shed	DI
10013	Load-1 Shorted	1= Shorted	DI
10031	Load-1 No Current Detected	1= No Current	DI
10033	Controller requesting Load-1 ON	1=Is Requesting	DI

LOAD-2 current measurement

The MPPT 20A CONTROLLER will monitor the independent current being consumed by equipment attached to LOAD-2. Exceeding 7.50 amps will disrupt and remove power to all equipment attached to LOAD-2 for a defined period. See Device Load – Power measurements. LOAD-2 may also be disrupted if the battery falls below an unsafe level. Non-critical equipment should be attached to Load-2. Load-2 has the lowest priory is the first load-shedding event to occur when prioritizing which LOAD to disrupt and when to load-shed.

LOAD-2 may also be manually cycled for 30 seconds by setting **Modbus DO register 00027** to "1". The Modbus register and power to Load-2 will automatically be reset after 30 seconds.

This function allows a SCADA operator to remotely power cycle all equipment attached to LOAD-2 eliminating having to send a technician to the field to cycle power on third-party equipment.

NOTE: If the battery is below the "battery load-shed reset voltage" and a manual power cycle for either load is sent, the loads may remain OFF until the battery voltage rises above the "battery load-shed reset voltage".

There are several other measurements associated with LOAD-1 to include:

- **Manually Keep Load Off:** Setting **D0 MODBUS REGISTER 00003 to "1"** manually keeps LOAD -2 off. Setting **Modbus DO register 00003** to "0" will return LOAD-2 to a normal function.
- **Load-2 Shed Timer:** Seconds remaining in load-shed **16-bit MODBUS REGISTER 30086**
- **Load-2 Shed Trip Count:** Number of load-sheds **16-bit MODBUS REGISTER 30088**
- **Load-2 Shed Active:** Load-shed State DI MODBUS REGISTER 10007, 1= In Load-shed
- **Load-2 Output Shorted:** Load-shed State DI MODBUS REGISTER 10018, 1= Output Shorted
- **Load-2 Current Detect:** No Current Detected **DI MODBUS REGISTER 10032, 1= No Current**

- **Load-2 Output Request ON:** System request Load to be ON DI MODBUS REGISTER 10034, 1= Controller is requesting LOAD-1 to be on

NOTE: If the battery voltages are lower than the minimum for LOAD-1 it is possible for this load to remain OFF until the battery voltage is above reset limits and any equipment used to send data to include data being sent form the MPPT 20A CONTROLLER will be disrupted.

See section Device load – Trigger level and timers for a detailed list of events that affect disruptions on LOAD-2.

Modbus register	Alias name	Range/units	Type
30024-25	Load-2 Current	0- 7.50 Amps	FLOAT
00027	Manual Cycle OFF for 30 seconds	1=Cycle Power	DO
00003	Manual Keep OFF	1=OFF, 0-ON	DO
30086	Load-2 Timer	900 to 0	16-bit
30088	Load-2 Trip Count	0 to 65535	16-bit
10007	Load-2 Load-shed Active	1= In Load-shed	DI
10018	Load-2 Shorted	1= Shorted	DI
10032	Load-2 No Current Detected	1= No Current	DI
10034	Controller requesting Load-2 ON	1=Is Requesting	DI

Battery temperature

The MPPT 20A CONTROLLER monitors the battery temperature of the connected lead acid battery. This sensor does not provide battery thermal compensation. Battery thermal compensation is measured and performed by a separate temperature sensor located below the Ethernet port.

Battery temperature is available in **MODBUS register 30026-30027**. The battery temperature AND the battery thermal compensation sensors should be placed as close to the battery. If possible mounted directly to the battery as shown.

If the battery temperature exceeds the HIGH temperature setting in **MODBUS HOLDING REGISTER 40000-01** the external exhaust-cooling fan will come on and remain on until the temperature falls below the LOW temperature setting in **MODBUS HOLDING REGISTER 40002-03**. The external exhaust cooling fan is not included and is sold separately.

The user can also set the battery HOT and COLD temperature limits.

If the battery temperature exceeds the HOT temperature set in **MODBUS HOLDING REGISTER 00004-05, MODBUS DI REGISTER 00009** is set to "1" and resets to "0" when the battery temperature falls 10°f below the HOT temperature setting.

If the battery temperature falls below the COLD temperature set in **MODBUS HOLDING REGISTER 00006-07, MODBUS DI REGISTER 00008** is set to "1" and resets to "0" when the battery temperature raises 10°f above the COLD temperature setting.

Modbus register	Alias name	Range/units	Type
30026-27	Battery temperature	-67°f to 257°f	FLOAT
40000-01	SET Exhaust Fan ON TEMP Limit	-67°f to 257°f	FLOAT
40002-03	SET Exhaust Fan OFF TEMP Limit	-67°f to 257°f	FLOAT
40004-05	SET Battery HIGH Temperature Limit	-67°f to 257°f	FLOAT
10009	Battery HOT LIMIT Indicator	User Defined	DI
40006-07	SET Battery LOW Temperature Limit	-67°f to 257°f	FLOAT
10008	Battery COLD LIMIT Indicator	User Defined	DI

Figure 36 - Thermal compensation and battery temperature measurement probe placement

Solar Supervisor internal enclosure/board temperature

Internal temperature is monitored as an indicator of the temperature level within the MPPT 20A CONTROLLER enclosure. The measurement is used for many functions to include when to turn on and off the enclosure fans.

If the Internal MPPT 20A CONTROLLER enclosure temperature exceeds 120°f the units cooling fans will come on and remain on until the temperature falls below 110°F.

Modbus register	Alias name	Range/units	Type
30028-29	MPPT 20A CONTROLLER Internal temperature F	-67°f to 257°f	FLOAT

External temperature

An external temperature sensor may be installed and is typically used to monitor outside ambient temperature. The sensor should be installed using the proper water/weatherproof cable gland and should penetrate from the bottom of the solar cabinet as shown below.

Modbus register	Alias name	Range/units	Type
30030-31	EXT Temperature F	-67°f to 257°f	FLOAT

Figure 37 – Correct positioning of the sensor

Total time is a 24-hour window the battery has been charging + discharging

This number is the sum of charging-time and discharging-time within a 24-hour window. When the battery is charging a "charging seconds timer" is incremented. When the battery is discharging a "discharging seconds timer" is decremented. This number is reset at midnight.

Modbus register	Alias name	Range/units	Type
30032-33	+Total Charge / -Discharge Time	SEC's	FLOAT

Percent of total time battery has been charging

This value is the percentage of total time in a 24-hour window spent charging. This number is reset at midnight.

Modbus register	Alias name	Range/units	Type
30034-35	Charge % Time	0-100%	FLOAT

MPPT charging temperature

The MPPT Temperature reading is an indication of heat being generated by the charging process. If the MPPT temperature rises above 134.00f it will enable the enclosures cooling fans and will disable the cooling fans when the temperature falls below 124.00f. There are several system measurements that may cause the cooling fans to come on, the MPPT temperature is just one of them. It is possible for the MPPT temperature to fall below 124.00 and the fans remain on.

Modbus register	Alias name	Range/units	Type
30036-37	MPPT charging temperature	-67°f to 257°f	FLOAT

Battery rate of charge/discharge

One of the analysis attributes is the determination of how fast the battery is discharging. Any value <-6.00% generates an alert by setting **DI MODBUS REGISTER 10041 = "1".** This event resets at noon (12pm).

There are three scenarios that would cause this event to occur:

1. A battery that is no longer holding a charge,
2. Large current being drawn from the loads and
3. A long-term discharge event where the battery did not receive charging for multiple days.

Modbus register	Alias name	Range/units	Type
30038-39	Battery Rate of Charge/Discharge	% of Change	FLOAT
10041	Battery ROC Failure	1= < -6.0%	DI

Solar peak watts

The solar peak watts are the recorded high PEAK solar watts detected within a 24-hour period. The peak wattage resets to "0" at midnight. This value may be used to verify the proper size of the solar panel.

Modbus register	Alias name	Range/units	Type
30040-41	Solar Peak Watts	0-1000 watts	FLOAT

Calculated MAX LOAD AMPS to sustain

Monitored load watt hours consumed by Load-1+Load-2			
Modbus register	**Alias name**	**Range/units**	**Type**
30042-43	Max battery discharge current to sustain desired autonomy	-8.00amps to -0.00 amps	FLOAT
10039	Battery discharge current too high to sustain Days of Autonomy	1= Batt Discharge Current < Max battery discharge current to sustain desired autonomy	DI

Number of power-up cycles

This register displays the number of times the MPPT 20A CONTROLLER has been restarted, reset, or powered up. There are several events that may cause a system reset, such as:

- Modbus communications timeout as outlined in Modbus communications Watchdog Timer (WDT).
- A remote system reset/restart as outlined in this manual or if the system is powered up.

Changes within this register may be an indicator of an improper configuration setting or an undersigned system.

As part of the system notification of a device power-up or restart, the MPPT 20A CONTROLLER sets **MODBUS Digital Output Register 00009** to "1" as an indicator it has been powered up. A SCADA system would need to write a "0" **to MODBUS Digital Output Register** 00009 to reset this event.

Modbus register	**Alias name**	**Range/units**	**Type**
30044-45	# system power cycles	0-4294967294	32-Bit
00009	Device has powered cycled	1= Power Cycled	DO

System run time

System run time is the total lifetime the MPPT 20A CONTROLLER has been powered up. This is not charging time; it is lapsed time the device has been powered. The time is in seconds. Total time is 0 to 136.19 Years. This register cannot be modified.

Modbus register	Alias name	Range/units	Type
30046-47	System life runtime (sec)	0-4294967294	32-Bit

Device up time since last power up

This Modbus register is the total time in seconds since the last device reset, restart or power-up. The register is reset to "0" after a power-up, reset, or restart.

Modbus register	Alias name	Range/units	Type
30048-49	Uptime sec. Resets on power up/reset	0-4294967294	32-Bit

Number of battery deep discharge cycle events and time in deep discharge

Deep discharging a battery reduces its life. A *deep cycle* is defined as the battery voltage level falling below 11.15vdc in a 12V system and 22.30vdc in a 24V system. This function and respective Modbus register keep track of the number of times the battery falls below the above levels. If the number of times exceeds 20 times within a month, the system will be flagged as under-designed, **MODBUS DI register 10023**. The complement function is **MODBUS register 30052-53**, which indicates the total time the battery has been deep discharged. More than 20 deep-discharge events in a single month generates an alarm by setting **DI MODBUS REGISTER 10023 = "1".**

In a properly operating and connected system, this event should never occur.

This event can be reset by writing the following sequence:

Modbus register	Alias name	Range/units	Type
30050-51	Deep Cycle Event Count	0-4294967294 COUNT	32-Bit
30052-53	Deep Cycle Time	0-4294967294 SEC	32-Bit
10023	More than 20 deep cycles in one month fault	1= Fault, 0= OK	DI

Time lapse of no deep cycle events

Indicates how long the system **has not** been in any deep discharge event. This is an indicator of how well the system is designed. This time is reset to "0" if any deep cycle event occurs, as defined in Number of battery deep discharge cycle events, OR a SCADA system forces a power cycle. Total time is 0 to 136.19 years (register is in seconds).

Modbus register	Alias name	Range/units	Type
30054-55	Time with no deep cycle events	0-4294967294 SEC	32-Bit

New battery install date

The New Battery install date is the date a new battery was installed to replace an old battery, or as a new site install. The month, date, year, and hour the battery was installed is placed into a 32-bit number. A 32-bit number consists of four bytes. Each of the four bytes is populated with the respective data listed. Each byte is defined as:

- Byte 0: Year
- Byte 1: Date
- Byte 2: Month
- Byte 3: Hours

The data is permanent until a new battery is installed AND the reset sequence when a new battery is installed begins. Writing a "1" to **DO MODBUS REG 00023** and **00024 at the same time** will record the new month, date, year, and hour the battery was installed. A technician may also perform a reset of the battery install date by rotating the Menu knob on the device to **MENU PAGE 29,** then pressing the Menu knob **IN** to change and set the new install date.

Modbus register	Alias name	Range/units	Type
30056-57	New BAT Install Date [hrs][mo][date][yr]	4-bytes	32-Bit
00023	New Battery Installed Lock1 (Make this a single DO function)	1= new batt installed	DO
00024	New Battery Installed Lock2	1= new batt installed	DO

Accumulated time external fan has been active or on

Indicates how long the accumulated life run time for the external cooling fan has been running. The time is in seconds. Total time is 0 to 136.19 years.			
Modbus register	**Alias name**	**Range/units**	**Type**
30058-59	EXT FAN On Time (sec)	0-4294967294	32-Bit

State of charge timer

This timer is used for system calculations and is not a user parameter.			
Modbus register	Alias name	Range/units	Type
30062-63	pseudo +coulomb counter	10800	32-Bit

Number of full battery charging cycles reaching complete absorb charge

The number of times the battery was fully charged. Fully charged is defined as reaching peak absorption charging voltage specification + reaching 100% fully charged.			
Modbus register	**Alias name**	**Range/units**	**Type**
30064-65	BATT fully charged cycles (>14/28)	0-4294967294	32-Bit

Number of times battery charging was less than absorption specifications

Number of times the battery charging voltage never made peak absorption charging voltage specifications. During the three-stage charging cycles, the absorption cycle must reach full absorption voltage. The peak voltage is typically 14.1v for a 12v system and 28.2v for a 24v system. If the charging cycle fails to make absorption voltages, it may be an indicator of a weather event, significant current consumption, or an under-rated or under-designed system.			
Modbus register	**Alias name**	**Range/units**	**Type**
30066-67	Voltage peak <14/28vdc count	0-4294967294	32-Bit

Number of battery charging anomalies

Number of battery charging failures when any of the following charging faults occur:

- Failure to reach max peak absorption charging levels
- Battery exceeds over voltage levels; **Modbus DI REG 10015**
- Battery failed to reach peak charging levels three days in a row: **Modbus DI REG 10028**
- Unknown battery configuration voltage on power up; **Modbus DI REG 10035**
- A sustained battery capacity where more AMP HOURS are required than installed; **Modbus DI REG 10044**
- A sustained solar watts production where more solar watts are required than installed; **Modbus DI REG 10038**

Modbus register	Alias name	Range/units	Type
30068-69	Number of any BAT charge faults	0-4294967294	32-Bit
10015	BATT VOLTAGE EXCEEDS UPPER LIMITS	1= Batt VDC > Hi	DI
10028	FAILED ABSORB 3DAYS in a row	1=ABSORB Failed >3days	DI
10035	UNKNOWN BATTERY System Voltage. Not 12v or 24v system	1= Unknown System Battery voltage	DI
10044	SUSTAINED BATT AMP HOURS CAPACITY	1=Sustained < Battery Capacity	DI
10038	SUSTAINED SOLARWATTS CAPACITY	1=Sustained < Panel Capacity	DI
10003	ANY FAULT THAT OCCURED	1= ANY FAULT	DI

Modbus communication watchdog timer

Countdown timer related to the user defined watchdog timer. The user may define a maximum timer from 120 to 432000 seconds (five days). The MPPT 20A CONTROLLER immediately begins to decrement the WDT timer. If the timer reaches "0" the MPPT 20A CONTROLLER attempts a complete system restart. Each time the MPPT 20A CONTROLLER receives a valid Modbus packet AND the valid packet is for the respective MPPT 20A CONTROLLER, the WDT timer is reset. This is considered a communications watchdog and is designed to detect potential RTU or SCADA lockup issues.

Modbus register	Alias name	Range/units	Type
30070-71	Modbus COMM WDT Timer	432000 – 120 (sec)	32-Bit
00000	Modbus COMM WDT ENABLE	1=Enable	DO

Tamper alarm event

To support this feature a tamper type normally open, dry contact switch must be mounted to the solar cabinet then connected to the MPPT 20A CONTROLLER.

Modbus register	Alias name	Range/units	Type
30072-73	Number of TAMPER events	0-4294967294	32-Bit
10026	Tamper Alert Flag	1=Tamper	DI

Never hit 12/24 absorb peak targets

The number of contiguous or number of times-in-a-row the battery failed to reach the peak absorb voltage. If the battery is not charged >= to 14.0 VDC / 28.00 VDC, this register increments and is reset to "0" if the absorb voltage is >= to 14.0 VDC / 28.00 VDC. This is a view into the number of times the battery never reaches full absorb mode. This may be an indicator that the solar panel is too small, there were not enough battery amp hours, a streak of bad weather, or the current load on the system is too great.

Modbus register	Alias name	Range/units	Type
30074-75	Number of contiguous absorb peak voltage limits missed.	0-4294967294	32-Bit

Number of battery charging cycles

The MPPT 20A CONTROLLER keeps track of the number of completed charging cycles. This is a basic charging cycle; it only requires the battery to absorb voltage to reach nominal limits in a confirmed charging mode. This function is different than **MODBUS register 30064-65.** The **MODBUS register 30064-65** function requires a FULL charge. **MODBUS register 30076** only requires a simple charge.

Modbus register	Alias name	Range/units	Type
30076	Battery charging cycles	0-65535	16-Bit

System battery voltage configuration detection

On power-up: If the MPPT 20A CONTROLLER detects battery voltage of > 9.5vdc but < 15.5vdc, the system is set to a 12 VOLT system. The system battery configuration is placed into **Modbus register 30077** and is a 16-bit unsigned value.

If the MPPT 20A CONTROLLER detects voltage battery of > 15.5vdc but < 31.2vdc, the system is set to a 24 VOLT system.

Any other voltages detected cause the MPPT 20A CONTROLLER to completely disable ALL charging functions and loads, and report an "Unknown Battery Configuration type", and the system sets to a "0" VOLT system. If the system detects an invalid battery configuration connected to the MPPT 20A CONTROLLER, it will set **DI MODBUS REGISTER 10035** to "1".

Any battery voltages below 6vdc may cause the system to shut down and will damage the battery beyond repair. Once the MPPT 20A CONTROLLER has determined a system voltage, it will monitor the battery system for over and under voltage limits. As an example, the system detects a 12-volt battery system, then later measures a voltage level of 15vd. The MPPT 20A CONTROLLER disables the charge controller, disables the loads, and issues an alarm.

The user needs to look at the battery input voltage and make the proper system design changes.

Modbus register	Alias name	Range/units	Type
30077	System Battery Voltage Detected	12/24/0	16-bit
10035	UNKNOWN BATTERY VOLATGE	1=Unknown Battery	DI

Battery amp hours required

The system number of battery amp hours required to sustain desired hours of autonomy. This is a system calculation based on the user's desired days of autonomy. This register tells the user how many battery amps hours this system requires to sustain the desired days of autonomy.

Modbus register	Alias name	Range/units	Type
30078	System required number of amp hours required	0-1000	16-bit

Time in Bulk Charging mode

Time the MPPT 20A CONTROLLER was in bulk charging mode. This number tells you how long bulk levels were sustained within a 24-hour cycle. In bad weather or low sunlight this number can be low.			
Modbus register	**Alias name**	**Range/units**	**Type**
30079	Time in Bulk mode	0-65535	16-bit

Time in Absorb Charging mode

Time the MPPT 20A CONTROLLER was in absorb voltage levels. This number tells you how long absorb levels were sustained within a 24-hour cycle. In bad weather or low sunlight this number can be low.			
Modbus register	**Alias name**	**Range/units**	**Type**
30080	Time in absorb mode	0-65535	16-bit

Time in float levels

Time the MPPT 20A CONTROLLER was in float voltage levels. This number tells you how long float levels were sustained within a 24-hour cycle. In bad weather or low sunlight this number can be low. It is possible for the battery to never enter FLOAT mode. It is possible the system never enters FLOAT mode; some of the causes are higher battery temperatures and time charging in absorb mode.			
Modbus register	**Alias name**	**Range/units**	**Type**
30081	Time in float mode	0-65535	16-bit

Time not charging

Time the MPPT 20A CONTROLLER was not charging within a 24-hour cycle.			
Modbus register	**Alias name**	**Range/units**	**Type**
30082	Time not charging	0-65535	16-bit

Warranty remaining

The MPPT 20A CONTROLLER has a one-year limited warranty and keeps track of the remaining warranty. The warranty cannot exceed 18 months from the date of purchase, terms and conditions apply. See Warranty for details.

Modbus register	Alias name	Range/units	Type
30083	Warranty remaining	100% to 0%	16-bit

LOAD-1 and LOAD-2 load-shedding timer

Indicates time remaining in load-shed for Load-1 and Load-2. In the event power is removed from third-party equipment attached to LOAD-1 or LOAD-2, the time remaining before the power is re-applied is indicated by these registers. These are countdown timers: once they display “0” power is reapplied. There are occasions where power may continue to remain off for a respective load output. One example is if the battery voltage falls below and remains at critical levels. The MPPT 20A CONTROLLER requires the voltage levels to return to save levels AND these timers to indicate “0”.

Modbus register	Alias name	Range/units	Type
30085	Load-1 Timer (20 min)	1200 to 0 SEC	16-Bit
30086	Load-2 Timer (20 min)	1200 to 0 SEC	16-Bit

Number of load trip events for LOAD-1 and LOAD-2

Indicates the total number of load-shedding events for LOAD-1 and LOAD-2 separately.

Modbus register	Alias name	Range/units	Type
30087	Number of load1 trip events	0-65535	16-Bit
30088	Number of load2 trip events	0-65535	16-Bit

Data Logger timer – Time to next data logging event

This timer counts to the user-defined "Sample Rate", then logs all data listed in the Data logger. This Modbus register displays the time in seconds "to the next logging event". All data is logged onto the SD card inserted into the MPPT 20A CONTROLLER.

Modbus register	Alias name	Range/units	Type
30089	Next Data Logger Event	0 to Sample Rate	16-Bit

Predicted and remaining days of autonomy

The MPPT 20A CONTROLLER attempts to calculate and predict the number of days the system will continue to safely operate without damaging the battery. This value is calculated when the battery is discharging. **NOTE**: When sunlight transitions from dusk to dawn and vice versa this reading may be exaggerated. This number is the most accurate in the absence of sunlight. **This value is stored in MODBUS INPUT REGISTOR 30119** and is a 16-bit number**.**

If the lack of sunlight is sustained during events like snow, short winter days, and so on, the ***Remaining Predicted Days of Autonomy*** begin to decrement. This value is stored **in MODBUS INPUT REGISTOR 30090** and is a 16-bit number**. PRO-TIP VALUE: This value is an indicator of when your system will fail. You must address issues within the "Remaining predicted Days.."**.

Modbus register	Alias name	Range/units	Type
30090	Remaining Predicted Days of Autonomy	0 to 30	16-Bit
30119	Predicted Days of Autonomy	0 to 30	16-Bit

Product code

The product code identifies the model number, features, and functions.

Modbus register	Alias name	Range/units	Type
30091	Product Code	Varies	16-Bit

RTU cooling fan “on” time for the last 24 hours

Indicates how long the accumulated run time within a 24-hour window for the on-board cooling fans. The time is in seconds. Total time is 0 to 18.20 hours.			
Modbus register	**Alias name**	**Range/units**	**Type**
30092	Fan ON Time last 24hrs	0-65535 SEC	16-Bit

Battery cabinet exhaust cooling fan “on” time for the last 24 hours

Indicates how long the accumulated run time within a 24-hour window for the external cabinet exhaust cooling fans. The time is in seconds. Total time is 0 to 18.20 hours.			
Modbus register	**Alias name**	**Range/units**	**Type**
30093	Exhaust FAN ON Time last 24hrs	0-65535 SEC	16-Bit

Real-time clock – date and time

Reads the internal real-time clock and returns the hours, minutes, seconds, month, date, and year of any respective MPPT 20A CONTROLLER.			
Modbus register	**Alias name**	**Range/units**	**Type**
30094	RTC HRS	0-23	16-Bit
30095	RTC MIN	0-59	16-Bit
30096	RTC SEC	0-59	16-Bit
30097	RTC Month	1-12	16-Bit
30098	RTC Date	1-31	16-Bit
30099	RTC Year 20:	20 -->	16-Bit

Total battery charging life timer

The MPPT 20A CONTROLLER keeps track of the total time the battery has been charging. The time is placed in four separate 16-bit Modbus registers: Days, Hours, Min, and Sec. This gives insight into how balanced the system is with respect to charging vs. discharging times.			
Modbus register	**Alias name**	**Range/units**	**Type**
30100	Lapse Days of Charge	0-65535	16-Bit
30101	Lapse Hours of Charge	0-23	16-Bit
30102	Lapse Min of Charge	0-59	16-Bit
30103	Lapse Sec of Charge	0-59	16-Bit

Total battery discharging life timer

The MPPT 20A CONTROLLER keeps track of the total time the battery has been discharging. The time is placed in 4 separate 16-bit Modbus registers: Days, Hours, Min, and Sec.			
Modbus register	**Alias name**	**Range/units**	**Type**
30104	Lapse Days of Discharge	0-65535	16-Bit
30105	Lapse Hours of Discharge	0-23	16-Bit
30106	Lapse Min of Discharge	0-59	16-Bit
30107	Lapse Sec of Discharge	0-59	16-Bit

Alarm mapping

The MPPT 20A CONTROLLER sets a series of alarms that may indicate upcoming issues. These are not necessarily critical or will cause the system to stop working. The only alarm that is critical is the "CRITICAL SYS VDC" alarm. Listed below are the bit-mapped alarms within the 16-bit **Modbus register 30108**.

Modbus register	Alias name	Range/units	Type
30108	SYSTEM SUSTAINABILITY	1= Fail	Bit-0
	FLOAT MODE 3DAY	1= Fail	Bit-1
	NEED MORE BATT CAPACITY SUSTAINED	1= Fail	Bit-2
	NEED MORE BATT CAPACITY REAL TIME	1= Fail	Bit-3
	NEED MORE SOLAR CAPACITY SUSTAINED	1= Fail	Bit-4
	NEED MORE SOLAR CAPACITY REAL TIME	1= Fail	Bit-5
	CRITICAL SYS VDC	1= Fail	Bit-6
	SOLAR INPUT TO HIGH	1= Fail	Bit-7
	LOAD1_SHORT	1= Fail	Bit-8
	LOAD2_SHORT	1= Fail	Bit-9

Battery amps hours to add to sustain days of autonomy

A system level indicator of how many amp hours to add. This is a real-time measurement and will change based on load demands, seasons, system age, and so on. This register is the recommended number of battery capacity in amp-hours to add to the solar system to sustain the user desired days of autonomy.

Modbus register	Alias name	Range/units	Type
30109	Add much amp hours	0-1000 Amps Hour	16-Bit

Solar panel watts to add to sustain system charging

A system level indicator of how many solar watts to add. This is a real-time measurement and will change based on battery demands, seasons, system age, etc. This register is the recommend number of solar panel watts to add to the solar system to sustain the user desired days of autonomy.

Modbus register	Alias name	Range/units	Type
30110	Add much solar watts	0-1000 watts	16-Bit

Solar panel sunshine exposure time in hours for the last 24 hours

The MPPT 20A CONTROLLER monitors and measures how many hours the solar panel was exposed to usable sunlight within a 24-hour window. This value is calculated by the “Usable Exposure” time the system can use and reflects the size of the solar panel and weather conditions.

Modbus register	Alias name	Range/units	Type
30111	Solar Panel exposure to sunlight	2-24 Hours	16-Bit

Instantaneous solar watts required

Displays the instantaneous demand in watts required by the system. This measurement may change drastically from measurement-to-measurement and is the result of changing attributes such as load current, battery charging needs, and so on. The measurement provides an instantaneous look into the system solar panel demand needs within a very narrow time frame.

Modbus register	Alias name	Range/units	Type
30112	Instantaneous Solar Watts Required	0-1000 Watts	16-Bit

Instantaneous battery amp hour required

Displays the instantaneous demand battery amp hours required by the system. This measurement may change drastically from measurement-to-measurement and is the result of changing attributes such as load current, battery charging needs, and so on. The measurement provides an instantaneous look into the autonomy target requirements.

Modbus register	Alias name	Range/units	Type
30113	Instantaneous Battery Amps Hours Required	0-1000 Amp Hours	16-Bit

Peak solar watts

Displays the peak solar watts demand on the solar panel within a 24-hour window. This value is reset at midnight.			
Modbus register	**Alias name**	**Range/units**	**Type**
30114	Peak Solar Watts	0-1000 Watts	16-Bit

Peak battery amp hours

Displays the peak solar watts demand on the solar panel within a 24-hour window. This value is reset at midnight.			
Modbus register	**Alias name**	**Range/units**	**Type**
30115	Peak battery amp hours	0-1000 Amp Hours	16-Bit

Solar panel sun exposure

The MPPT 20A CONTROLLER monitors and measures how many seconds the solar panel was exposed to usable sunlight within a 24-hour window. This value is calculated by the "Usable Exposure" time the system can use and reflects the size of the solar panel and weather conditions.			
Modbus register	**Alias name**	**Range/units**	**Type**
30116	Sunshine exposure (Seconds)	0-65535 SEC	16-Bit

Predicted solar watts required based on load

The predicted solar watts required based on the system load and provides a predicted look into the system solar panel demand needs. This measurement reflects power consumed by LOAD-1 and LOAD-2 and is a close indicator of solar panel sizing requirements. Battery charging current demands or current requirements are not reflected in this value. **PRO-TIP VALUE: This value is a system sizing attribute.**			
Modbus register	**Alias name**	**Range/units**	**Type**
30117	Predicted solar watts required for loads only	0-1000 Watts	16-Bit

Predicted battery amp hours required based on load

The predicted battery amp hours required to sustain the system load and provides a predicted look into the system battery capacity needs. This measurement reflects power consumed by LOAD-1 and LOAD-2 and a close indicator of battery amp hour sizing requirements. **PRO-TIP VALUE: This value is a system sizing attribute.**			
Modbus register	**Alias name**	**Range/units**	**Type**
30118	Predicted battery amps hours required for loads only	0-1000 Amp Hours	16-Bit

Common practice: Charging amps required

This is a basic common practice calculation and is subject to be removed or repurposed.			
Modbus register	**Alias name**	**Range/units**	**Type**
30120	Common practice: charging amps required	0-500 Amp Hours	16-Bit

Common practice: Charging time required

This is a basic common practice calculation and is subject to be removed or repurposed.			
Modbus register	**Alias name**	**Range/units**	**Type**
30121	Common practice: charging time required	0-24 Hours	16-Bit

Device firmware revision

Displays the firmware revision running within the device.			
Modbus register	**Alias name**	**Range/units**	**Type**
30122	Device firmware revision	Varies	16-Bit

Device hardware revision

Displays the hardware revision.			
Modbus register	**Alias name**	**Range/units**	**Type**
30123	Device hardware revision	Varies	16-Bit

4000X – Analog holding registers

Set exhaust fan HIGH and LOW temperature limits

If the battery temperature exceeds the HIGH Temperature setting in **MODBUS HOLDING REGISTER 00000-01** the external exhaust-cooling fan comes on and remains on until the temperature falls below the LOW temperature setting in **MODBUS HOLDING REGISTER 00002-03**. The external exhaust cooling fan is not included and is sold separately.

Modbus register	Alias name	Range/units	Type
40000-01	SET Exhaust Fan HIGH TEMP Limit	-67°f to 257°f	FLOAT
40002-03	SET Exhaust Fan LOW TEMP Limit	-67°f to 257°f	FLOAT

Set HIGH and LOW battery temperature limits

The user can set battery HOT and COLD temperature alarm limits.

If the battery temperature exceeds the HOT temperature set in **MODBUS HOLDING REGISTER 00004-05, MODBUS DI REGISTER 00009** is set to "1" and resets to "0" when the battery temperature falls 10°f below the HOT temperature setting.

If the battery temperature falls below the COLD temperature set in **MODBUS HOLDING REGISTER 00006-07, MODBUS DI REGISTER 00008** is set to "1" and resets to "0" when the battery temperature raises 10°f above the COLD temperature setting.

Modbus register	Alias name	Range/units	Type
40004-05	Battery HIGH TEMP Limit	-67°f to 257°f	FLOAT
40006-07	Battery LOW TEMP Limit	-67°f to 257°f	FLOAT

Set communications watchdog timer

The user may define a max timer from 120 to 432000 seconds (two minutes to five days). The MPPT 20A CONTROLLER immediately begins to decrement the WDT timer, if the timer reaches "0", the MPPT 20A CONTROLLER attempts a complete system restart. Each time the MPPT 20A CONTROLLER receives a valid Modbus packet AND the valid packet is for the respective MPPT 20A CONTROLLER, the WDT timer is reset. This is considered a communications watchdog and is designed to detect potential RTU or SCADA lock up issues. This register allows the user to set the desired WDT time.

Modbus register	Alias name	Range/units	Type
40008 - 09	Communication WDT Timeout Time	120-432000	32-Bit

Device serial number

Although the device serial number is placed in a holding register, it is READ ONLY and is not adjustable. See Board serial number for details.

Modbus register	Alias name	Range/units	Type
40010-11	Device Serial Number Low Order	0-4294967294	32-Bit
40012-13	Device Serial Number High Order	0-4294967294	32-Bit

Set derated charging cycles

Allows a user to set the estimated number of charges already completed, as an example; this may be a battery already installed for several months or years. The user can simply estimate the days the battery has been in use and set register 40016 to the estimated number of days.

Modbus register	Alias name	Range/units	Type
40016	Set de-rated charging cycles	0 – 4380 (12 Years)	16-bit

Set desired days of autonomy

The desired days of autonomy are the number of days you want the system to operate safely in the event the solar panel fails to receive the proper levels of sunlight over a long period of time.

Setting these values is important and is used to calculate other predictions. This parameter is not the same as the ***Predicted and Remaining Days of autonomy*** described in this manual. **PRO-TIP VALUE: This value is a system sizing attribute.**

Modbus register	Alias name	Range/units	Type
40019	Set desired days of autonomy	2 – 30 (days)	16-bit

Set system real-time clock

Sets the system real-time clock. There are five separate clock registers: hours, min, sec, month, date, and year. The process to set the solar supervisor's real-time clock is:

Write to HOURS, MIN, MONTH, DATE and YEAR registers, then write a "1" to Holding DO register 00001. The system sets the time and resets register 00001 to "0".

Modbus register	Alias name	Range/units	Type
40021	Set RTC Hours	0-23	16-Bit
40022	Set RTC Min	0-59	16-Bit
40023	Set RTC Month	1-12	16-Bit
40024	Set RTC Date	1-31	16-Bit
40025	Set RTC Year	15 -->	16-Bit
00001	set_rtc	1=set	DO

Set system total battery amp hours installed

Allows a user to set the actual total number of battery amp hours installed. It is important to set this value with the actual installed battery amp-hours. Each battery has a listed Amp Hour rating, amps hours with batteries in parallel add. Failure to set this register with the actual battery size installed will cause the system to calculate improper predictive analysis and recommendations. **PRO-TIP VALUE: This value is a system sizing attribute.**

Modbus register	Alias name	Range/units	Type
40026	Set system battery amp hours installed	0 – 1000	16-bit

Set system total solar panel watts installed

Allows a user to set the actual solar panel size of watts installed. Each solar panel has a listed power rating in watts. It is important to set this value with the actual solar panel size in watts. Failure to set this register with the actual panel size in watts installed will cause the system to calculate improper predictive analysis and recommendations. **PRO-TIP VALUE: This value is a system sizing attribute.**

Modbus register	Alias name	Range/units	Type
40027	Set system solar panel watts installed	0 – 1000	16-bit

Set battery life number of charges spec'd by manufacturer

Modbus holding register 40028 is the manufacturer's estimated number of total charges for the battery's life. This is also a settable Modbus register, and the user can configure the proper max life charging cycles.

Modbus register	Alias name	Range/units	Type
40028	Set the max number of battery LIFE charging cycles	0 – 4380	16-bit

Set data-logger logging interval

The MPPT 20A CONTROLLER is equipped with an embedded data logger.

Data is collected and recorded on the inserted SD card. The rate at which the data is recorded is controlled by a user defined sampling/logging rate. This is a count-up timer, once the timer reaches the set interval data will be collected and logged.

If the MPPT 20A CONTROLLER does not have an SD card inserted or if it's inserted incorrectly, data will not be written to the SD card. The warranty is void without an SD card installed.

Modbus register	Alias name	Range/units	Type
40029	Set data logger logging interval	10 – 255 SEC	8-bit

Set MAX maintenance days and number of days to maintenance

User-defined parameters allow for scheduling maintenance. This is a completely arbitrary event and can mean anything the user chooses. The "MAX" number is a target and the "Number of Maintenance days" is incremented until it meets the "MAX" number. This event sets the Indicator time to service battery indicator to a "1", which indicates service is required. Service is arbitrary and solely depends on how the user wants to use the "service" event. An example is a technician checking a system every 60 days. In this use case, Modbus register 40030 is set to 60 and Modbus register 40031 is set to "0". Modbus register 40031 is automatically incremented daily, and when it reaches "60" this alarm is set to a "1". **NOTE**: The user/SCADA system MUST set Modbus register 40031 to "0" days to reset this event.

Modbus register	Alias name	Range/units	Type
40030	SET BATT MAX maintenance days	0-365	16-Bit
40031	SET BATT Number of maintenance days	0-365	16-Bit

0000X – Digital output registers

Enable/disable Modbus communications WDT

This Modbus register enables and disables the communications watchdog timer. Setting this register to "1" enables the communications WDT. This register works with **MODBUS HOLDING REGISTERS 40008-09** and **MODBUS INPUT REGISTERS 30089.**

Modbus register	Alias name	Range/units	Type
00000	MODBUS COMM WDT enable	1=EN, 0=DIS	DO
40008 - 09	Communication WDT timeout time	120-432000	32-Bit AO
30089	Next data logger event	0 to Sample Rate	16-Bit AI

Set real time clock

This DO is used to set the Solar Supervisor's real-time clock.

The process to set the solar supervisor's real-time clock is:

Write to HOURS, MIN, MONTH, DATE and YEAR registers, then write a "1" to holding DO register 00001. The system will set the time and reset register 00001 to "0".

Modbus register	Alias name	Range/units	Type
00001	set_rtc	1-set rtc	DO
40021	Set RTC Hours	0-23	16-Bit
40022	Set RTC Min	0-59	16-Bit
40023	Set RTC Month	1-12	16-Bit
40024	Set RTC Date	1-31	16-Bit
40025	Set RTC Year	15 -->	16-Bit

Reserved f1_reserved2

This DO register is reserved.

Modbus register	Alias name	Range/units	Type
00002	f1_reserved2	undefined	DO

Set LOAD-2 manually OFF

Setting this Modbus register to "1" manually disables LOAD-2. Setting this register to "0" returns it to a normal operating state. When this command is set to "1", LOAD-2 remains OFF, regardless of other conditions, until this requester is set back to "0".

Modbus register	Alias name	Range/units	Type
00003	Set LOAD-2 manually off	1= OFF	DO

Reserved f1_reserved3-4-5-6

These Modbus DO are reserved.			
Modbus register	**Alias name**	**Range/units**	**Type**
00004	f1_reserved3	undefined	DO
00005	MQTT Broker Detected	FACTORY	DO
00006	Valid Internet PING	FACTORY	DO
00007	Ethernet port is active	FACTORY	DO

Set power cycle to third-party charge controller

Setting this Modbus register to “1” cycles power to the charge controller. This register is automatically set to “0” after 30 seconds, and power is restored to the charge controller. This function is provided to allow a system to remotely restart the charge controller in the event its required.			
Modbus register	**Alias name**	**Range/units**	**Type**
00008	Set cycle power to charge controller	1= Cycle Power	DO

System or controller has restarted or powered up notification

This Modbus register is automatically set to “1” when the MPPT 20A CONTROLLER restarts for any reason and is designed to notify a system of a restart or power-up. Setting this register to “0” resets this state.			
Modbus register	**Alias name**	**Range/units**	**Type**
00009	Powered up notification	1= Powered Up	DO

Set exhaust fan manually ON

Setting this Modbus register to “1” manually turns on the exhaust fan. Setting this register to “0” returns the fan to a normal operating state.			
Modbus register	**Alias name**	**Range/units**	**Type**
00010	Set cooling fan manually ON	1= ON	DO

Set RETRORTU (Solar Supervisor) cooling fan manually ON

Setting this Modbus register to "1" will manually turn on the MPPT 20A CONTROLLER's external exhaust fan. Setting this register to "0" returns the fan to a normal operating state.			
Modbus register	**Alias name**	**Range/units**	**Type**
00011	Set exhaust manually ON	1= ON	DO

Reserved f1_reserved6-7-8-9-10

These Modbus DO are reserved.			
Modbus register	**Alias name**	**Range/units**	**Type**
00012	f1_reserved6	undefined	DO
00013	f1_reserved7	undefined	DO
00014	f1_reserved8	undefined	DO
00015	f1_reserved9	undefined	DO
00016	f1_reserved10	undefined	DO

Reset solar watts peak demand

Resets the PEAK solar watts held in **MODBUS HOLDING REGISTER 30114.**			
Modbus register	**Alias name**	**Range/units**	**Type**
00017	Reset Peak Solar Watts demand	1= reset	DO
30114	Peak Solar Watts	0-1000 Watts	16-Bit

Reset battery amp hour peak demand

Resets the PEAK battery amp hours held in **MODBUS HOLDING REGISTER 30115.**			
Modbus register	**Alias name**	**Range/units**	**Type**
00018	Reset peak battery amp hour demand	1= reset	DO
30115	Peak battery amp hours	0-500 Amp Hours	16-Bit

Reserved f1_reserved11-12-13

These Modbus DO are reserved.			
Modbus register	**Alias name**	**Range/units**	**Type**
00019	f1_reserved11	undefined	DO
00020	f1_reserved12	undefined	DO
00021	f1_reserved13	undefined	DO

Set Acknowledge All Alarms

Setting this Modbus DO register to "1" clears all active alarms. The register automatically clears itself to "0". It is possible for any one of the following alarms to return to an alarm state if the alarm has returned.			
Modbus register	**Alias name**	**Range/units**	**Type**
00022	Set acknowledge alarms	1 =ACK	DO
30108	SYSTEM SUSTAINABILITY	1= Fail	Bit-0
	FLOAT MODE 3DAY	1= Fail	Bit-1
	NEED MORE BATT CAPACITY SUSTAINED	1= Fail	Bit-2
	NEED MORE BATT CAPACITY REAL TIME	1= Fail	Bit-3
	NEED MORE SOLAR CAPACITY SUSTAINED	1= Fail	Bit-4
	NEED MORE SOLAR CAPACITY REAL TIME	1= Fail	Bit-5
	CRITICAL SYS VDC	1= Fail	Bit-6
	SOLAR INPUT TO HIGH	1= Fail	Bit-7
	LOAD1_SHORT	1= Fail	Bit-8
	LOAD2_SHORT	1= Fail	Bit-9

Set new battery Install date

This data is permanent until a new battery is installed AND the reset sequence when a new battery is installed completes. Writing a "1" to **DO MODBUS REG 00023** and **00024** **at the same time** records the new Month, Date, Year, and Hour the battery was installed.			
Modbus register	**Alias name**	**Range/units**	**Type**
00023	Set new battery install date CODE 1	1 AND	DO
00024	Set new battery install date CODE 2	1	DO

Reserved f1_reserved14

This Modbus DO is reserved.			
Modbus register	**Alias name**	**Range/units**	**Type**
00025	f1_reserved14	Undefined	DO

Cycling power to equipment attached to LOAD-1 or LOAD-2

Load-1 may be manually cycled for 30 seconds by setting **DO Modbus register 00026** to "1". The Modbus register and power to LOAD-1 automatically resets after 30 seconds.

This function allows a SCADA operator to remotely power cycle all equipment attached to LOAD-1, eliminating the need to send a technician to the field to cycle power on third-party equipment.

LOAD-2 can be manually cycled for 30 seconds by setting **Modbus DO register 00027** to "1". The Modbus register and power to LOAD-2 automatically resets after 30 seconds.

This function allows a SCADA operator to remotely power cycle all equipment attached to LOAD-2, eliminating the need to send a technician to the field to cycle power on third-party equipment.

Use care when invoking this function. It is possible for LOAD-1 and/or LOAD-2 to remain OFF even after the 30-second timeout IF the battery voltage is below the low battery levels.

Modbus register	**Alias name**	**Range/units**	**Type**
00026	Cycle Power on Load-1	1=Cycle Pwr	DO
00027	Cycle Power on Load-1	1=Cycle Pwr	DO

Set restart the MPPT 20A CONTROLLER controller/monitor

Setting Modbus DO register to "1" causes the MPPT 20A CONTROLLER to restart. During the restart phase you may lose complete communications, and all power is removed and cycled on all equipment attached to LOAD-1 and LOAD-2.

Use care when invoking this function. It is possible for LOAD-1 and/or LOAD-2 to remain OFF even after the 30-second timeout IF the battery voltage is below the low battery levels.

Modbus register	Alias name	Range/units	Type
00028	Set restart MPPT 20A CONTROLLER	1=Restart	DO

1000X – Digital inputs registers

Indicator battery is fully charged

This does not indicate that the battery has met its full absorption phase or its bulk charge. This indicator is meant to ensure the battery meets or exceeds a charge level and time threshold. If both TIME and LEVEL thresholds are met, this Modbus register indicates a "1".

There are other attributes outlined in this manual that indicate if the battery has met all its charging phases.

Modbus register	Alias name	Range/units	Type
10000	BATT fully charged	0=Charged	DI

Indicator charger is in Bulk mode

Indicates battery is in Bulk changing mode.

Modbus register	Alias name	Range/units	Type
10001	In Bulk charging mode	1= In Bulk Mode	DI

Indicator charger in FLOAT mode

Indicates battery is in FLOAT changing mode.

Modbus register	Alias name	Range/units	Type
10002	In FLOAT Charging Mode	1=In FLOAT Mode	DI

Indicator charger failed to charge

Indicates a battery charging anomaly. This is not always a complete failure. It is possible for a failure to occur but the battery is fully charged.

Failures that would cause this register to set to "1":

- Absorb mode did not reach full 14/28 Vdc peak levels a single time
- Battery voltage reached a HIGH voltage
- Absorb mode did not reach full 14/28 Vdc peak levels three days in a row
- Unknown battery voltage, NOT 12- or 24-volt setup
- A sustained failure to meet battery amp hour capacity requirements
- A sustained failure to meet solar power capacity requirements

Modbus register	Alias name	Range/units	Type
10003	Battery charge anomaly	1=FAIL	DI

Indicator MPPT 20A CONTROLLER cooling fan is running

Indicates the Solar Supervisor's cooling fan in on.

Modbus register	Alias name	Range/units	Type
10004	Solar Supervisor cooling fan is running	1=Running/Active	DI

Indicator exhaust cooling fan is running

Indicates the cabinet's exhaust cooling fan is on. (If equipped. This fan is sold separately.)

Modbus register	Alias name	Range/units	Type
10005	Exhaust cooling fan is running	1=Running/Active	DI

Indicator LOAD-1 or LOAD-2 in an active load-shed

Indicates load-shed status for LOAD-1 or LOAD-2

Modbus register	Alias name	Range/units	Type
10006	Load-1 active load-shed event	1= In load-shed	DI
10007	Load-2 active load-shed event	1= In load-shed	DI

Indicator high battery too HOT and battery too COLD alarms

Battery exceeded battery HOT or COLD temperature limits			
Modbus register	**Alias name**	**Range/units**	**Type**
10008	ALRM: Battery Cold	1=COLD LIMIT	DI
10009	ALRM: Battery Hot	1=HOT LIMIT	DI

Indicator time to service battery

User-defined parameters allow for scheduling maintenance. This is a completely arbitrary event and can mean anything the user chooses. The "MAX" number is a target and the "Number of Maintenance days" is incremented until it meets the "MAX" number. This event sets the **Indicator time to service battery** indicator to a "1", indicating service is required. Service is arbitrary and solely depends on how the user wants to use the "service" event. An example might be a technician checking a system every 60 days. In this use case, Modbus register 40030 is set to 60 and Modbus register 40031 is set to "0". Modbus register 40031 is automatically incremented daily, and when it reaches "60" this alarm is set to a "1". **NOTE**: The user/SCADA system MUST set Modbus register 40031 to "0" days to reset this event.			
Modbus register	**Alias name**	**Range/units**	**Type**
10010	Time to service battery	1=Service	DI

Charging time exceeds common practice charging time

This register is a general indicator and is subject to be removed or repurposed.			
Modbus register	**Alias name**	**Range/units**	**Type**
10011	Common practice: charging time > solar panel light exposure time	1=Exceeds	DI

Battery charging suspended

Battery charging may be suspended for the following reasons:

- Solar voltage > 50vdc
- Unknown battery system voltage, not a 12 or 24 volt system
- User requested the third-party controller to be in power cycle mode.

Modbus register	Alias name	Range/units	Type
10012	Battery charging time suspended	1=suspended	DI

LOAD-1 or LOAD-2 short detected

The RETRO-RTU can detect if LOAD-1 or LOAD-2 may have a short. If **MODBUS DI REGISTER 10013** OR **10018** is active, the controller may not be able to control the respective LOAD outputs. As a quick test to determine if the respective load output is operating correctly, command the load to cycle. If the load turns off then back on after 30 seconds, the load output is working correctly. If the load remains on after the load-shed command, continued use is NOT recommended. Return unit to the factory for repairs.

Modbus register	Alias name	Range/units	Type
10013	LOAD-1 shorted	1=shorted	DI
10018	LOAD-2 shorted	1=shorted	DI

Battery amp hour capacity exceeded

Indicator the system amp hour demand exceeds the capacity set by the user.

Modbus register	Alias name	Range/units	Type
10014	Battery amp hour demand exceeds battery capacity	1=Exceeds	DI

Battery voltage exceeds voltage limits

Indicator the battery voltage exceeds limits. This error disables all loads and charging until resolved. This error must be investigated to determine why the battery voltage is high.			
Modbus register	**Alias name**	**Range/units**	**Type**
10015	Battery voltage exceeds voltage limits	1=Exceeds	DI

Indicator battery capacity is low

Indicator the battery capacity is less than 45%.			
Modbus register	**Alias name**	**Range/units**	**Type**
10016	Battery capacity < 45%	1= < 45%	DI

Indicator to replace battery status

The battery health value is a measurement of how many charge cycles remain of the factory number of life cycles. Every battery has a specified number of life charging cycles. The MPPT 20A CONTROLLER keeps track of the number of completed charging cycles and other system and environmental measurements and calculates the remaining life. **Modbus holding register 40016** lets a user set the estimated number of charges already completed. As an example, this may be a battery already installed for several months or years. The user can simply estimate the days the battery has been in use and set register 40016 to the estimated number of days.

Modbus holding register 40028 is the manufacture's estimated number of total charges for the battery's life. This is also a settable Modbus register and the user can configure the proper max life charging cycles

The system will indicate poor battery health if the life is less than 40% and when to replace the respective battery.

Modbus register	**Alias name**	**Range/units**	**Type**
10017	Replace Battery (<40%)	1=Replace	DI

Indicator alarm active

Register is set to "1" for any of the alarms listed in **MODBUS REGISTER 30108.**			
Modbus register	**Alias name**	**Range/units**	**Type**
10019	Alarm active	1= Fail	DI
30108	SYSTEM SUSTAINABILITY	1= Fail	Bit-0
	ABSORB PEAK MODE 3DAY	1= Fail	Bit-1
	NEED MORE BATT CAPACITY SUSTAINED	1= Fail	Bit-2
	NEED MORE BATT CAPACITY REAL TIME	1= Fail	Bit-3
	RESERVED	1= Fail	Bit-4
	RESERVED	1= Fail	Bit-5
	CRITICAL SYS VDC	1= Fail	Bit-6
	SOLAR INPUT TO HIGH	1= Fail	Bit-7
	LOAD1_SHORT	1= Fail	Bit-8
	LOAD2_SHORT	1= Fail	Bit-9
	RATE OF DISCHARGE HIGH	1= Fail	Bit-10
	POSSIBLE BAD BATTERY DETECTED	1= Fail	Bit-11
	CHRAGER TOO HOT	1= Fail	Bit-12

Solar panel voltage exceeds voltage limits

Indicator the solar panel voltage exceeds limits. This error must be investigated to determine why the solar panel voltage is high. One cause may be the solar panel reaching a high voltage due to a high VAC. When the battery is nearing charge completion there is less demand on the panel, and the panel voltage increases towards its VAC spec.			
Modbus register	**Alias name**	**Range/units**	**Type**
10020	Solar voltage exceeds voltage limits	1=Exceeds	DI

System OK to charge

System has met the minimum solar input voltage to start charging the battery.			
Modbus register	**Alias name**	**Range/units**	**Type**
10021	System is OK to start charging	1=OK	DI

Battery charging is active

Battery is actively charging.			
Modbus register	**Alias name**	**Range/units**	**Type**
10022	Battery is charging	1=Charging	DI

Deep discharge more than 20 times in one month event indicator

Battery voltage has fallen below deep discharge thresholds.			
Modbus register	**Alias name**	**Range/units**	**Type**
10023	Battery Deep Charge > 20 times in one-month Event	1=Deep Discharge Event > 20 times	DI

Potential excessive load current event indicator

Potential condition where the peak solar demand exceeds load demand.			
Modbus register	**Alias name**	**Range/units**	**Type**
10024	Excessive Load Current	1=excessive	DI

Predicted remaining days reached ZERO Indicator

Remaining predicted days of autonomy reached zero.			
Modbus register	**Alias name**	**Range/units**	**Type**
10025	Remaining predicted days of autonomy reached ZERO	1=Out of remaining days of Autonomy	DI

Tamper switch active indicator

Tamper switch active.			
Modbus register	**Alias name**	**Range/units**	**Type**
10026	Tamper switch is active	1=Tamper Active	DI

SD card inserted indicator

Indicator is the SD card is installed.			
Modbus register	**Alias name**	**Range/units**	**Type**
10027	SD card inserted	1=SD Card Inserted	DI

Battery failed to reach absorption peak voltage three days in a row indicator

Battery failed to reach Absorb peak voltage levels three-days in a row.			
Modbus register	**Alias name**	**Range/units**	**Type**
10028	Missed Absorb Peak voltage three days in a row.	1=Failed	DI

Not defined 10029

Not defined			
Modbus register	**Alias name**	**Range/units**	**Type**
10029	NOT DEFINED	NOT DEFINED	DI

Indicator charger is in trickle mode

Indicates battery is in trickle changing mode			
Modbus register	**Alias name**	**Range/units**	**Type**
10030	In trickle charging mode	1= In trickle mode	DI

No current detected on LOAD-1

LOAD-1 is active and functioning but current is not detected. There may be a reason for a load not to be detected:

- Nothing is attached to LOAD-1
- Current draw is too small to detect.

This is a warning that there may be an expectation to have equipment attached and the equipment failed.

Modbus register	Alias name	Range/units	Type
10031	No Load detected on Load-1	1= No Load Detected	DI

No current detected on LOAD-2

LOAD-2 is active and functioning but current is not detected. There may be a reason for a load not to be detected:

- Nothing is attached to LOAD-2
- Current draw is too small to detect

This is a warning that there may be an expectation to have equipment attached and the equipment failed.

Modbus register	Alias name	Range/units	Type
10032	No load detected on LOAD-2	1= No Load Detected	DI

MPPT 20A CONTROLLER is requesting LOAD-1 or LOAD-2 to activate

The MPPT 20A CONTROLLER is asking for LOAD-1 or LOAD-2 to activate. This is basically the controller attempting to turn either or both loads on. There may be instances where the request is made but events such as load-shedding keep the load from powering up equipment attached to the respective LOAD(s).

Modbus register	Alias name	Range/units	Type
10033	Request to activate Load-1	1= Request ON	DI
10034	Request to activate Load-2	1= Request ON	DI

Unknown battery voltage

The system detected a battery voltage that does not fit a 12 volt or 24-volt profile. This may be caused by too many batteries in series, bad batteries, and so on. The system will disable itself until the issue is addressed. All loads and the charging process will be disabled.			
Modbus register	**Alias name**	**Range/units**	**Type**
10035	Unknown Battery voltage type	1= Not 12- or 24-volt system	DI

Failed to read RTU temperature sensor

The internal temperature sensor failed to read. If this indicator remains “1”, return to factory for repair.			
Modbus register	**Alias name**	**Range/units**	**Type**
10036	Failed to read RTU internal temperature	1= Failed	DI

Solar watts capacity failed

The system needs more solar power capacity than the panel can provide. This may be an instantaneous or peak issue.			
Modbus register	**Alias name**	**Range/units**	**Type**
10037	System requires more solar power than provided	1= Failed	DI

Solar watts sustained capacity failed

Much like the solar capacity outlined in Modbus DI REGISTER 10037, this event requires a sustained event to occur over a period of time.			
Modbus register	**Alias name**	**Range/units**	**Type**
10038	System requires a sustained need for more solar power than provided	1= Failed	DI

Battery discharging at a high current indicator

1= Battery discharge current < Max battery discharge current to sustain desired autonomy.			
Modbus register	**Alias name**	**Range/units**	**Type**
10039	Battery discharge current too high to sustain days of autonomy	1= High Batt Discharge	DI

Peak absorb voltage achieved

Battery achieved peak Absorb voltage. Status is reset to "0" at midnight.			
Modbus register	**Alias name**	**Range/units**	**Type**
10040	Battery achieved peak Absorb voltage.	1= Peak Absorb V	DI

Battery rate of charge/discharge

One of the analysis attributes is the determination of how fast the battery is discharging. Any value <-6.00% generates an alert by setting **DI MODBUS REGISTER 10041 = "1".** This event resets at noon (12PM).

There are three scenarios that would cause this event to occur:

- A battery that is no longer holding a charge
- Large current being drawn from the loads
- A long-term discharge event where the battery did not receive charging for multiple days

Modbus register	**Alias name**	**Range/units**	**Type**
10041	Battery ROC Failure	1= ROC < -6.0%	DI
30038-39	Battery Rate of Charge/Discharge	% of Change	FLOAT

System internal power supply

Monitors a critical power supply embedded within the RETRORTU design. If the register indicates a "1", the device must be returned to the factory for repair.			
Modbus register	**Alias name**	**Range/units**	**Type**
10042	Vboost	1= FAILED	DI

Battery charging in Absorb mode

Battery in ABSORB voltage charging mode.			
Modbus register	**Alias name**	**Range/units**	**Type**
10043	Battery in absorb mode	1= Absorb	DI

Battery amp hour capacity sustained capacity failed

Much like the battery capacity outlined in Modbus DI REGISTER 10037, this event required a sustained event to occur over a period of time.			
Modbus register	**Alias name**	**Range/units**	**Type**
10044	System requires a sustained need for more battery capacity than provided by the batteries	1= Failed	DI

System sustainability failure

Low battery amp hours sustained for more than four hours.			
Modbus register	**Alias name**	**Range/units**	**Type**
10045	Cannot sustain system	1= Failed	DI

Alarms acknowledged

If an alarm occurs and is acknowledged this Modbus DI register is set to “1”.

There are three ways an alarm may be acknowledged:

- via Modbus
- via MQTT
- via the selection knob located on the MPPT 20A CONTROLLER

Modbus register	**Alias name**	**Range/units**	**Type**
10046	Alarms acknowledged	1= Failed	DI

Invalid device serial number

Every MPPT 20A CONTROLLER has a unique serial number. If the boot process fails to detect the proper serial number, this Modbus DI register indicates a "1". To clear the error, restart the MPPT 20A CONTROLLER by cycling power, pressing the reset button, or remotely via Modbus. If the error fails to clear, the device will need to be returned to the factory.

Modbus register	Alias name	Range/units	Type
10047	Serial number detected not matching device	1= Failed	DI

Battery temperature compensation sensor disconnected failure

Indicates the battery's temperature compensation sensor has been disconnected. This must be addressed and fixed.

Modbus register	Alias name	Range/units	Type
10048	Compensation sensor disconnected	1= Disconnected	DI

Battery temperature compensation high temperature failure

Indicates the battery temperature is outside of the valid range of -4°F to 122°F. The temperature fault condition remains until the temperature returns within 5°F to 113°F. During a temperature fault, charging is halted. Charging automatically restarts when temperatures return to a normal range. While in a temperature fault the "FULLY CHARGED" and "BULK" LEDs l flash in concert.

Modbus register	Alias name	Range/units	Type
10049	Low or high compensation temperature fault	1= < -4°f or > 122°f	DI

Charger timer failure

Indicates the charger timing as failed. This event will address itself.

Modbus register	Alias name	Range/units	Type
10050	Charger timer error	1= Timer error	DI

Charger battery under voltage

Indicates the battery voltage is lower than allowable limits.			
Modbus register	**Alias name**	**Range/units**	**Type**
10051	Charger battery under voltage timer error	1= Timer error	DI

Battery damaged

Indicates the battery is not holding a charge under normal load conditions.			
Modbus register	**Alias name**	**Range/units**	**Type**
10052	Battery may be damaged and is not holding a charge	1= Damaged	DI

Web portal

MPPT 20A CONTROLLER models with IP functionality such as MODBUS TCP and MQTT also have an embedded web page. The default IP address is 192.168.1.100. The default username and password are admin/cartoon

Logging In

The MPPT 20A CONTROLLER is password protected and requires a user to log in with the proper username and password.

Figure 38 – Logging in to the web portal

Menus

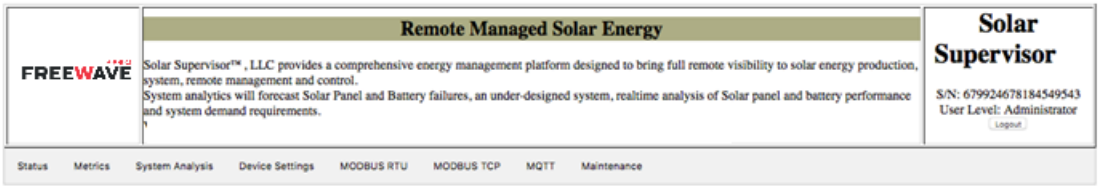


Figure 39 – Web portal menus

Status menu

Status menu contains three subsections:

- Linux status
- RTU system status
- RTU alarm

Metrics menu

The metrics menu is a basic site measurement panel.

System Analysis menu

The System Analysis menu displays predictions and recommendations.

System Sizing Analysis

This section provides real-time calculations of performance of your system based on actual operating conditions collected over time and will change as new measurements are collected.

- A majority of failures are caused by a undersized systems
- Battery Volatges less than 11vdc/22vdc will permanently damaged battery
- System predictions should be used as a guide
- There are key system calculations generated by the **RETRORTU20A** that will guide system enhancements to improve up time and decrease failures.

Load Predictions

To maintain **5** Days of Autonomy:

- System current load (LOAD-1+LOAD-2): **1.225** Amps
- The system is predicting the need for a **180 WATT SOLAR PANEL**
- The system detected a **SOLAR WATTS PEAK** of **0.00 Watts** in the last 24 hours
- The system is predicting the need for **450 AMP HOURS**
- *This is based on the system load current cunsumption in Amps and does not consider functions such as current to charge the battery.*

System Autonomy Predictions

User is asking for **5** Days of Autonomy

- The system is predicting **4 Days of Autonomy**
- The system has **2 Predicted remaining Days of Autonomy**

Instantaneous System Predictions

To maintain **5** Days of Autonomy:

- The system is predicting the instantaneous need for a **0 WATT SOLAR PANEL**
- The system needs an addtional **0 Solar Watts**
- The system is predicting the instantaneous need for a **510 BATTERY AMP HOURS**
- The system needs an addtional **314 AMP HOURS**
- *This is a predictive indicator of the entire system*
- *If the battery is charging you may see "0" BATTERY AMP HOURS required. This is because the system is not requiring power from the battery.*
- *If the solar panel is not generating power or is OFF you may see "0" for SOLAR WATTS required. Currently Solar Watts= **0.00** Watts*

Figure 40 – The System Analysis menu

Device Settings menu

The device setting menu allows the user to configure set points, network settings, and battery configuration.

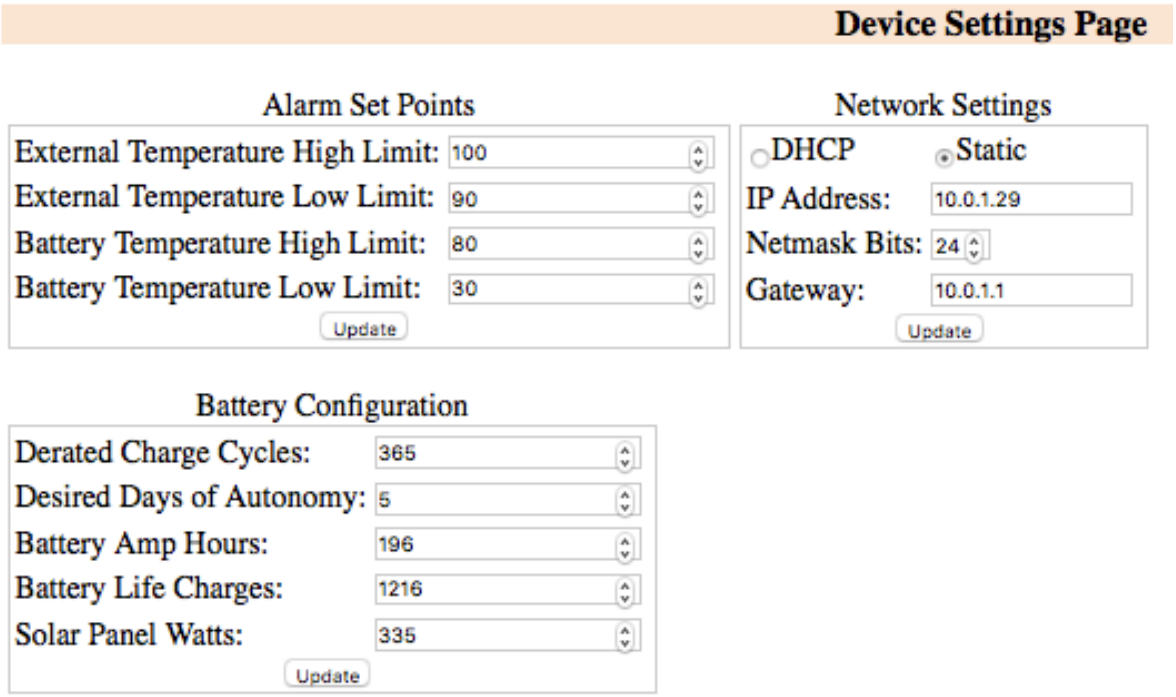


Figure 41 – The Device Settings menu

Modbus RTU menu

The MPPT 20A CONTROLLER does not support Modbus RTU if the product already supports IP functions.

The Modbus RTU menu displays all the measurements capable of being collected and lists all the devices/system measurements. These are not configurable.

MODBUS RTU Settings

MODBUS Register Definitions (with last received value)

Function 1 Registers [*Last Updated: 4 seconds ago*]

Address	Name	Format	Value
0	set_enable_rtu_modbuscomm_wdt	bit	0
1	f1_reserved1	bit	0
2	f1_reserved2	bit	0
3	set_load2_manually_off	bit	0
4	f1_reserved3	bit	0
5	set_mqtt_broker_led	bit	1
6	set_internet_ping_led	bit	1
7	set_enetport_active_led	bit	1
8	set_powercycle_charge_controller	bit	0
9	system_has_power_cycled	bit	0
10	set_ext_fan_manually	bit	0
11	set_rtu_fan_manually	bit	0
12	f1_reserved6	bit	0
13	f1_reserved7	bit	0
14	f1_reserved8	bit	0
15	f1_reserved9	bit	0
16	f1_reserved10	bit	0
17	reset_solarwatts_peak_demand	bit	0
18	reset_battamphes_peak_demand	bit	0
19	f1_reserved11	bit	0
20	f1_reserved12	bit	0
21	f1_reserved13	bit	0
22	set_acknowledge_alarms	bit	0
23	set_new_batt_installed_code1	bit	0
24	set_new_batt_installed_code2	bit	0
25	f1_reserved14	bit	0
26	set_cycle_load1_power	bit	0
27	set_cycle_load2_power	bit	0
28	set_system_restart	bit	0
29	set_reset_sys_parmeters_code1	bit	0
30	set_reset_sys_parmeters_code2	bit	0
31	set_reset_sys_parmeters_code3	bit	0

Function 2 Registers [*Last Updated: 5 seconds ago*]

Address	Name	Format	Value
0	batt_fully_charged_flag	bit	0
1	in_bulk_mode_flag	bit	0
2	in_float_mode_flag	bit	0
3	batt_charge_failed_flag	bit	1
4	rtu_fan_active_flag	bit	1
5	external_fan_active_flag	bit	0
6	load1_loadshed_active_flag	bit	0
7	load2_loadshed_active_flag	bit	0
8	batt_cold_limit_reached_flag	bit	0
9	batt_hot_limit_reached_flag	bit	1
10	batt_needs_service_flag	bit	0
11	batt_charging_time_required_exceeds_sun_exposure_time_status_flag	bit	1
12	batt_charging_suspended_flag	bit	0
13	load1_shorted_flag	bit	0
14	batt_amphour_capacity_exceeded_flag	bit	1
15	batt_voltage_high_exceeded_flag	bit	0
16	batt_health_low_flag	bit	0
17	replace_battery_flag	bit	0
18	load2_shorted_flag	bit	0
19	alarm_active_flag	bit	1
20	solar_voltage_input_high_flag	bit	0
21	system_ok_to_charge_flag	bit	0
22	system_charging_active_flag	bit	0
23	batt_deepcycle_event_flag	bit	0
24	potential_excessive_load_current_draw_flag	bit	0
25	predict_remain_days_autonomy_fail	bit	0
26	tamper_alert_flag	bit	1
27	sdcard_insert_flag	bit	1
28	battery_failed_float_3days_flag	bit	0
29	weather_forecast_flag	bit	0
30	in_trickle_mode	bit	1
31	load1_no_current_detected_flag	bit	0
32	load2_no_current_detected_flag	bit	1
33	load1_request_on_flag	bit	1
34	load2_request_on_flag	bit	1
35	unknown_battery_type_flag	bit	0
36	rtu_temperature_read_fail_flag	bit	0
37	solarpanel_watts_capacity_falied_flag	bit	0
38	solarpanel_watts_sustained_capacity_falied_flag	bit	0

Figure 42 – Modbus RTU menu

Modbus TCP menu

The Modbus TCP allows the user to select the Modbus Slave ID and the TCP port. The Modbus TCP IP address is the same as the device IP address.

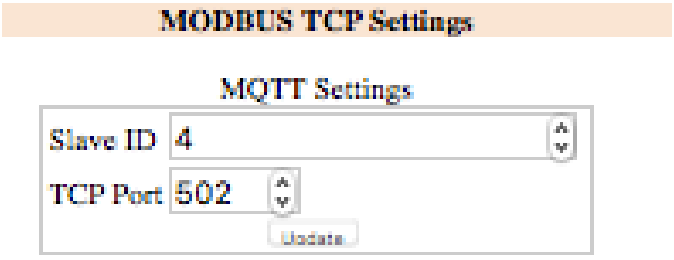


Figure 43 – Modbus TCP menu

Modbus menu

The Modbus TCP allows the user to select the Modbus Slave ID and the TCP port.

Modbus registers

3000X – Analog Input Registers – FLOAT – ABCD Format		
Modbus register	**Alias name**	**Range/units**
30000-01	batt_vdc	6 to 52vdc
30002-03	batt_amps	-11amps to +22amps
30004-05	batt_watts	batt_vdc * batt_amps
30006-07	batt_percent_capacity	0-100%
30008-09	batt_percent_life_health	0-100%
30010-11	battvdc_peak_min	6-53vdc
30012-13	battvdc_peak_max	6-53vdc
30014-15	batt_watt_hours	Varies
30016-17	solar_vdc	0 to 52vdc
30018-19	solar_amps	0 to 16.0 amps
30020-21	solar_watts	solar_vdc * solar_amps
30022-23	load1_amps	0 to 8.0 amps
30024-25	load2_amps	0 to 8.0 amps
30026-27	batt_temperature	-55°C ~ 125°C / -67F ~ 257F
30028-29	solarsupervisor_temperature	-55°C ~ 125°C / -67F ~ 257F
30030-31	external_temperature	-55°C ~ 125°C / -67F ~ 257F
30032-33	charge_discharge_time_sec	varies
30034-35	percent_time_charging	0-100%
30036-37	mppt_board_temperatire	-55°C ~ 125°C / -67F ~ 257F
30038-39	battery_rate_of_discharge	-100% to 100%
30040-41	solar_peak_watts	Peak solar_vdc * solar_amps
30042-43	max_allowable_battery_i	-8.0 amps to -0.00 Amps

3000X – Analog Input Registers 32-BIT		
30044-45	system_powerup_cycles	0-4294967294
30046-47	system_life_run_time_sec	0-4294967294
30048-49	system_up_time_fromboot_sec	0-4294967294
30050-51	batt_deep_discharge_count	0-4294967294
30052-53	batt_deep_discharge_time	0-4294967294
30054-55	time_from_last_batt_deep_discharge_event	0-4294967294
30056-57	new_batt_install_date	0-4294967294
30058-59	external_fan_on_time	0-4294967294
30060-61	rtu_fan_on_time	0-4294967294
30062-63	pseudo_coulomb_counter	0-4294967294
30064-65	batt_fully_charged_count	0-4294967294
30066-67	never_hit_hipeak_14_28V_count	0-4294967294
30068-69	batt_charge_fault_count	0-4294967294
30070-71	modbus_wdt_counter	0-4294967294
30072-73	tamper_count	0-4294967294
30074-75	never_hit_1428vdc_contiguious_count	0-4294967294

3000X – Analog Input Registers 16-BIT		
Modbus register	**Alias name**	**Range/units**
30076	batt_charging_cycles	0-10000
30077	batt_system_voltage_detected	12 or 24
30078	batt_amphrs_req_user	0-65535 SEC
30079	time_in_bulk	0-65535 SEC
30080	time_in_asorb	0-65535 SEC
30081	time_in_float	0-65535 SEC
30082	time_not_charging_suspended	0-65535 SEC
30083	warranty_remaining	0-100%
30084	batt_charge_trend	0-2
30085	load1_timer	0-65535 SEC

30086	load2_timer	0-65535 SEC
30087	load1_trip_count	0-65535
30088	load2_trip_count	0-65535
30089	next_datalog_event	10 - 300
30090	remaining_predict_days_autonomy	0-65535
30091	product_model_code	Varies
30092	rtu_fan_on_time_last24hrs	0-65535
30093	external_fan_on_time_last24hrs	0-65535
30094	RTC_hours	0-23
30095	RTC_min	0-59
30096	RTC_sec	0-69
30097	RTC_month	1-12
30098	RTC_day	1-31
30099	RTC_year	20-->
30100	charging_time_days	0- Varies
30101	charging_time_hours	0-23
30102	charging_time_mins	0-59
30103	charging_time_sec	0-59
30104	discharging_time_days	0- Varies
30105	discharging_time_hours	0-23
30106	discharging_time_mins	0-59
30107	discharging_time_sec	0-59
30108	alarm_bit_map	Varies
30109	add_this_much_batt_amp_hours	0-65535
30110	add_this_much_solar_watts	0-65535
30111	sunshine_hours_last_24hours	0-65535
30112	instantaneous_solar_watts_required	0-65535
30113	instantaneous_batt_amphours_required	0-65535
30114	peak_solar_watts_required	0-65535
30115	peak_batt_amphours_required	0-65535
30116	daily_sunshine_exposure_sec	0-65535

30117	predicted_solar_watts_using_load	0-65535
30118	predicted_batt_amphours_using_load	0-65535
30119	predicted_days_autonomy	0-65535
30120	rule_of_thumb_charging_amps_required	0-65535
30121	rule_of_thumb_charging_time_required	0-65535
30122	device_firmware_rev	Varies
30123	device_hardware_rev	Varies

4000X – Analog Holding Registers – FLOAT – ABCD Format

Modbus register	Alias name	Range/units
40000-01	set_external_temperature_alarm_high_limit	Temperature High Limit
40002-03	set_external_temperature_alarm_low_limit	Temperature Low Limit
40004-05	set_batt_temperature_hot_alarm_limit	Batt Temperature HOT Limit
40006-07	set_batt_temperature_cold_alarm_limit	Batt Temperature COLD Limit

4000X – Analog Holding Registers 32-BIT

40008-09	set_local_modbus_communcations_wdt	0-7200
40010-11	rtu_serial_number_highorder	NOT FOR USE
40012-13	rtu_serial_number_loworder	NOT FOR USE
40014-15	mass_reset_command	NOT FOR USE

4000X – Analog Holding Registers 16-BIT

Modbus register	Alias name	Range/units
40016	set_derated_charging_cycles	0-65535
40017	set_weather_event_in_xdays	0-65535
40018	set_weather_event_for_ydays	0-65535
40019	set_desired_days_of_autonomy	1-30
40020	set_sunrise_time	1-24
40021	set_solarsupervisor_rtc_hours	0-23
40022	set_solarsupervisor_rtc_min	0-59
40023	set_solarsupervisor_rtc_month	1-12
40024	set_solarsupervisor_rtc_date	1-31

40025	set_solarsupervisor_rtc_year	20 -->
40026	set_system_batt_amphour_configuration	0-500
40027	set_system_solarpanel_watts_configuration	0-65535
40028	set_batt_life_charges	1-10000
40029	set_datalogger_logging_time_sec	0-65535
40030	set_batt_desired_maint_days	0-10000
40031	set_derated_batt_maint_days	0-10000
40032	set_hi_ipaddr	NOT FOR USE
40033	set_lo_ipaddr	NOT FOR USE

0000X – Digital Output Registers

Modbus register	Alias name	Range/units
00000	set_enable_rtu_modbuscomm_wdt	1=Eable
00001	set_rtc	1= Set RTC with Holding REG values
00002	f1_reserved2	RESERVED
00003	set_load2_manually_off	1=Keep Load2 off forever
00004	f1_reserved3	RESERVED
00005	set_mqtt_broker_led	1=Sees MQTT BROKER
00006	set_internet_ping_led	1=Can Ping
00007	set_enetport_active_led	1=Ethernet Port Active
00008	set_powercycle_charge_controller	1=Power Cycle Charger Attached
00009	system_has_power_cycled	1=Monitor has power Cycled
00010	set_ext_fan_manually	1= Manual ON
00011	set_rtu_fan_manually	1= Manual ON
00012	f1_reserved6	RESERVED
00013	f1_reserved7	RESERVED
00014	f1_reserved8	RESERVED
00015	f1_reserved9	RESERVED
00016	f1_reserved10	RESERVED
00017	reset_solarwatts_peak_demand	1=Reset
00018	reset_battamphes_peak_demand	1=Reset

00019	f1_reserved11	RESERVED
00020	f1_reserved12	RESERVED
00021	f1_reserved13	RESERVED
00022	set_acknowledge_alarms	RESERVED
00023	set_new_batt_installed_code1	1= set new batt installed
00024	set_new_batt_installed_code2	1= set new batt installed
00025	f1_reserved14	RESERVED
00026	set_cycle_load1_power	1= Cycle Power on load 1
00027	set_cycle_load2_power	1= Cycle Power on load 2
00028	set_system_restart	1= Restart Monitor Controller
00029	set_reset_sys_parmeters_code1	NOT FOR USE
00030	set_reset_sys_parmeters_code2	NOT FOR USE
00031	set_reset_sys_parmeters_code3	NOT FOR USE

1000X – Digital Inputs Registers

Modbus register	Alias name	Range/units
10000	batt_fully_charged_flag	1=Full
10001	In_bulk_mode_flag	1=To Absorb
10002	in_float_mode_flag	1=In FLOAT
10003	batt_charge_failed_flag	1=Failed
10004	solarsupervisor_fan_active_flag	1=Running
10005	external_fan_active_flag	1=Running
10006	load1_loadshed_active_flag	1=In Load-shed
10007	load2_loadshed_active_flag	1=In Load-shed
10008	batt_cold_limit_reached_flag	1=Cold Limits
10009	batt_hot_limit_reached_flag	1=Hot Limits
10010	batt_needs_service_flag	1=Service
10011	batt_charging_time_required_exceeds_sun_exposure_time_status_flag	1=Failed
10012	batt_charging_suspended_flag	1=Suspended
10013	load1_shorted_flag	1=Shorted
10014	batt_amphour_capacity_exceeded_flag	1=Exceeded

10015	batt_voltage_high_exceeded_flag	1=Exceeded
10016	batt_capacity_low_flag	1=Low
10017	replace_battery_flag	1=Replace
10018	load2_shorted_flag	1=Shorted
10019	alarm_active_flag	1=Alarm Active
10020	solar_voltage_input_high_flag	1=High
10021	system_ok_to_charge_flag	1=Ok
10022	system_charging_active_flag	1=Active
10023	batt_deepcycle_event_flag	1=Deep
10024	potential_excessive_load_current_draw_flag	1=Excessive
10025	predict_remain_days_autonomy_fail	1=Fail
10026	tamper_alert_flag	1=Tamper
10027	sdcard_insert_flag	1=Inserted
10028	battery_failed_float_3days_flag	1=Failed
10029	weather_forecast_flag	1= Weather Event
10030	In_trickle_mode	1= Low
10031	load1_no_current_detected_flag	1= No Current
10032	load2_no_current_detected_flag	1= No Current
10033	load1_request_on_flag	1=Asking
10034	load2_request_on_flag	1=Asking
10035	unknown_battery_type_flag	1=No Such BATT
10036	solarsupervisor_temperature_read_fail_flag	1=Failed
10037	solarpanel_watts_capacity_falied_flag	1=Failed
10038	solarpanel_watts_sustained_capacity_falied_flag	1=Failed
10039	battery_charging_high_current_flag	1=High discharge
10040	hit_peak_absorb_mode_flag	1=Hit
10041	battery_rapid_discharge_failure	1=Hit
10042	system_vboost_flag	1=vboost Failed
10043	in_absorb_mode_flag	1=In Absorb
10044	battery_amphours_sustained_capacity_falied_flag	1=Failed
10045	system_sustainability_failure_flag	1=Failed

10046	alarms_acknowledged_flag	1=Acknowledged
10047	invalid_device_serialnum	1= Invalid
10048	chr_battery_disconnect_failure	1= battery disconnected
10049	chr_invalid_battery_temperature_failure	1= battery Comp Temp
10050	chr_timer_failure	NOT USED
10051	chr_battery_undervdc_failure	NOT USED
10052	battery_charge_retention_failure	1= wont hold change

Troubleshooting guide

Symptom	Possible Fix
Battery not charging	Check circuit breaker: Verify display is working.
	Check 12v/24v setting. Make sure it matches your battery configuration.
	A battery thermal compensation sensor missing or damaged or the battery temperature is >123.00f or -20.00f
No power at odds	Check load status and any circuit breakers
System fails to boot	Check circuit breakers, fuses, and battery voltage. Possible Inverter board failure.
Load(s) not turning on	Load-shed occurred and BATT is less than 12.6VDC for 12V systems and 25.2V for 24V systems. Wait for Battery to return to proper voltage
Loads will not turn off, shed, or if it will allow for manual override	Check LOAD-1 or LOAD-2 shorted. If LOADs indicate Shorted then return to factory for repair.
No solar voltage Indicated	Check Polarity, check circuit breakers, measure voltage at solar panel output.
Battery not fully charging	Check the third-party charger and measure output voltage.
Erratic measurements	Be sure the device and any related cables are not near RF or inductive type equipment such as motors.
Will not enter FLOAT mode	Battery charging current exceeds 1.6 amps OR excessive load current.

Manual revision tracking

Release date	Revision
B 6/22/2023	Initial limited preliminary release
B 7/10/2023	Initial limited preliminary release – documentation update

Terms

Acronyms

- **BSR** – Battery Series Resistance
- **COMM WDT** - Modbus Communications Watchdog Timer
- **DO** – digital output
- **HW** – hardware
- **Impp** – Maximum power point current (the current of the module at the maximum power point)
- **Isc** – Short circuit current
- **LCD** – liquid crystal display
- **MPPT** – Maximum Power Point Tracking (a type of charging algorithm)
- **MQTT** - Message Queuing Telemetry Transport. (a lightweight, publish-subscribe, machine-to-machine network protocol)
- **NOCT** – normal operating cell temperature
- **PLC** – programmable logic controller
- **Pmax** – Maximum power (the maximum rated power output of a solar panel)
- **PWM** – Pulse Width Modulation (a type of charging algorithm)
- **ROC** – The rate of battery charge or discharge
- **RTC** – real-time clock
- **RTU** – Remote Transmission Unit
- **SCADA** - Supervisory Control and Data Acquisition (SCADA systems are used for controlling, monitoring, and analyzing industrial devices and processes)
- **STC** – standard test conditions
- **SYSLED** – system LED
- **TCP** – Transmission Control Protocol
- **VAC** – Volts Alternating Current
- **VDC** – Volts Direct Current

- **Vmpp** – Voltage at maximum power point
- **Voc** – open circuit voltage
- **WDT** – watchdog timer

Vocabulary

- **amp hour, ampere hour** - The amount of energy charge in a battery that enables 1 ampere of current to flow for one hour
- **days of autonomy** - An indicator of how long a battery should last when no solar power is available
- **derating** - The operation of a device at less than its rated maximum capability
- **DIN rail** - A metal rail of a standard type widely used for mounting circuit breakers and industrial control equipment inside equipment racks
- **FLOAT mode** - When the voltage on the battery is maintained at approximately 2.25 volts per cell, or 13.5 volts for a 12V battery. One of four separate charging cycles
- **gassing voltage** - The voltage at which electrolysis begins and water is electrically split into its gaseous constituents, oxygen and hydrogen
- **Irradiance** - The energy per unit time that strikes a unit horizontal area per unit wavelength interval.
- **load output** - A feature available on some solar charge controllers that enables manual or automatic control of the load
- **load shedding** - Deliberate shutdown of electric power in a part or parts of a power-distribution system, generally to prevent failure when the demand strains the capacity of the system
- **Modbus** – A request-response data communications protocol
- **power cycling** – Turning a piece of equipment off and then on again
- **RETRORTU** – Solar Supervisor
- **watchdog timer -** A simple countdown timer which is used to reset a microprocessor after a specific interval of time.

MQTT SUB sample data

The following is an example of the MQTT data publishing:

`SolarMonitor/686578886184549391/batt_vdc`

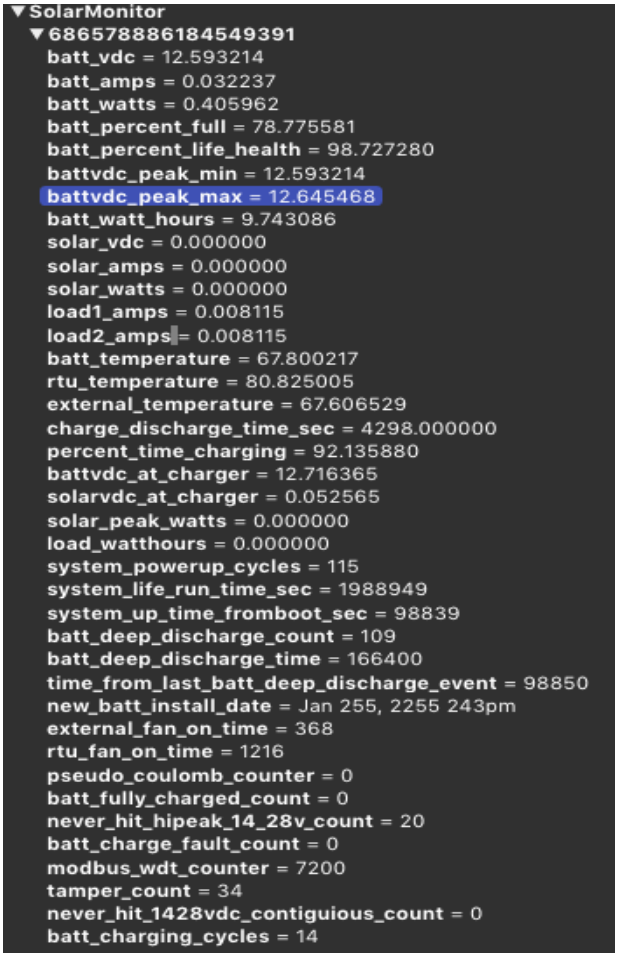


Figure 44 – MQTT SUB sample data

APPENDIX A – Audit report – Noon - Sample

>> Audit Report <<

12/10/20 12:00:00
Serial#: 0028B9FDD10B00008A
Up Time (sec): 94864
Product Model Code: 201
Firmware Rev: 110
Hardware Rev: 702
System is in warranty. 99.11% Remaining

** Solar Info **

Solar Voltage: 16.40
Solar Current: 4.37
Solar Watts: 71.70

** BATT Info **

BATT Voltage: 14.12
Battery Charge Current: 4.41
Battery Watts: 62.37
Battery is 95.34% Full
BATT VDC MIN: 12.54
BATT VDC MAX: 14.80
BATT AMPS MIN: -1.03
BATT AMPS MAX: 7.09
BATT Temperature: 64.36f

** Fan Info **
Fan1 total on Time 0
EXT Fan total on Time: 0
Fan1 on Time last 24hrs: 0
EXT Fan on Time last 24hrs: 0

** General Info **

Life charge Time: 1:3:43:42

Life Discharge Time: 2:1:28:49
Percent Charging 24HRS: 21.1%
Percent Discharging 24HRS: 78.8%
CPU Board power-up cycles: 6
Tamper Count: 5
Board TEMP: 84.42f
EXT TEMP: 59.86f
MPPT TEMP: 91.61f
Charging ROC: 2.05f
Deep Cycle Count/Time [Count:0] [Time:0]
Charging Cycles: 374
Full Charging Cycles: 0
BATT Maintenance ok, SCH: 8 of 60 Days
System Life Runtime: 279564 Seconds
Total Missed 14/28vdc PEAK Count: 0
Last Contiguous missed days 14/28vdc PEAK Count: 0

** Charging Characteristics **

Total Time in Bulk: 15272 SEC
Total Time in Absorb: 131 SEC
Total Time in FLOAT: 0 SEC
Total Time not Charging: 34184 SEC
Total Time Sun Exposure: 9109 SEC 6 Hours last 24 hours
Peak/Actual Battery Amp Hours required/Installed: 390 AMPHRS 98 AMPHRS last 24 hours
Peak/Actual Solar Watts required/Installed: 837 Watts 100 Watts last 24 hours

** Load Info **

Load 1: 0.15 Amps
Load 1: 2.17 Watts
Load 2: 0.43 Amps
Load 2: 6.18 Watts
Total Load Amps: 0.59
Total Load Watts: 8.36
Predicted Solar WATTS required based on total Load power demand: 96 Solar Watts
Predicted Battery Amp Hours required based on total Load power demand: 240 Battery Amp Hours
Load1 over-current count: 0
Load2 over-current count: 0

Did not Load-shed within the last 24HRS

**** System Analysis ****

Load Analysis:

The system is predicting the need for a 96 Solar Panel
And detected a solar WATTS Peak of 115.377 Watts
The system is predicting the need for 240 AMP HOURS
Over the last 24 hours the system required 390 Battery Amp Hours to sustain 5 days of autonomy.

Currently have 98 Battery Amp Hours. Add 292 more Amp Hours to your system.
Over the last 24 hours the system required 837 Solar Watts to sustain daily charging.
Solar Panel is 100 Watts. Add 737 more Solar Watts
System maintained 6 hours of Sunshine [9109 SEC]
Predicted Number of Autonomy Days: [0 DAYS]
Predicted Number of Remaining Autonomy Days: [0 DAYS]
No system sustainable FLAGS indicated

APPENDIX B – Audit report – Midnight - sample

>> Audit Report <<

12/10/20 00:00:00
Serial#: 0028B9FDD10B00008A
Up Time (sec): 51494
Product Model Code: 201
Firmware Rev: 110
Hardware Rev: 702
System is in warranty. 99.25% Remaining

** Solar Info **

Solar Voltage: 0.05
Solar Current: -0.01
Solar Watts: 0.00

** BATT Info **

BATT Voltage: 12.81
Battery Charge Current: -0.96
Battery Watts: -12.38
Battery is 89.00% Full
BATT VDC MIN: 12.75
BATT VDC MAX: 14.70
BATT AMPS MIN: -1.03
BATT AMPS MAX: 4.67
BATT Temperature: 61.48f

** Fan Info **

Fan1 total on Time 0
EXT Fan total on Time: 0
Fan1 on Time last 24hrs: 0
EXT Fan on Time last 24hrs: 0

** General Info **

Life charge Time: 1:1:11:48
Life Discharge Time: 1:16:1:54
Percent Charging 24HRS: 44.1%
Percent Discharging 24HRS: 55.8%
CPU Board power-up cycles: 6
Tamper Count: 5
Board TEMP: 76.32f
EXT TEMP: 55.73f
MPPT TEMP: 70.06f
Charging ROC: -3.91f
Deep Cycle Count/Time [Count:0] [Time:0]
Charging Cycles: 373
Full Charging Cycles: 0
BATT Maintenance ok, SCH: 7 of 60 Days
System Life Runtime: 236195 Seconds
Total Missed 14/28vdc PEAK Count: 0
Last Contiguous missed days 14/28vdc PEAK Count: 0
** Charging Characteristics **

Total Time in Bulk: 6436 SEC
Total Time in Absorb: 20664 SEC
Total Time in FLOAT: 0 SEC
Total Time not Charging: 28637 SEC
Total Time Sun Exposure: 22606 SEC 6 Hours last 24 hours
Peak/Actual Battery Amp Hours required/Installed: 390 AMPHRS 98 AMPHRS last 24 hours
Peak/Actual Solar Watts required/Installed: 545 Watts 100 Watts last 24 hours

** Load Info **

Load 1: 0.36 Amps
Load 1: 4.67 Watts
Load 2: 0.65 Amps
Load 2: 8.42 Watts
Total Load Amps: 1.02
Total Load Watts: 13.09
Predicted Solar WATTS required based on total Load power demand: 156 Solar Watts
Predicted Battery Amp Hours required based on total Load power demand: 390 Battery Amp Hours
Load1 over-current count: 0
Load2 over-current count: 0
Did not Load-shed within the last 24HRS

**** System Analysis ****

Load Analysis:

The system is predicting the need for a 156 Solar Panel
And detected a solar WATTS Peak of 77.887 Watts
The system is predicting the need for 390 AMP HOURS
Over the last 24 hours the system required 390 Battery Amp Hours to sustain 5 days of autonomy.

Currently have 98 Battery Amp Hours. Add 292 more Amp Hours to your system.
Over the last 24 hours the system required 545 Solar Watts to sustain daily charging.
Solar Panel is 100 Watts. Add 445 more Solar Watts
System maintained 6 hours of Sunshine [22606 SEC]
Predicted Number of Autonomy Days: [2 DAYS]
Predicted Number of Remaining Autonomy Days: [3 DAYS]
No system sustainable FLAGS indicated

>> Audit Report <<

12/10/20 12:00:00
Serial#: 0028B9FDD10B00008A
Up Time (sec): 94864
Product Model Code: 201
Firmware Rev: 110
Hardware Rev: 702
System is in warranty. 99.11% Remaining

** Solar Info **

Solar Voltage: 16.40
Solar Current: 4.37
Solar Watts: 71.70

** BATT Info **

BATT Voltage: 14.12
Battery Charge Current: 4.41
Battery Watts: 62.37
Battery is 95.34% Full
BATT VDC MIN: 12.54
BATT VDC MAX: 14.80
BATT AMPS MIN: -1.03
BATT AMPS MAX: 7.09
BATT Temperature: 64.36f

** Fan Info **

Fan1 total on Time 0
EXT Fan total on Time: 0
Fan1 on Time last 24hrs: 0
EXT Fan on Time last 24hrs: 0

** General Info **

Life charge Time: 1:3:43:42
Life Discharge Time: 2:1:28:49
Percent Charging 24HRS: 21.1%

Percent Discharging 24HRS: 78.8%
CPU Board power-up cycles: 6
Tamper Count: 5
Board TEMP: 84.42f
EXT TEMP: 59.86f
MPPT TEMP: 91.61f
Charging ROC: 2.05f
Deep Cycle Count/Time [Count:0] [Time:0]
Charging Cycles: 374
Full Charging Cycles: 0
BATT Maintenance ok, SCH: 8 of 60 Days
System Life Runtime: 279564 Seconds
Total Missed 14/28vdc PEAK Count: 0
Last Contiguous missed days 14/28vdc PEAK Count: 0

** Charging Characteristics **

Total Time in Bulk: 15272 SEC
Total Time in Absorb: 131 SEC
Total Time in FLOAT: 0 SEC
Total Time not Charging: 34184 SEC
Total Time Sun Exposure: 9109 SEC 6 Hours last 24 hours
Peak/Actual Battery Amp Hours required/Installed: 390 AMPHRS 98 AMPHRS last 24 hours
Peak/Actual Solar Watts required/Installed: 837 Watts 100 Watts last 24 hours

** Load Info **

Load 1: 0.15 Amps
Load 1: 2.17 Watts
Load 2: 0.43 Amps
Load 2: 6.18 Watts
Total Load Amps: 0.59
Total Load Watts: 8.36
Predicted Solar WATTS required based on total Load power demand: 96 Solar Watts
Predicted Battery Amp Hours required based on total Load power demand: 240 Battery Amp Hours
Load1 over-current count: 0
Load2 over-current count: 0
Did not Load-shed within the last 24HRS

**** System Analysis ****

Load Analysis:
The system is predicting the need for a 96 Solar Panel
And detected a solar WATTS Peak of 115.377 Watts
The system is predicting the need for 240 AMP HOURS
Over the last 24 hours the system required 390 Battery Amp Hours to sustain 5 days of autonomy.

Currently have 98 Battery Amp Hours. Add 292 more Amp Hours to your system.
Over the last 24 hours the system required 837 Solar Watts to sustain daily charging.
Solar Panel is 100 Watts. Add 737 more Solar Watts
System maintained 6 hours of Sunshine [9109 SEC]
Predicted Number of Autonomy Days: [0 DAYS]
Predicted Number of Remaining Autonomy Days: [0 DAYS]
No system sustainable FLAGS indicated

APPENDIX C – System log - Sample

```
Syslog: 12/11/20 00:00:01  Mid-Reset values 12.49 Batt Volts 0.78 Load Amps
Syslog: 12/11/20 00:00:01  Normal Battery 12VDC System Setup [12.49Vdc]
Syslog: 12/11/20 00:00:02  Sustained battery amp hours used exceeds battery capacity. RT[285 AH] TG[98 AH]
BATVDC[12.49VDC] BATAMP[-0.77ADC]
Syslog: 12/11/20 00:00:02  BATT Charge Fault: [3] Sustained Failure, System needs more system Amp hours
Syslog: 12/11/20 02:34:09  Calculating Rate of charge decay. ROC:-3.50 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/11/20 07:05:36  CHARGE STATE: IN BULK Mode PV5.72V PI:0.00A BATV:12.44V BATI:-0.67A
Syslog: 12/11/20 07:05:36  CHARGE STATE: Not in TRICKLE Mode PV:5.72V PI:0.00A BATV:12.44V BATI:-0.67A
Syslog: 12/11/20 07:32:48  Calculating Rate of charge decay. ROC:-3.63 MAX Movement: 15.00 Predicted Days of
Autonomy: 4
Syslog: 12/11/20 07:51:55  HIGH BATTERY DISCHARGE CURRENT RETRY 0.03 -0.816A
Syslog: 12/11/20 08:16:02  BATT Charged: 375 1
Syslog: 12/11/20 08:32:32  Calculating Rate of charge decay. ROC:30.84 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/11/20 09:32:16  Calculating Rate of charge decay. ROC:4.01 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/11/20 10:32:00  Calculating Rate of charge decay. ROC:3.86 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/11/20 10:55:22  INIT COMMWDT Via MODBUS
Syslog: 12/11/20 10:55:22  Alarm Acknowledged: Sustained, need more battery capacity
Syslog: 12/11/20 10:55:22  Alarm Acknowledged: Realtime, need more battery capacity
Syslog: 12/11/20 10:55:22  Alarm Acknowledged: High ROC Possible Bad Battery Check
Syslog: 12/11/20 10:55:23  INIT COMMWDT Via MODBUS
Syslog: 12/11/20 11:11:22  Sustained Solar Watts used exceeds Solar capacity. RT[564 AH] TG[100 AH]
SOLARVDC[15.61VDC] SOLARAMP[5.18ADC]
Syslog: 12/11/20 11:31:44  Calculating Rate of charge decay. ROC:2.86 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/11/20 12:17:02  CHARGE STATE: IN ABSORB Mode PV15.76V PI:5.18A BATV:14.43V BATI:4.96A
Syslog: 12/11/20 12:17:02  CHARGE STATE: Not in BULK Mode PV:15.76V PI:5.18A BATV:14.43V BATI:4.96A
Syslog: 12/11/20 12:17:02  CHARGE STATE: HIT FULL ABSORB Mode PV15.76V PI:5.18A BATV:14.43V BATI:4.96A
```

```
Syslog: 12/11/20 12:17:03  BATT Fully Charged: 1 10800
Syslog: 12/11/20 16:25:51  CHARGE STATE: Not IN ABSORB Mode PV:16.97V PI:0.52A BATV:13.86V BATI:-0.03A
Syslog: 12/11/20 16:25:51  CHARGE STATE: IN BULK Mode PV16.97V PI:0.52A BATV:13.86V BATI:-0.03A
Syslog: 12/11/20 16:26:33  CHARGE STATE: OUT OF FULL ABSORB Mode PV:16.08V PI:0.32A BATV:13.75V BATI:-0.29A
Syslog: 12/11/20 17:23:37  CHARGE STATE: Not in BULK Mode PV:5.57V PI:0.01A BATV:13.07V BATI:-0.61A
Syslog: 12/11/20 17:23:37  CHARGE STATE: IN TRICKLE Mode PV5.57V PI:0.01A BATV:13.07V BATI:-0.61A
Syslog: 12/11/20 17:57:21  BATTERY DISCHARGE CURRENT TO HIGH -0.83 -0.816A
Syslog: 12/11/20 18:29:51  Calculating Rate of charge decay. ROC:-0.01 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/11/20 21:29:03  Calculating Rate of charge decay. ROC:-0.74 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/11/20 22:28:46  Calculating Rate of charge decay. ROC:-3.66 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/11/20 23:28:30  Calculating Rate of charge decay. ROC:-3.81 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/11/20 23:48:38  BATT Fully Charged Reset: 1 1701
Syslog: 12/12/20 00:00:01  Mid-Reset values 12.81 Batt Volts 0.77 Load Amps
Syslog: 12/12/20 00:00:01  Normal Battery 12VDC System Setup [12.81Vdc]
Syslog: 12/12/20 00:00:02  Sustained battery amp hours used exceeds battery capacity. RT[300 AH] TG[98 AH]
BATVDC[12.81VDC] BATAMP[-0.80ADC]
Syslog: 12/12/20 00:00:02  BATT Charge Fault: [4] Sustained Failure, System needs more system Amp hours
Syslog: 12/12/20 00:17:18  BATT Charged Reset: 375 0
Syslog: 12/12/20 00:28:14  Calculating Rate of charge decay. ROC:-3.21 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/12/20 01:27:58  Calculating Rate of charge decay. ROC:-2.30 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/12/20 03:27:26  Calculating Rate of charge decay. ROC:-2.98 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/12/20 06:26:38  Calculating Rate of charge decay. ROC:-3.07 MAX Movement: 20.00 Predicted Days of
Autonomy: 3
Syslog: 12/12/20 07:02:02  CHARGE STATE: IN BULK Mode PV5.78V PI:0.00A BATV:12.65V BATI:-0.67A
Syslog: 12/12/20 07:02:02  CHARGE STATE: Not in TRICKLE Mode PV:5.78V PI:0.00A BATV:12.65V BATI:-0.67A
Syslog: 12/12/20 07:52:47  HIGH BATTERY DISCHARGE CURRENT RETRY 0.03 -0.816A
Syslog: 12/12/20 08:26:05  Calculating Rate of charge decay. ROC:8.86 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/12/20 08:39:43  BATT Charged: 376 1
Syslog: 12/12/20 09:25:49  Calculating Rate of charge decay. ROC:3.11 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/12/20 10:13:46  CHARGE STATE: IN ABSORB Mode PV16.24V PI:4.46A BATV:14.49V BATI:4.31A
Syslog: 12/12/20 10:13:46  CHARGE STATE: Not in BULK Mode PV:16.24V PI:4.46A BATV:14.49V BATI:4.31A
Syslog: 12/12/20 10:13:46  CHARGE STATE: HIT FULL ABSORB Mode PV16.24V PI:4.46A BATV:14.49V BATI:4.31A
Syslog: 12/12/20 10:25:33  Calculating Rate of charge decay. ROC:3.93 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/12/20 11:25:17  Calculating Rate of charge decay. ROC:3.78 MAX Movement: 0.00 Predicted Days of
Autonomy: 0
Syslog: 12/12/20 11:25:22  BATT Fully Charged: 2 9820
```