SOLAR ELECTRIC POWER SYSTEM

INSTALLATION, OPERATION, AND MAINTENANCE (IOM) MANUAL

Model: SPWR-12VDC-XXX

AH/12VDC/ NEMA 4X/SS10L, 1.5” POLE

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1. INTRODUCTION
Thank you for purchasing an Ascendance Wireless solar electric power system. The solar electric system is designed to provide operating power to a specified load. Using loads other than those for which the system was designed for will result in poor system performance and possible damage to the batteries.

System components have been carefully selected and configured for the intended application. Solar module, support structure, and battery components maybe provided separately.

1.1. Important: Special Considerations before beginning the installation
To ensure proper operation of the power system, it must be installed per the instructions in Section 3.

Special care must be taken when selecting the solar module mounting location to prevent possible shadowing effects from cut hillsides, trees or utility poles. Any shading of the modules, during any period of the day, will result in a reduction in the output of the solar array and reduced system performance and must be avoided.

Connecting loads with power requirements greater than those for which the system was designed for will result in poor system performance and possible damage to the batteries.

Additionally, the solar modules must be properly oriented for the specific geographic region to maximize the solar radiation available at the site. This includes the tilt angle and alignment to True South (refer to Section 3.3)

While performing the installation of your system, consideration of the above factors will result in the system performing reliably to its’ original specifications.

1.2. Definition of Warning Statements

DANGER: Failure to heed this warning may result in serious injury.

CAUTION: Failure to heed this warning may result in damage to the load or system equipment.

NOTE: Information or instructions that will assist in the proper installation and operation of the system.

1.3. Technical Support
We strive to provide quality service and support. Please feel free to contact us at any time should a question arise as to the proper installation and operation of the system. A proper installation will help to ensure reliable system operation.

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2. THEORY OF OPERATION

2.1 System Overview

There are three major components in the photovoltaic system: solar modules, batteries, and the system charge controller. Throughout the year, all of the power to the load is provided by the solar array.

The photovoltaic array will supply current to charge the battery bank. The controller regulates the battery charging by monitoring the battery terminal voltage and limits the charging current to the battery bank as required. The controller will charge the battery until the voltage reaches 14.1 VDC, then taper the current to maintain a float voltage of 13.7 VDC. The controller also contains a temperature probe and adjusts the charge voltage at a rate of \(-0.030\) VDC/°C from 25°C. This temperature compensation feature assures the battery is properly charged in cold temperatures and not overcharged in warm temperatures. (Refer to the controller manual in the Appendix for additional details on charge regulation.)

Additionally, the controller contains a Low Voltage Disconnect (LVD). This feature will prevent the battery from being over-discharged to a level that could damage and shorten its life. This feature will disconnect the load if battery voltage falls to a voltage of 11.5 VDC. When the battery has been charged to a voltage of 12.6 VDC, the controller will reconnect the battery to the load.

2.1 Component Descriptions

Solar Module:
A VLS-85W photovoltaic module is used in this system. The module is rated 85W, 4.72A @ 18.0VDC under standard test conditions (STC). Additional information on the VLS photovoltaic module can be found in the Appendix.

Battery (provided by others):
The MK (Deka/East Penn) 8G27 gelled electrolyte battery is recommended for use in this system. The Valve Regulated Lead Acid (VRLA) battery is specifically designed for deep cycle photovoltaic systems. The 12VDC nominal battery has a capacity of 99AH at the 100 hour rate to 1.75VPC. Two batteries may be installed for up to 198AH of energy storage at 12VDC.

Controllers:
The MorningStar SunSaver charge regulator is used in these solar power systems. The regulator is rated for 10A of charge current and 10A of discharge current at a nominal 12 VDC. Refer to the manual in the Appendix for additional information on the regulator’s ratings and operation.
3  SYSTEM INSTALLATION
Perform the installation of the system in the order of and as described in the following subsections.

3.1  Overview
The SK Systems come pre-assembled and tested. All that is required is to mount the modules and enclosure on a 1.5” SCH 40 pole (provided by others), install the batteries, and make the final wire terminations.

3.2  Recommended Installation Tools
- Compass (magnetic or GPS)
- Multimeter
- Phillips Head Screwdrivers
- Straight Blade Screwdrivers
- Socket Set
- Combination Wrench Set
- Wire Cutters
- Wire Strippers
- Electrical Tape
- Cable Ties (for wire dressing)

3.3  Site Location
Shading of the photovoltaic modules will significantly reduce their energy output and consequently proper battery charging! Be sure to select an array mounting location that will not be shaded by towers, poles, buildings, vegetation (e.g. trees), or hillside cuts through the day.

In order for the solar array to receive the maximum energy from the sun, the array must face TRUE South. It is recommended to use a GPS or a magnetic compass to find TRUE South. If using a magnetic compass, ensure there are not steel objects nearby to affect the reading, also be sure to adjust for magnetic declination. (e.g. for Phoenix, AZ, true south is 11 degrees east of magnetic south). Refer to the map below, Figure 2 and the diagram to the right, Figure 1. Note that in general, locations east of the Mississippi will find True South to the west of magnetic south, and locations west of the Mississippi will find True South to the east of magnetic south.

![Figure 1 – True South is 11 degrees East of Magnetic South for Phoenix, AZ](image-url)
3.4 Mechanical Assembly

**WARNING: Electrical Shocks and Burns Hazard**

Photovoltaic (PV) modules generate electricity when exposed to light, even when they are not connected in a circuit. Shocks and burns can result from contact with module output wiring. These hazards are increased when multiple modules are interconnected to increase array output current or voltage. Cover module front surfaces completely with an opaque cloth or other opaque material before performing any operation involving module or system electrical connections. Use appropriate safety equipment (insulated tools, insulating gloves, etc.) and procedures.
CAUTION: Module Breakage
The module glass is tempered and will shatter if exposed to impact. Avoid rough handling and lay the modules on a flat, protected surface during assembly. This will also prevent power output at the electrical terminals. Avoid shorting the terminals whenever sunlight is present on the module front surface.

3.4.1 Mounting Pole Installation
All solar equipment is to be attached to a 1.5” SCH 40 pole (provided by others). Ensure the concrete has had adequate time to cure before placing equipment on the pole. Refer to the Site Layout drawing for details.

3.4.2 Solar Module Support Structure Assembly
Observe the following mounting and assembly guidelines:

- Refer to the structure assembly instructions included with the structure and the Site Layout drawing (in the Appendix) for assembly details.
- Protect the glass surface of the modules. It is usually best to place the modules face down on a protected surface (e.g. the packing cardboard that came with the module) when attaching the support rails.
- Use care when working around the back surface of the module as the material can be easily torn or punctured. If the material is damaged, repair the damage with the use of a 100% silicone sealant.

1. Fasten the pole bracket to the pole using the 1.5” U-bolts.
2. Attach the module rails to the end brackets on the pole bracket using the structure hardware provided.
3. Loosen the bolts attaching the pole bracket to the end brackets and slide the end brackets until the module rails line up with the mounting holes on the solar module.
4. Place the PV module on top of the module rails and secure using the module hardware provided.
5. Align the structure to True South and adjust to the correct tilt angle, tighten all hardware.

3.4.3 System Enclosure Mounting
Attach the system enclosure to the pole below the solar array using the pole clamps provided. The pole clamps slide into the slot on the U-channel. Refer to the Site Layout drawing.

3.5 System Wiring
WARNING: Electrical Hazard
Photovoltaic modules generate high voltage whenever exposed to sunlight. Voltages can be as high as 22 VDC.
CAUTION: Electrical Hazard
Ensure all fuses are removed and all circuit breakers are in the OFF position before beginning any wiring.

3.5.1 Grounding
The system enclosure should be grounded using the 12AWG ground conductor routed in the load conduit. One end of this wire is connected inside the enclosure to a backplate mounting stud by a 3/8" ring terminal. Connect the other end of wire to the site ground (provided by others).

3.5.2 Array Wiring
Route the conduit labeled ARRAY up the pole to the module junction box. Open the module junction box. Knock out one of the 1/2” knockouts. Remove the locknut from the conduit connector. Insert the connector into the junction box and secure with the locknut. Terminate the red wire to the module positive output terminal and the black wire to the module negative output terminal using the fork terminals provided. Refer to the System Wiring Diagram in the Appendix.

3.5.3 Load Installation and Wiring
The load can be mounted on the backplate DIN rail, placed on the backplate shelf, or mounted externally from the system enclosure. For external loads, route the conduit labeled LOAD to the load equipment. Enter the load equipment through a 1/2” knockout, and secure using the conduit connector. Terminate the red wire to the load positive input terminal and the black wire to the load negative input terminal. Refer to the System Wiring Diagram in the Appendix.

3.5.4 Battery Installation and Wiring (batteries provided by others)
WARNING: Electrical Hazard
Batteries contain high discharge currents; use insulated tools on and around batteries.

WARNING: Chemical Hazard
Batteries contain sulfuric acid which can cause burns and other serious injury. In the event of contact with sulfuric acid, flush immediately and thoroughly with water. The use of safety goggles, rubber apron, and rubber gloves is recommended.

WARNING: Explosive Hazard
Batteries can generate explosive gases, which when released, can explode and cause blindness and other serious injury. Keep sparks, flames, and smoking materials away from the battery area.
One or two batteries may be used with this system. Remove the top cover foam from the enclosure. Place the first battery in the bottom of the enclosure with the terminals toward the enclosure side (as shown in the Enclosure Layout drawing in the Appendix). Connect the red wire with the red boot cover to the battery positive terminal and the black wire with the black boot cover to the battery negative terminal. If two batteries are used, place the second battery in the bottom of the enclosure with the terminals toward the enclosure side. Install the battery parallel interconnect cables from the first battery to the second battery. When done, place the top cover foam on top of the batteries. Refer to the System Wiring Diagram in the Appendix.

**WARNING: Battery Parallel Cables**
If only one battery is used, ensure the battery parallel cables are NOT connected to the battery.

### 3.6 System Checkout and Commissioning
At the end of the installation it is important to confirm and verify all mechanical and electrical connections. Perform the following system checkout and complete the System Installation Checklist.

1. Confirm the proper tilt angle and orientation of the solar module; ensure it is facing true south (and adjusted for magnetic declination if a magnetic compass is used).
2. Ensure all mechanical fasteners are tight and secure.
3. At the controller, check the module short circuit current and open circuit voltage.
4. At the controller, check the voltage and polarity of the battery. The voltage should be approximately 12.5 VDC.
5. Switch on the battery circuit breaker. Verify the green "CHARGING" indicator on the regulator is lit. If it is not lit, go back and check the connections.
6. Switch on the load(s) and verify its' proper operation. Ensure the load is operating within the energy design of the system. If needed perform a series current draw.
System Installation Checklist and Start-Up Table

Module facing true south: ______ (Yes/No)
Module at correct tilt angle: ______ (Yes/No)
All mechanical fasteners tight: ______ (Yes/No)

Record the module open circuit voltage (VOC) and short circuit current (ISC) at the controller.
Open Circuit Voltage: ______ VDC
Short circuit Current: _____ A

Record the initial battery voltage at the controller.
Battery bank: _____ VDC

Controller Operation:
Charging LED illuminated: ______ (Yes/No)
Load Disconnect LED illuminated: ______ (Yes/No)
Load operating properly: ______ (Yes/No)

INSTALLATION IS NOW COMPLETE

_____________________________________________________
Tested By: Date:

_____________________________________________________
Approved By: Date:
4 RECOMMENDED MAINTENANCE

Although the solar electric power system should require minimal maintenance a few minutes time every 3-6 months can help to maintain the performance of the system and extend its’ service life.

4.1 Solar Array

1. The solar array should not need to be completely cleaned unless the dirt build-up is particularly bad. Special care should be taken to look for and remove any bird drops or mud as these essentially shade the module and reduce the output current. When cleaning the front surface of the array use a soft non-abrasive cloth or brush and water. Avoid the use of any cleaning products that may leave residue on the module or promote corrosion on the structure and its’ fasteners.

2. The tilt angle and orientation should be confirmed per the installation instructions in Section 3.

3. Inspect all electrical connections for looseness, corrosion, chafing, etc.

4. Inspect the module back surface for damage or punctures. Seal any punctures that are found with a commercial grade RTV sealant. If significant impact damage is observed, replace the affected solar module.

4.2 Charge Controller

1. Inspect all electrical connections for looseness or corrosion.

2. Check Charge Controller operation per the manual in the Appendix.

4.3 Battery Bank

1. Inspect all electrical connections for looseness or corrosion.

2. Check and record battery voltages.

4.4 System Wiring

1. Inspect all wiring and connections for tightness, corrosion, insulation integrity, damage, etc. Repair or replace as necessary.
5 SYSTEM TROUBLESHOOTING

If the system is not functioning correctly, there are a few simple steps to isolate the problem.

The solar power system sites must be inspected regularly for damage due to vandalism or wildlife. Loose or damaged wiring can cause severe voltage drop (power loss) or an open circuit of the array, battery or load. In general, basic maintenance should be performed (per Section 4 above) first, as sometimes the potential cause maybe found (e.g. dirty or damaged module, lose wire, etc.)

Following are some of the typical factors that contribute to the failure of the system to operate within design parameters:

1. **Load greater than system design** – Installing loads greater than the system was designed for will reduce the performance of the system and damage the batteries. Excessive load operation can either be power, current, or operating time. Daily load energy consumption should be checked to verify it is within the operation parameters of the system. If the load is greater than the system design, the load should be decreased or the system increased (e.g. array, battery, controller, etc.)

2. **Shading** – Even partial shading of the solar module can result in zero output from the module and will result in reduced system performance. Shading can result from improper overgrown vegetation (e.g. trees), cut hillsides, utility poles, towers, buildings; or from excessive dirt or bird droppings. The solar array must be inspected and cleaned at regular intervals (per the maintenance instructions in Section 4); vegetation should be cut or trimmed as necessary. Careful attention should be observed at the time of installation to prevent shading from towers, buildings, poles, etc. and the site moved relocated as necessary to avoid the obstruction.

3. **Incorrect orientation or tilt angle** – Refer to the installation instructions in Section 3 for proper orientation, alignment, and tilt adjustment. Incorrect alignment of the solar array will result in reduced array output and system performance.

4. **Poor sunlight conditions** – Although rare, occasionally unusual weather patterns may occur for an extended period (exceeding the sunless days of battery reserve designed into the system) which will result in reduced system performance and non-operation of the load. Recent weather patterns should be recorded to verify available solar energy. If poor weather conditions prevail the battery capacity or solar array can be increased to increase system performance.

5. **System component damage or malfunction** – If none of the above has corrected the problem; then a failed component is most likely the cause and should be isolated and replaced.

   a. A damaged solar module will produce less or no power at all (depending on the severity of the damage). Examine the solar module for visible damage. If no damage is found, open the junction box and disconnect the output wires. Using a multimeter, check the short circuit current and open circuit voltage on a clear
sunny day. These values should approximate those on the module specification sheet.

b. The charge controller may experience malfunction due to excessive currents or a lightning strike. Refer to the controller manual in the Appendix for details on troubleshooting.

c. Battery failure may be caused by several factors: age, controller failure, or excessive load operation. If the battery is more than 5 years old is probably nearing the end of its’ service life and may need to be replaced. A capacity test can confirm the ability of the battery to support the load. If the battery is relatively new (1 to 2 years old) the system should be checked for proper operation. The controller should be tested per the instructions in the controller manual (Appendix). Excessive load operation may result in permanent battery damage (excessive deep discharge). The load should be monitored to confirm it is operation within the design parameters of the system design.

6. If any of the above fails to correct the problem or if new components are required contact technical support (refer to Section 1.3) for additional assistance, please have available the system model number and a brief description of the problem.
GLOSSARY OF TERMS

Air Mass: Equal to the cosine of the zenith angle - that angle from directly overhead to a line intersecting the sun. The air mass is an indication of the length of the path solar radiation travels through the atmosphere. An air mass of 1.0 means the sun is directly overhead and the radiation travels through one atmosphere (thickness).

Alternating Current (ac): An electric current that reverses direction periodically.

Ambient Temperature: The temperature of the surrounding area.

Ampere (A): Unit of electric current. The rate of flow of electrons in a conductor equal to one coulomb per second.

Ampere-Hour (Ah): The quantity of electrical energy equal to the flow of current of one ampere for one hour. The term is used to quantify the energy stored in a battery.

Angle of Incidence: The angle that a light ray striking a surface makes with a line perpendicular to the surface.

Anode: The positive electrode in an electrochemical cell (battery). Also, the earth ground in a cathodic protection system. Also, the positive terminal of a diode.

Array: A collection of electrically connected photovoltaic (PV) modules.

Array Current: The electrical current produced by a PV array when it is exposed to sunlight.

Array Operating Voltage: The voltage produced by a PV array when exposed to sunlight and connected to a load.

Availability: The quality or condition of a PV system being available to provide power to a load. Usually measured in hours per year. One minus availability equals downtime.

Azimuth: Horizontal angle measured clockwise from true north; 180° is true south.

Battery: A device that converts the chemical energy contained in its active materials directly into electrical energy by means of an electrochemical oxidation-reduction (redox) reaction.

Battery Capacity: The total number of ampere-hours that can be withdrawn from a fully charged battery at a specified discharge rate and temperature. See Ampere-Hour.

Battery Cell: The smallest unit or section of a battery that can store electrical energy and is capable of furnishing a current to an external load.

Battery Cycle Life: The number of times a battery can be discharged and recharged before failing. Battery manufacturers specify Cycle Life as a function of discharge rate and temperature.

Battery Self-Discharge: Loss of energy by a battery that is not under load.
**Battery State of Charge (SOC):** Percentage of full charge or 100 percent minus the depth of discharge. See Depth of Discharge.

**Bypass Diode:** A diode connected in parallel with a PV module to provide an alternate current path in case of module shading or failure.

**Cathode:** The negative electrode in an electrochemical cell. Also, the negative terminal of a diode.

**Charge:** The process of adding electrical energy to a battery.

**Charge Controller:** A device that controls the charging rate and/or state of charge for batteries.

Charge Controller Terminology:

**High Voltage Disconnect (HVD):** The voltage at which the charge controller will disconnect the array from the batteries to prevent overcharging.

**Low Voltage Disconnect (LVD):** The voltage at which the charge controller will disconnect the load from the batteries to prevent over-discharging.

**Low Voltage Alarm (LVA):** A warning alarm (contact closer) or light (or LED) that indicates that the battery is at a low state of charge (SOC).

**Maximum Power Tracking or Peak Power Tracking:** Operating the array at the peak power point of the array's I-V curve where maximum power is obtained.

**Pulse Width Modulation (PWM) Controller:** High frequency (100 to 1000Hz) solid state series controller which uses PWM to taper the charge current to the battery.

**Reverse Current Protection:** Any method of preventing unwanted current flow from the battery to the PV array (usually at night).

**Series Controller:** A controller that interrupts the charging current by open circuiting the PV array. The control element is in series with the PV array and battery.

**Shunt Controller:** A controller that redirects or shunts the charging current away from the battery. The controller requires a large heat sink to dissipate the current from the short-circuited PV array. Most shunt controllers are for smaller systems producing 30 amperes or less.

**Temperature Compensation:** A circuit that adjusts the charge controller activation points depending on battery temperature. This feature is recommended if the battery temperature is expected to vary more than +/-5°C from ambient temperature. The temperature coefficient for lead acid batteries is typically -3 to -5 millivolts/°C per cell.

**Charge Factor:** A number representing the time in hours during which a battery can be charged at a constant current without damage to the battery. Usually expressed in relation to the total battery capacity, i.e., C/5 indicates a charge factor of 5 hours. Related to Charge Rate.

**Charge Rate:** The current used to recharge a battery. Normally expressed as a percentage of total battery capacity. For instance, C/5 indicates a charging current equal to one-fifth of the battery's capacity.
Cloud Enhancement: The increase in solar intensity caused by reflected irradiance from nearby clouds.

Current (Amperes, Amps, A): The flow of electric charge in a conductor between two points having a difference in potential (voltage).

Cutoff Voltage: The voltage levels (activation) at which the charge controller disconnects the array from the battery or the load from the battery.

Cycle: The discharge and subsequent charge of a battery.

Days of Storage: The number of consecutive days the stand-alone system will meet a defined load without solar energy input. This term is related to system availability.

DC/DC Converter: A unit that converts a dc voltage to another dc voltage.

Deep Cycle: Type of battery that can be discharged to a large fraction of capacity many times without damaging the battery.

Design Month: The month having the combination of insolation and load that requires the maximum energy from the array.

Depth of Discharge (DOD): The percent of the rated battery capacity that has been withdrawn. See Battery State of Discharge.

Direct Current (dc): Electric current flowing in only one direction.

Discharge: The withdrawal of electrical energy from a battery.

Discharge Factor: A number equivalent to the time in hours during which a battery is discharged at constant current usually expressed as a percentage of the total battery capacity, i.e., C/5 indicates a discharge factor of 5 hours. Related to Discharge Rate.

Discharge Rate: The current that is withdrawn from a battery over time. Expressed as a percentage of battery capacity. For instance, a C/5 discharge rate indicates a current equal to one-fifth of the rated capacity of the battery.

Disconnect: Switch gear used to connect or disconnect components in a PV system.

Duty Cycle: The ratio of active time to total time. Used to describe the operating regime of appliances or loads in PV systems.

Efficiency: The ratio of output power (or energy) to input power (or energy). Expressed in percent.

Equalization Charge: The process of mixing the electrolyte in batteries by periodically overcharging the batteries for a short time.

Fixed Tilt Array: A PV array set in at a fixed angle with respect to horizontal.
**Float Charge:** A charge current to a battery that is equal to or slightly greater than the self-discharge rate.

**Frequency:** The number of repetitions per unit time of a complete waveform, expressed in Hertz (Hz).

**Insolation:** The solar radiation incident on an area over time. Equivalent to energy and usually expressed in kilowatt-hours per square meter.

**Inverter:** An inverter converts dc power from the PV array/battery to ac power compatible with the utility and ac loads.

**Irradiance:** The solar power incident on a surface. Usually expressed in kilowatts per square meter. Irradiance multiplied by time equals insolation.

**Kilowatt (kw):** One thousand watts. A unit of power.

**Kilowatt Hour (kwh):** One thousand watt-hours. A unit of energy. Power multiplied by time equals energy.

**Life:** The period during which a system is capable of operating above a specified performance level.

**Load:** The amount of electric power used by any electrical unit or appliance at any given time.

**Load Current (A):** The current required by the electrical device.

**Module:** The smallest replaceable unit in a PV array. An integral, encapsulated unit containing a number of PV cells.

**Normal Operating Cell Temperature (NOCT):** The estimated temperature of a PV module when operating under 800 w/m² irradiance, 20°C ambient temperature and wind speed of 1 meter per second. NOCT is used to estimate the nominal operating temperature of a module in its working environment.

**Nominal Voltage:** A reference voltage used to describe batteries, modules, or systems (i.e., a 12-volt or 24-volt battery, module, or system).

**Open Circuit Voltage:** The maximum voltage produced by an illuminated photovoltaic cell, module, or array with no load connected. This value will increase as the temperature of the PV material decreases.

**Operating Point:** The current and voltage that a module or array produces when connected to a load. The operating point is dependent on the load or the batteries connected to the output terminals of the array.

**Orientation:** Placement with respect to the cardinal directions, N, S, E, W; azimuth is the measure of orientation from north.

**Overcharge:** Forcing current into a fully charged battery. The battery will be damaged if
overcharged for a long period.

Panel: A designation for a number of PV modules assembled in a single mechanical frame.

Parallel Connection: Term used to describe the interconnecting of PV modules or batteries in which like terminals are connected together. Increases the current at the same voltage.

Peak Load: The maximum load demand on a system.

Peak Sun Hours: The equivalent number of hours per day when solar irradiance averages 1,000 w/m². For example, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance for six hours been 1,000 w/m².

Photovoltaic System: An installation of PV modules and other components designed to produce power from sunlight and meet the power demand for a designated load.

Power (Watts): A basic unit of electricity equal (in dc circuits) to the product of current and voltage.

Remote Site: A site not serviced by an electrical utility grid.

Series Connection: Connecting the positive of one module to the negative of the next module. This connection of PV modules or batteries increases the voltage while the current remains the same.

Short Circuit Current (Isc): The current produced by an illuminated PV cell, module, or array when its output terminals are shorted.

Stand-Alone PV System: A photovoltaic system that operates independent of the utility grid.

State of Charge (SOC): The instantaneous capacity of a battery expressed at a percentage of rated capacity.

String: A number of modules or panels interconnected electrically in series to produce the operating voltage required by the load.

System Availability: The percentage of time (usually expressed in hours per year) when a PV system will be able to fully meet the load demand.

Tilt Angle: The angle of inclination of a solar collector measured from the horizontal.

Volt (V): The unit of electromotive force that will force a current of one ampere through a resistance of one ohm.

Watt (W): The unit of electrical power. The power developed when a current of one ampere flows through a potential difference of one volt; 1/746 of a horsepower.

Watt Hour (Wh): A unit of energy equal to one watt of power connected for one hour.
5. Ground point established by others.
4. Unless otherwise specified, wiring to be #12 red positive (+), black negative (-), green ground (Ø).
3. Batteries to be installed in the field.
2. Connections to batteries to be completed in the field.
1. Connections to array to be completed in the field.

Notes:
Drawing 2: Site Layout

- Solar Module: VLS-85W
- Battery and Control Enclosure
- Dimensions: 24.7 x 30.2
- Connections: To Array, To Load
- Steel Pole (Provided by Others): 1.5in SQ 4400 [1.0in O.D.]
2. BATTERY TO HAVE EXPANDED POLYSTYRENE FOAM INSULATION ON ALL SIDES AND DOOR.
1. ENCLOSURE DOOR NOT SHOWN FOR CLARITY.
NOTES:
1. Landscape module orientation shown, for models: VLS-ROW and 490U.

NOTES:
**Drawing 5: SPM1-Multi-V3-Portrait**

Channels accept 2-3" nominal U-bolts.

Hardware included:
- 2" LD U-bolt with saddle and flange nuts (2 PL.)
- 1" bracket hardware with flange nuts (4 PL.)
- 1" module hardware with flat & split (4 PL.)
- 5/8" bracket hardware with flat & split (4 PL.)

1. Portrait module orientation shown for models: VLE-72W, 440J, 450J, and 360J.
2. Rails must be flipped inward as shown for 440J.

Notes:
Solar Panel Specifications

Economical Panels for Off-Grid Applications - VLS-85W

Value Line Series (VLS) - 85W Panel
The Value Line Series (VLS) family of solar modules is a reliable, rugged, and economic panel designed for off-grid solar applications. The VLS line offers the rugged and reliable construction, materials, and performance.

The VLS-85W Panel features:
- Rugged construction, precision engineering, and quality components
- Tempered glass, EVA lamination, and weatherproof backskin that fosters long-life and enhanced cell performance

Manufactured according to International Quality and Environment Management System (ISO9001, ISO14001)

**ELECTRICAL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum power ($P_{max}$)</td>
<td>85W</td>
</tr>
<tr>
<td>Tolerance ($P_{tol}$)</td>
<td>±5%</td>
</tr>
<tr>
<td>Open circuit voltage ($V_{oc}$)</td>
<td>22.3V</td>
</tr>
<tr>
<td>Maximum power voltage ($V_{mp}$)</td>
<td>18.0V</td>
</tr>
<tr>
<td>Short circuit current ($I_{sc}$)</td>
<td>5.15A</td>
</tr>
<tr>
<td>Maximum power current at ($I_{mp}$)</td>
<td>4.72A</td>
</tr>
<tr>
<td>Maximum system (DC) voltage</td>
<td>80V</td>
</tr>
<tr>
<td>Operation temperature range</td>
<td>-40°C - 85°C</td>
</tr>
<tr>
<td>NOCT(2)</td>
<td>48±3°C</td>
</tr>
<tr>
<td>Temperature coefficient of $I_{sc}$</td>
<td>0.084%/°C</td>
</tr>
<tr>
<td>Temperature coefficient of $V_{oc}$</td>
<td>-0.3%/°C</td>
</tr>
</tbody>
</table>

1. Values at Standard Test Conditions (STC): 1000W/m² irradiance, AM 1.5 solar spectrum and 25°C module temperature
2. Nominal Operating Cell Temperature: Module operation temperature at 800W/m² irradiance, 20°C air temperature, 1m/s wind speed

**MECHANICAL CHARACTERISTICS**

- Dimensions: 1210 x 536 x 50mm / 47.64 x 21.10 x 1.97 in
- Weight: 7.3kg / 16.1lbs

**DIMENSIONS**

**IV CURVES**

Photographs are intended to portray typical module appearance; actual module appearance may vary. Diagrams may not be proportionate and are intended for illustrative purposes only. 06/07/13
SunSaver Models Included in this Manual:
- SS-6-12V / SS-6L-12V
- SS-10-12V
- SS-10L-12V / SS-10L-24V
- SS-20L-12V / SS-20L-24V

Morningstar Corporation
8 Pheasant Run
Newtown, PA 18940 USA
www.morningstarcorp.com
1.0 Important Safety Information

Save These Instructions

This manual contains important safety, installation and operating instructions for the SunSaver solar controller. The following symbols are used throughout this manual to indicate potentially dangerous conditions or mark important safety instructions:

WARNING: Indicates a potentially dangerous condition. Use extreme caution when performing this task.

CAUTION: Indicates a critical procedure for safe and proper operation of the controller.

NOTE: Indicates a procedure or function that is important for the safe and proper operation of the controller.

WARNING: These servicing instructions are for use by qualified personnel only. To reduce the risk of electric shock, do not perform any servicing other than that specified in the operating instructions unless you are qualified to do so.

Safety Information

- Read all of the instructions and cautions in the manual before beginning installation.
- There are no user serviceable parts inside the SunSaver. Do not disassemble or attempt to repair the controller.
- Disconnect all sources of power to the controller before installing or adjusting the SunSaver.
- There are no fuses or disconnects inside the SunSaver. Do not attempt to repair.
- Install external fuses/breakers as required.

Installation in Hazardous Locations

THIS EQUIPMENT IS SUITABLE FOR USE IN CLASS I, DIVISION 2, GROUPS A, B, C AND D OR NON-HAZARDOUS LOCATIONS ONLY.

Information de sécurité

- Lisez toutes les instructions et les avertissements figurant dans le manuel avant de commencer l'installation.
Installation Safety Precautions

WARNING: This unit is not provided with a GFDI device. This charge controller must be used with an external GFDI device as required by the Article 690 of the National Electrical Code for the installation location.

- Mount the SunSaver indoors. Prevent exposure to the elements and do not allow water to enter the controller.
- Install the SunSaver in a location that prevents casual contact. The SunSaver heatsink can become very hot during operation.
- Use insulated tools when working with batteries.
- Avoid wearing jewelry during installation.
- The battery bank must be comprised of batteries of the same type, make, and age.
- Do not smoke in the vicinity of the battery bank.
- Mount the controller at least 3 ft (1 m) away from vented batteries unless separated by a barrier or located in a separate compartment.
- Power connections must remain tight to avoid excessive heating from a loose connection.
- Use properly sized conductors and circuit breakers.
- This charge controller is to be connected to DC circuits only. These DC connections are identified by the symbol below.

Direct Current Symbol

2.0 General Information

2.1 Overview

Thank you for selecting the SunSaver solar charge controller. The SunSaver is an advanced PWM solar battery charger and load controller for stand-alone PV systems.

The SunSaver battery charging process has been optimized for long battery life and improved system performance. Self-diagnostics and electronic over-protection prevent damage when installation mistakes or system faults occur.

Although the SunSaver is very simple to install and use, please take the time to read this operator’s manual and become familiar with the controller.
2.2 Features

The features of the SunSaver are shown in Figure 1 below. An explanation of each feature is provided.

1 - Status LED
An LED indicator that shows charging status and also indicates when a solar input fault condition exists.

2 - Power Terminal Block
Power terminations for system Solar, Battery, and Load connections.

3 - Battery Select Jumper
A removable jumper to select the battery type.

4 - Local Temperature Sensor
Measures ambient temperature. Battery regulation is adjusted based on ambient temperature changes.

5 - Battery Status LEDs
Provides approximate battery state of charge indication and also indicates when a system or load fault condition exists.

6 - Mounting Holes
Four (4) mounting holes (mounting screws provided)

2.3 Regulatory Information

NOTE: This section contains important information for safety and regulatory requirements.

The SunSaver controller should be installed by a qualified technician according to the electrical rules of the country in which the product will be installed.

SunSaver controllers comply with the following EMC standards:
- Immunity: EN50160-6-2:1999
- Emissions: EN60022:1994 with A1 and A3 Class B1
- Safety: EN60335-1 and EN60335-2-29 (battery chargers)

A means shall be provided to ensure all pole disconnection from the power supply. This disconnection shall be incorporated in the fixed wiring.

Using the SunSaver grounding terminal (in the wiring compartment), a permanent and reliable means for grounding shall be provided. The clamping of the earthing shall be secured against accidental loosening.

The entry openings to the SunSaver wiring compartment shall be protected with conduit or with a bushing.

FCC requirements:

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by Morningstar for compliance could void the user’s authority to operate the equipment.

Note:
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communication. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment on and off, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.

- Increase the separation between the equipment and receiver.

- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

- Consult the dealer or an experienced radio/TV technician for help.

This Class B digital apparatus complies with Canadian ICES-003. Cet appareil numérique de la classe B est conforme à la norme NMB-003 du Canada.
3.0 Installation Instructions

3.1 General Installation Notes

- Read through the entire installation section before beginning installation.
- Be very careful when working with batteries. Wear eye protection. Have fresh water available to wash and clean any contact with battery acid.
- Use insulated tools and avoid placing metal objects near the batteries.
- Explosive battery gasses may be present during charging. Be certain there is sufficient ventilation to release the gasses.
- Do not install in locations where water can enter the controller.
- Loose power connections and/or corroded wires may result in resistive connections that melt wire insulation, burn surrounding materials, or even cause fire. Ensure tight connections and use cable clamps to secure cables and prevent them from swaying in mobile applications.
- The SunSaver charging algorithm is compatible with lead-acid or NiCd batteries. NiMH, Li-ion, and other battery chemistries are not compatible with the SunSaver charging algorithm.
- The SunSaver Battery connection may be wired to one battery or a bank of batteries. The following instructions refer to a singular battery, but it is implied that the battery connection can be made to either one battery or a group of batteries in a battery bank.

3.2 User Selections

Select a Battery Type

The SunSaver provides a Battery Select Jumper to choose the battery type. See Section 7.0 Technical Specifications for detailed charging information for each battery type.

The battery select jumper is secured in the terminal block between terminal #6 and terminal #7 as shown in figure 2a. The second column in table 1 specifies whether the jumper should be removed or remain in place, depending on the desired battery type.

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Battery Jumper</th>
<th>Absorption</th>
<th>Float</th>
<th>Equalize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealed</td>
<td>Inserted</td>
<td>14.10V</td>
<td>13.70V</td>
<td>N/A</td>
</tr>
<tr>
<td>Flooded</td>
<td>Removed</td>
<td>14.40V</td>
<td>13.70V</td>
<td>14.20V</td>
</tr>
</tbody>
</table>

Table 1. Battery Type selection

![Figure 2a. Removing the Battery Select jumper.]

Choose Regulation Method (optional)

Choose between Pulse Width Modulation (PWM) charging or Slow Switching charging. PWM charging is the default regulation method and is the method recommended for most systems.

Slow Switching regulation should only be selected if noise or interference exists in the system due to PWM charging. This regulation method limits the switching frequency to 10 Hz (maximum), which can eliminate noise issues in some systems.

PWM charging is selected by default. To enable Slow Switching regulation do the following:

1. Remove all four screws that secure the faceplate on the SunSaver. See Figure 2b.
2. Gently pry the faceplate off the SunSaver. Occasionally, epoxy encapsulant will cause the faceplate to stick. Use a small flat-head screwdriver to separate the faceplate from the SunSaver body. See Figure 2c.
3. A loop of wire protrudes from the epoxy. Cut the loop with wire cutters to switch the regulation method to Slow Switching. See Figure 2d.
4. Tape the cut ends with electrical tape to prevent contact with the faceplate.
5. Replace the faceplate and secure with the four screws.

![Figure 2b. Remove faceplate screws.]

![Figure 2c. Remove faceplate.]

![Figure 2d. Cut the Regulation Select wire loop.]

3.3 Mounting

**CAUTION:** Equipment Damage or Risk of Explosion
Never install the SunSaver in an enclosure with wetted/flooded batteries. Battery fumes are flammable and will corrode and destroy the SunSaver circuits.

**CAUTION:** Equipment Damage
When installing the SunSaver in an enclosure, ensure sufficient ventilation. Installation in a sealed enclosure will lead to over-heating and a decreased product lifespan.

**PRUDENCE:** Endommagement de l'équipement
N'installez jamais le SunSaver dans une enceinte avec des batteries à densité électrolyte liquide. Les vapeurs des batteries sont inflammables et corroderont et détruiront les circuits du SunSaver.

**PRUDENCE:** Endommagement de l'équipement
Assurez-vous que la ventilation suffit en cas d'installation du SunSaver dans une enceinte. L'installation dans une enceinte hermétique entraîne une surchauffe et une réduction de la durée de vie du produit.

**Step 1: Choose Mounting Location**
Locate the SunSaver on a vertical surface protected from direct sun, high temperatures, and water. The unit should be located at the same ambient temperature as the battery. Locate the controller within 10 ft. (3 m) of the battery bank. Mounting the controller on a horizontal surface does not provide optimal airflow and could lead to overheating.

**Step 2: Check for Clearance**
Place the SunSaver in the location where it will be mounted. Verify that there is sufficient room to run wires and that there is ample room above and below the controller for airflow.

3.4 Wiring

**NOTE:** A recommended connection order has been provided for maximum safety during installation.
- The controller will not be damaged regardless of the sequence of connections.

**NOTE:** The SunSaver is a negative ground controller. Any combination of negative connections can be earth grounded as required. Grounding is recommended, but not required for correct operation.

**NOTE:** To comply with the NEC, the SunSaver must be installed using wiring methods in accordance with Articles 690 of the latest edition of the National Electric Code, NFPA 70.

**NOTE:** The total current draw of all system loads connected to the SunSaver LOAD terminals cannot exceed the controller's load current rating.

**NOTE:** For mobile applications, be sure to secure all wiring. Use cable clamps to prevent cables from bouncing when the vehicle is in motion. Unsecured cables create loose and sensitive connections which may lead to excessive heating or failure.

**WARNING:** EXPLOSION HAZARD - DO NOT DISCONNECT WHILE G&R/CIRCUIT IS LIVE UNLESS AREA IS KNOWN TO BE NON-HAZARDOUS.

**AVERTISSEMENT:** RISQUE D'EXPLOSION. NE PAS DÉBRANCHE MÊME QUE LE CIRCUIT EST SOUS TENSION, A MOINS QUE NE S'AISSE D'UN EMPLACEMENT NON DANGEREUX.

**Step 1: Load Wiring**
The SunSaver load output connection will provide battery voltage to system loads such as lights, pumps, motors, and electronic devices. See Section 4.3 Load Control Information for more details about load control.

![Image of load wiring](image-url)

**Step 2: Connect Load**
Connect load positive (+) and negative (-) load wires to the system load(s) or load distribution panel as shown in figure 4. Refer to the wire gauge chart on page 30 of this manual for correct wire size. Use 75°C copper wire.

If required, the negative load connection may be earth grounded. Use appropriate gauge wire and proper grounding methods for the installation site.

An in-line fuse holder should be wired in series in the load positive (+) wire as shown. DO NOT INSERT A Fuse AT THIS TIME. A circuit breaker may be used in lieu of a fuse. Keep the breaker in the open (disconnected) position at this time.

If wiring the load connection to a distribution panel, each load circuit should be fused separately. The total load draw should not exceed the the SunSaver's maximum load rating.
Step 2: Battery Wiring

WARNING: Shock Hazard
Fuses, circuit breakers, and disconnect switches should never open grounded system conductors. Only GFCI devices are permitted to disconnect grounded conductors.

AVERTISSEMENT: Risque de décharge électrique
Les fusibles, coupe-circuits ou interrupteurs ne doivent jamais ouvrir les conducteurs du système mis à la terre. Seuls les dispositifs GFCI sont autorisés à déconnecter les conducteurs reliés mis à la terre.

The nominal battery voltage must match the SunSaver voltage rating. For 12 V SunSaver models, only a 12 V battery may be used. Connect only 24 V batteries (or two 12 V batteries in series) to 24 V SunSaver models.

Before connecting the battery, measure the battery voltage. Battery voltage must be greater than 6 volts to power the SunSaver (12V or 24V models).

Connect the battery to the SunSaver. Refer to the wire gauge chart on page 30 of this manual for correct wire size. Use 75 °C copper wire.

If required, the negative battery connection may be earth grounded. Use appropriate gauge wire and proper grounding methods for the installation site.

Wire an in-line fuse holder no more than 6 inches (150 mm) from the battery positive terminal. DO NOT INSERT A FUSE AT THIS TIME. A circuit breaker may be used in lieu of a fuse. Keep the breaker in the open (disconnected) position at this time.

Step 3: Solar Wiring

WARNING: Shock Hazard
The solar PV array can produce open-circuit voltages in excess of 40 Vdc when in sunlight. Verify that the solar input breaker or disconnect has been opened (disconnected) before installing the system wires.

AVERTISSEMENT: Risque du décharge électrique
Le niveau PV solaire peut produire des tensions de circuit ouvert supérieures à 40 Vcc à la lumière du soleil. Vérifiez que le coupe-circuit ou l’interrupteur d’entrée solaire a été ouvert (désconnecté) avant d’installer les câbles du système.

The nominal solar module voltage must match the SunSaver voltage rating. For 12 V SunSaver models, only a 12 V nominal solar module having a maximum open circuit voltage of 30 V may be used. Connect only 24V nominal solar modules (or two 12V arrays in series) to 24V SunSaver models. The maximum open circuit voltage of the 24V array must be less than 60V.

Connect the solar module(s) to the SunSaver. Refer to the wire gauge chart on page 30 of this manual for correct wire size. Use 75 °C copper wire.

If required, the negative solar connection may be earth grounded. Use appropriate gauge wire and proper grounding methods for the installation site.

Step 4: Confirm Wiring

Re-check the wiring in steps 1 through 3. Confirm correct polarity at each connection. Verify that all seven (7) SunSaver power terminals are tightened.

Step 5: Install the Terminal Cover

The terminal cover prevents contact with the power terminals when energized. UL / ETL Listed systems must install the terminal cover. The terminal cover installation is optional for systems that are not listed to UL / ETL.

Begin by removing the two (2) lower faceplate screws as shown in figure 8a. Set the screws aside.
4.0 Operation

4.1 LED Indications

STATUS LED

The Status LED indicates charging status and any existing solar input error conditions. The Status LED is on when charging during the day and off at night. The Status LED will flash red whenever an error condition(s) exists. Table 2 lists the Status LED indications.

<table>
<thead>
<tr>
<th>Color</th>
<th>Indication</th>
<th>Operating State</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Off (with heartbeat)</td>
<td>Night</td>
</tr>
<tr>
<td>Green</td>
<td>On Solid</td>
<td>Charging</td>
</tr>
<tr>
<td>Red</td>
<td>Flashing</td>
<td>Error</td>
</tr>
<tr>
<td>Red</td>
<td>On Solid</td>
<td>Critical Error</td>
</tr>
</tbody>
</table>

1 Status LED heartbeat indication flickers ON briefly every 5 seconds
2 Status LED heartbeat indication flickers OFF briefly every 5 seconds

For more information on Status LED errors, see Section 5.1 Error Indications.

BATTERY SOC LEDs

Three (3) battery “state of charge” (SOC) LEDs indicate the level of charge on the battery. The SOC indication is based only on battery voltage setpoints, which only provides an approximation of the actual state of charge of the battery. Table 3 lists the SOC LED indications.

<table>
<thead>
<tr>
<th>SOC LED</th>
<th>Indication</th>
<th>Battery Status</th>
<th>Load Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>Fast Flashing (2 Flash / sec)</td>
<td>Full Battery: Equalize Charge</td>
<td>Load On</td>
</tr>
<tr>
<td>Green</td>
<td>Med. Flashing (1 Flash / sec)</td>
<td>Full Battery: Absorption Charge</td>
<td>Load On</td>
</tr>
<tr>
<td>Green</td>
<td>Slow Flashing (1 Flash / sec)</td>
<td>Full Battery: Float Charge</td>
<td>Load On</td>
</tr>
<tr>
<td>Green</td>
<td>On solid</td>
<td>Battery Nearly Full</td>
<td>Load On</td>
</tr>
<tr>
<td>Yellow</td>
<td>On solid</td>
<td>Battery Half Full</td>
<td>Load On</td>
</tr>
<tr>
<td>Red</td>
<td>Flashing (1 Flash / sec)</td>
<td>Battery Low</td>
<td>Load On</td>
</tr>
<tr>
<td>Red</td>
<td>On solid</td>
<td>Battery Missing</td>
<td>Load Off</td>
</tr>
<tr>
<td>None</td>
<td>No LEDs On</td>
<td>Battery Missing</td>
<td>Load Off</td>
</tr>
</tbody>
</table>

Table 3. Battery SOC LED definitions

NOTE: An error condition exists if multiple Battery SOC LEDs are flashing. See Section 5.1 Error Indications for more information.
4.2 Battery Charging Information

The SunSaver has a 4-stage battery charging algorithm for rapid, efficient, and safe battery charging. Figure 9 shows the sequence of the stages.

![SunSaver charging algorithm](image)

**Bulk Charge**
In this stage, the battery voltage has not yet reached absorption voltage and 100% of available solar power is used to recharge the battery.

**Absorption**
When the battery has recharged to the Absorption voltage setpoint, constant-voltage regulation is used to prevent heating and excessive battery gassing.

**Float**
After the battery is fully charged the SunSaver reduces the battery voltage to a float charge which is sometimes called a trickle charge. Depending on battery history, the battery remains in the absorption stage for 3 or 4 hours before transitioning to the float stage.

**Equalize (flooded battery type only)**
The SunSaver will equalize a flooded battery for three (3) hours every 28 days. Equalize charging raises the battery voltage above the standard absorption voltage so that the electrolyte gasses. This process prevents electrolyte stratification and equalizes the individual cell voltages within the battery.

**WARNING:** Risk of Explosion
Equalizing vented batteries produces explosive gases. The battery bank must be properly ventilated.

**CAUTION:** Equipment Damage
Excessive overcharging and gassing too vigorously can damage the battery plates and cause shedding of active material from the plates. An equalization that is too high or for too long can be damaging. Review the requirements for the particular battery being used in your system.

**AVERTISSEMENT:** Risque d’explosion
Les batteries à ventilation produisent des gaz explosifs. Le groupe de batteries doit être correctement ventilé.

**PRUDENCE:** Endommagement de l’équipement
Une surcharge excessive et un dégagement excessif trop vigoureux peuvent endommager les plaques des batteries et provoquer l’élimination du matériau sur les plaques. Une compensation trop élevée ou trop longue peut provoquer des dégâts. Examinez les exigences pour la batterie particulière utilisée dans votre système.

**Dead Battery Charging**
The SunSaver has a special charging function to recover batteries that have discharged too low. If the terminal voltage of the battery is greater than 1 Volt, the SunSaver will detect the battery and provide approximately 85% of available charge current until the battery reaches the minimum operating voltage of the controller. When the battery has recharged to the minimum operating voltage of the SunSaver, 100% of available charge current will flow to the battery and normal operation will resume.

4.3 Load Control Information

The primary purpose of the load control function is to disconnect system loads when the battery has discharged to a low state of charge and reconnect system loads when the battery is sufficiently recharged. System loads may be lights, pumps, motors, DC appliances, and other electronic devices. The total current draw of all loads must not exceed the SunSaver maximum load rating.

**NOTE:** Do not wire an AC inverter of any size to the load terminals of the SunSaver. Damage to the load control circuit may result. Connect inverters directly to the battery or battery bank.

**Load Control Settings**
Load control is fully automatic. The load will be disconnected and reconnected based upon the Low Voltage Disconnect (LVD) and Low Voltage Reconnect (LVR) voltage thresholds. The LVD and LVR thresholds are listed in the back of the manual.

**LVD Warning**
As the battery discharges the Battery Status LEDs will transition from green to yellow and then from yellow to flashing red. The flashing red indication is a warning that a low voltage disconnect event will occur soon. The amount of time between a green SOC indication and load disconnect will depend on many factors including:
- rate of discharge (amount of load draw)
- capacity of the battery
- health of the battery
- LVD setpoint

If the battery discharges to the LVD setpoint the load will disconnect and a solid red Battery Status LED indication will be displayed.

**General Load Control Notes**
- Only SS-6L/10L/20L models provide load control.
- A 15 V maximum regulation voltage limit (30 V @ 24 V nominal) exists for all battery types. This limit ensures that the battery and load terminal voltages will never exceed 15 V / 30 V. This protects certain DC loads that may be damaged by high input voltage.
- The load connection is NOT a regulated voltage output. The load terminal voltage is approximately the same as battery voltage unless the controller is in LVD condition (load turned off).
- Do not wire multiple SunSaver load outputs together in parallel to power DC loads with a current draw greater than the lowest rated controller's maximum load rating. Equal current sharing cannot be guaranteed and an over-load condition will likely occur on one or more controllers.
- Exercise caution when connecting loads with specific polarity to a live load circuit. A reverse polarity connection may damage the load. Always re-check load connections before applying power.
- The SunSaver will go straight to LVD on start-up if the battery voltage is at or below 11.7V / 23.4V.
4.4 Protections

Solar Overload
(Charging Status LED: Red flashing) If the solar current exceeds the maximum solar rating, the SunSaver will stop charging until the solar current returns to within its operational rating. See Section 7.0 Technical Specifications for more information.

Load Overload
(Battery Status LEDs: G&R - Y sequencing) If the load current exceeds the maximum load current rating, the SunSaver will disconnect the load.

The SunSaver will attempt to reconnect the load two (2) times approximately 10 seconds apart. If the overload remains after the first two (2) attempts, the fault must be cleared by removing and reapplying power.

Solar Short Circuit
(Charging Status LED: off) Solar input power wires are short-circuited. Charging automatically resumes when the short is cleared.

Load Short Circuit
(Battery Status LEDs: G&R - Y sequencing) Fully protected against load wiring short-circuits. After two (2) automatic load reconnect attempts (10 seconds apart), the fault must be cleared by removing and reapplying power.

PV Reverse Polarity
(Charging Status LED: off) Fully protected against reverse solar connection. No damage to the controller will result. Correct the mistake to resume normal operation.

Battery Reverse Polarity
(Battery Status LED: G&R - Y) Fully protected against reverse battery connection. No damage to the controller will result. Correct the mistake to resume normal operation.

Damaged Local Temperature Sensor
(Battery Status LED: R - Y - G sequencing, Charge Status LED: R on solid) The local ambient temperature sensor is short-circuited or damaged. Charging stops to avoid over- or under-charging. This is a critical error. Contact your authorized Morningstar dealer for service.

Damaged Internal Temperature Sensor
(Battery Status LED: R - Y - G sequencing, Charge Status LED: R on solid) The internal heatsink temperature sensor is damaged. This is a critical error. Contact your authorized Morningstar dealer for service.

High Temperature
(Battery Status LED: R - Y sequencing) The heatsink temperature has exceeded 85 °C and the solar and load is disconnected. The SunSaver will automatically reconnect when the heatsink cools to 80 °C.

High Voltage Disconnect
(Battery Status LED: R - G sequencing) The battery voltage has exceeded the controller's maximum regulation limit. The solar and load will be disconnected until the battery voltage decreases to the SunSaver's High Voltage Reconnect threshold. See Section 7.0 Technical Specifications for more information.

4.5 Inspection and Maintenance

The following inspections and maintenance tasks are recommended at least two times per year for best controller performance.

- Tighten all terminals. Inspect for loose, broken, or corroded connections.
- Verify that all wire clamps and tie-downs are secure.
- Check that the controller is mounted in a clean, protected environment; free of dirt, insects, nests, and corrosion.
- If applicable, check enclosure ventilation and air flow holes for obstructions.
- Verify LED indication is consistent with the present system conditions.

5.0 Troubleshooting

5.1 Error Indications

Status LED Error Indications

- Solar overload: Flashing Red
- High Voltage Disconnect: Flashing Red
- High Temperature Disconnect: Flashing Red
- Damaged local temp. sensor: Solid Red
- Damaged heatsink temp. sensor: Solid Red
- Damaged input MOSFETs: Solid Red
- Firmware Error: Solid Red

1 - A heartbeat indication flickers the Status LED off briefly every 5 seconds. A solid red Status LED indicates that a critical fault has been detected. Critical faults typically indicate that the controller is damaged and requires service.

Battery Status LED Error Indications

- High Voltage Disconnect: R - G Sequencing
- High Temperature Disconnect: R - Y Sequencing
- External Wiring Error: R&G - Y Sequencing
- Load Overcurrent: R&G - Y Sequencing
- Load Short Circuit: R&G - Y Sequencing
- Self-test Error: R - Y - G Sequencing

Note:
LED error indications can be interpreted as follows:

"R - G sequencing" means that the Red LED is on, then the Green LED is on, then Red LED is on...

"R&G - Y sequencing" means that both the Red LED and Green LED are on, then just the Yellow LED is on, then Red and Green LED are on...
5.2 Common Problems

Problem: No LED indications
Solution: With a multi-meter, check the voltage at the Battery terminals on the SunSaver and the Solar terminals on the SunSaver. The solar module must be in good sun and battery voltage must be at least 1 V to power the SunSaver and activate the dead battery charging function.

Problem: The SunSaver is not charging the battery.
Solution: If the Status LED is solid or flashing red, see Section 5.1 Error Indications. If the Status LED is off, measure the voltage across the Solar input terminals of the SunSaver. Input voltage must be greater than battery voltage. Check fuses and solar wiring connections. The solar module must be in full natural sunlight.

Problem: No load output
Solution: If the battery status indication is Solid Red, the SunSaver is in the Low Voltage Disconnect (LVD) condition. The load will automatically switch on when the battery recharges to the Low Voltage Reconnect (LVR) threshold voltage. See the specifications in section 7.0 for LVD & LVR settings.

NOTE: If the SunSaver model is SS-6-12V or SS-10-12V (no load control feature), the controller may be damaged.

Full testing documentation is available on our website at:

http://support.morningscorp.com/

6.0 Warranty

The SunSaver charge controller is warranted to be free from defects in material and workmanship for a period of FIVE (5) years from the date of shipment to the original end user. Morningstar will, at its option, repair or replace any such defective products.

CLAIM PROCEDURE

Before requesting warranty service, check the Operator’s Manual to be certain that there is a problem with the controller. Return the defective product to your authorized Morningstar distributor with shipping charges prepaid. Provide proof of date and place of purchase.

To obtain service under this warranty, the returned products must include the model, serial number, detailed reason for the failure, the module type, array size, type of batteries and system loads. This information is critical to a rapid response to your warranty claim.

Morningstar will pay the return shipping charges if the repairs are covered by the warranty.

WARRANTY EXCLUSIONS AND LIMITATIONS

This warranty does not apply under the following conditions:
- Damage by accident, negligence, abuse or improper use.
- PV or load currents exceeding the ratings of the product.
- Unauthorized product modification or attempts repair.
- Damage occurring during shipment.

THE WARRANTY AND REMEDIES SET FORTH ABOVE ARE EXCLUSIVE AND IN LIEU OF ALL OTHERS, EXPRESS OR IMPLIED. MORNINGSTAR SPECIFICALLY DISCLAIMS ANY AND ALL IMPLIED WARRANTIES INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Morningstar is not responsible for incidental or consequential damages of any kind, including but not limited to lost profits, downtime, goodwill or damage to equipment or property.

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Newtown, PA 19460 USA  
Email: info@morningscorp.com  
Website: www.morningscorp.com

7.0 Technical Specifications

Electrical

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal system voltage</td>
<td>12 V or 24 Vdc</td>
</tr>
<tr>
<td>Max. solar input voltage</td>
<td>30 V or 60 V</td>
</tr>
<tr>
<td>Max. solar current</td>
<td>6.5 A or 10 A or 20 A</td>
</tr>
<tr>
<td>Battery voltage range</td>
<td>6 V – 15 V or 30 V</td>
</tr>
<tr>
<td>Self-consumption</td>
<td>&lt; 8 mA</td>
</tr>
<tr>
<td>Voltage Accuracy</td>
<td>1.0%</td>
</tr>
<tr>
<td>Transient Surge Protection</td>
<td>1500 S per connection</td>
</tr>
</tbody>
</table>

Protections (Solar & Load): short circuit, over-current, reverse polarity, high temperature, high voltage

Battery Charging

| Regulation Method          | 4 stage PWM                          |
| Temp. Compensation Coefficient | 12 V - 30 mV / °C                   |
| Temp. Compensation Range   | -30°C to +60°C                       |
| Temp. Compensated Setpoints | Absorption, Float, Equalize         |

Battery Status LEDs

<table>
<thead>
<tr>
<th>LED State</th>
<th>Falling V</th>
<th>Rising V</th>
</tr>
</thead>
<tbody>
<tr>
<td>G to Y</td>
<td>12.1</td>
<td>13.1</td>
</tr>
<tr>
<td>Y to Flash</td>
<td>11.7</td>
<td>11.8</td>
</tr>
<tr>
<td>Flash R to</td>
<td>11.5</td>
<td>12.6</td>
</tr>
<tr>
<td>R to Y</td>
<td>12.1</td>
<td>13.1</td>
</tr>
</tbody>
</table>

Note: Multiply x2 for 24 Volt systems.

Battery Setpoints (@ 25°C)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sealed 12 V or 24 V</th>
<th>Flooded 12 V or 24 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorption Voltage</td>
<td>14.1 V or 28.2 V</td>
<td>14.4 V or 28.8 V</td>
</tr>
<tr>
<td>Absorption Duration</td>
<td>3 hr</td>
<td>3 hr</td>
</tr>
<tr>
<td>Float Voltage</td>
<td>13.7 V or 27.4 V</td>
<td>13.7 V or 27.4 V</td>
</tr>
<tr>
<td>Equalize Voltage</td>
<td>none</td>
<td>14.9 V or 29.8 V</td>
</tr>
<tr>
<td>Equalize Duration</td>
<td>none</td>
<td>3 hrs</td>
</tr>
<tr>
<td>Equalize Calendar</td>
<td>none</td>
<td>28 days</td>
</tr>
</tbody>
</table>

Environmental

<table>
<thead>
<tr>
<th>Condition</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Temperature Range</td>
<td>-40°C to +60°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>-55°C to +60°C</td>
</tr>
<tr>
<td>Humidity</td>
<td>100% N.C.</td>
</tr>
<tr>
<td>Enclosure</td>
<td>IP10 (encased)</td>
</tr>
</tbody>
</table>
Mechanical
Power terminals wire size (max.)
- Solid: #10 AWG / 5 mm²
- Multistrand: #10 AWG / 5 mm²
- Fine strand: #10 AWG / 5 mm²
- Terminal Diameter: 0.210 in / 5.4 mm
- Power terminals torque (max.): 10.6 in-lb / 1.2 Nm
- Dimensions: see inside front cover
- Weight (unpacked): 8 oz / 0.23 kg

Certifications
CSA C22.2#213 Non-incendive Electrical Equipment for Use in Class I, Division 2 Hazardous Locations. 1987/01/03.

EMC Directives
- Immunity: EN61000-6-2:1999
- Emissions: EN55022:1994 with A1 and A3 Class B1
- Safety: EN60335-1 and EN60335-2-29 (battery chargers)

Charts
Fuse Chart
<table>
<thead>
<tr>
<th>Wire Gauge (AWG)</th>
<th>Max. Fuse Size*</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>15 Amps</td>
</tr>
<tr>
<td>12</td>
<td>20 Amps</td>
</tr>
<tr>
<td>10</td>
<td>30 Amps</td>
</tr>
</tbody>
</table>

* per 2011 NEC NFPA 70, Article 240. For copper wire only. Refer to the wire charts on page 41 for appropriate wire size.

12 Volt Nominal Wire Chart

<table>
<thead>
<tr>
<th>amps</th>
<th>One-way Wire Distance (Red)</th>
<th>One-way Wire Distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wire Gauge (AWG)</td>
<td>Wire Gauge (mm²)</td>
</tr>
<tr>
<td>14</td>
<td>13 10 8 6</td>
<td>3.9 3.5 3.0 2.5</td>
</tr>
<tr>
<td>12</td>
<td>11 8 6 5</td>
<td>2.9 2.6 2.2 1.8</td>
</tr>
<tr>
<td>10</td>
<td>9 6 5 4</td>
<td>2.0 1.8 1.6 1.3</td>
</tr>
<tr>
<td>8</td>
<td>7 5 4 3</td>
<td>1.4 1.2 1.0 0.8</td>
</tr>
<tr>
<td>6</td>
<td>5 3 2</td>
<td>0.6 1.0 1.5 2.0</td>
</tr>
<tr>
<td>4</td>
<td>3 2</td>
<td>3.0 3.5 4.0 4.5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>7.0 7.5 8.0 8.5</td>
</tr>
</tbody>
</table>

24 Volt Nominal Wire Chart

<table>
<thead>
<tr>
<th>amps</th>
<th>One-way Wire Distance (Red)</th>
<th>One-way Wire Distance (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wire Gauge (AWG)</td>
<td>Wire Gauge (mm²)</td>
</tr>
<tr>
<td>14</td>
<td>13 10 8 6</td>
<td>3.9 3.5 3.0 2.5</td>
</tr>
<tr>
<td>12</td>
<td>11 8 6 5</td>
<td>2.9 2.6 2.2 1.8</td>
</tr>
<tr>
<td>10</td>
<td>9 6 5 4</td>
<td>2.0 1.8 1.6 1.3</td>
</tr>
<tr>
<td>8</td>
<td>7 5 4 3</td>
<td>1.4 1.2 1.0 0.8</td>
</tr>
<tr>
<td>6</td>
<td>5 3 2</td>
<td>0.6 1.0 1.5 2.0</td>
</tr>
<tr>
<td>4</td>
<td>3 2</td>
<td>3.0 3.5 4.0 4.5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>7.0 7.5 8.0 8.5</td>
</tr>
</tbody>
</table>

Specifications subject to change without notice.
Designed in the U.S.A.
Assembled in Taiwan.
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MS-ZMAN-SS-A v02
Morningstar is pleased to introduce our third generation SunSaver. Since its first market introduction in 1996, over 1 million SunSaver controllers have been installed in over 73 countries for numerous solar power systems including oil/gas, telecom and instrumentation, marine and boating, and remote homes. We have retained much of our legacy design including the same ratings, footprint and simple user interface, and have added several new and advanced high value features:

- Full electronic protections
- 4 stage battery charging
- Self-diagnostics to detect critical faults
- Multi-color status LED
- 3 LED’s for battery state of charge
- Dead battery recovery
- Telecom mode for sensitive loads
- Maximum charge limiting for sensitive loads
- Cover to protect wire terminals
- Additional certifications

**Key Features and Benefits**

- **Extremely High Reliability**
  - Failure rate of less than 1 per 1,000 shipped (<0.1%)
  - 100% solid state. Power MOSFET design
  - Manufactured in an ISO 9000 factory
  - 100% pre-shipment functional testing

- **Longer Battery Life**
  - Advanced PWM charging
  - Series design (not shunt) for cool operation
  - 4-stage charging: bulk, absorption, float, equalize
  - Optimized sealed or flooded battery set points
  - Temperature compensated charging
  - Low voltage load disconnect on several versions

- **Designed for Harsh Environments**
  - Temperature rating of -40°C to +60°C
  - Epoxy encapsulation for protection against humidity and dust ingress
  - Corrosion protection: marine rated terminals and anodized aluminum case
  - Certified for use in hazardous locations

- **Easy to Install and Use**
  - Factory pre-sets result in no required install settings
  - Electronic protections prevent damage from wiring mistakes
  - Fully automatic operation and fault recovery
  - LED’s display about status, faults and battery condition
### SunSave Versions

<table>
<thead>
<tr>
<th>Solar Current</th>
<th>Load Voltage</th>
<th>System Current</th>
<th>LVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS-6-12V</td>
<td>6A</td>
<td>6A</td>
<td>12V No</td>
</tr>
<tr>
<td>SS-6L-12V</td>
<td>6A</td>
<td>6A</td>
<td>12V Yes</td>
</tr>
<tr>
<td>SS-10-12V</td>
<td>10A</td>
<td>10A</td>
<td>12V No</td>
</tr>
<tr>
<td>SS-10L-12V</td>
<td>10A</td>
<td>10A</td>
<td>12V Yes</td>
</tr>
<tr>
<td>SS-10L-24V</td>
<td>10A</td>
<td>10A</td>
<td>24V Yes</td>
</tr>
<tr>
<td>SS-20L-12V</td>
<td>20A</td>
<td>20A</td>
<td>12V Yes</td>
</tr>
<tr>
<td>SS-20L-24V</td>
<td>20A</td>
<td>20A</td>
<td>24V Yes</td>
</tr>
</tbody>
</table>

### Technical Specifications

#### Electrical
- Max. PV and load ratings: Per above 12 or 24 volts
- System voltage: 1 volt
- Min. battery voltage: 12 volt 24 volt
  - Sealed battery: 14.1 V 28.2 V
  - Flooded battery: 14.4 V 28.8 V
- Load disconnect: 11.5 V 23.0 V
- LVD reconnect: 12.6 V 25.2 V
- Max. solar voltage: 12V battery 30 volts
  - 24V battery 60 volts
- Load in-rush capability
  - SunSaver 6: 45 amps
  - SunSaver 10: 65 amps
  - SunSaver 20: 140 amps
- Self-consumption: < 8 mA
- Voltage accuracy: 12V: +/- 25 mV (typical)
  - 24V: +/- 48 mV (typical)
- Transient surge protection: 1500W per connection

#### Mechanical
- Wire size: 5 mm² / #10 AWG
- Weight (unpacked): 0.23kg / 8 oz.
- Dimensions
  - 15.2 x 5.5 x 3.4 cm
  - 6.0 x 2.2 x 1.3 inch

#### Environmental
- Ambient temperature: -40°C to +60°C
- Storage temperature: -55°C to +80°C
- Humidity: 100% non-condensing
- Tropicalization
  - Epoxy encapsulation
  - Marine rated terminals
  - Anodized aluminum case
- SunSave shown with wire terminal cover.

#### Electronic Protections
- Solar: Overload, short-circuit, high voltage
- Load: Overload, short-circuit, high voltage
- Battery: High voltage
- All: Reverse polarity, high temperature, lightning and transient surges
- Reverse current at night

#### Battery Charging
- Charging method: 4 stage series PWM
- Charging stages: Bulk, absorption, float, equalize
- Temperature compensation
  - Coefficient: 12V: -30mV/°C
  - Range: 24V: -60mV/°C
  - Set points: -30°C to +60°C
  - Absorption, float, equalize
- LED Indications
  - Status LED (1): Charging or not charging
  - Battery LED’s (3): Battery error conditions

#### Certifications
- ETL Listed to UL 1741 and CSA C22.2 No. 107.1-01
- Hazardous Locations: Class 1, Division 2, Groups A,B,C,D
- CSA C22.2#213
- EMCDirectives
  - Immunity, emissions, safety
  - FCC
  - CE
- RoHS
- ISO 9000

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