Seametrics

Solar & Battery Power Guidlines

"I bought an expensive deep-cycle battery for my solar system and it only lasted a year."

"The battery went dead after an unusually long period of gray overcast weather and power was lost just when it was needed."

"Lightning struck nearby and now the battery doesn't recharge."

"I just discovered that my solar panel has a bullet hole through it and a year ago the battery and solar panel were stolen."

Fortunately the above occurrences are rare, and in most cases they are easily preventable by proper component selection, installation and maintenance based on an understanding of solar power principles and practice.

This application note explains the causes of solar power problems and provides simple installation and maintenance precautions that will assure that your Seametrics solar powered system will be reliable, trouble-free and achieve low lifetime cost. For most small 12V solar systems, such problems are preventable if you follow the recommendations as described in detail below.

To begin, a solar system consists of the following:
• The solar panel, which is the power source, and its mounting hardware
• The solar charge controller which charges the battery
• The battery, the power storage element
• The device being powered, or load, which for this discussion is a flow sensor or meter and any associated accessories such as remote display
• And, of course, the wiring between these parts

Each of these will be discussed in turn. But first, a precautionary note. Although much of what is discussed below also applies to large solar systems, a large system is far more complex, and what applies to one does not necessarily apply to the other. So this discussion will be limited to systems with small solar panels (5 or 10 Watts) and small loads (less than 50 milliamps average current drain.) Unlike large RV or residential systems no specialized design calculations are needed for Seametrics solar components when used with low or medium power (less than 50 milliamp current requirement) Seametrics products (see Table 1.)

The Seametrics RSP5 components are not intended to power the high power products listed in Table 1. For these products, solar panel and battery sizes are much larger and must be specifically calculated using local meteorological data. Solar panel requirements typically increase to 10 or 25 Watts. Battery size can be estimated using the procedure outlined in footnote 3. However, in all but the sunniest climates, cost may rule out using solar power for these products. Consult a solar system distributor/designer for feasibility.

Table 1 - Power Requirements for Seametrics Products

POWER REQUIREMENT	METER TYPE	AVERAGE EMPTY PIPE CURRENT (Amps)	AVERAGE FULL PIPE CURRENT (Amps)	AVERAGE FULL PIPE CURRENT WITH FLOW (Amps)
LOW	Mechanical Meter with Electronic Rate/Total Indicator*	0.010	0.010	0.010
MEDIUM	AG2000	0.0002	0.0018	0.030
	EX (low power option) with electronic Rate/Total Indicator*	0.016	0.044	0.044
	WMP101	0.0002	0.018	0.018
	WMX101	0.0002	0.0018	0.030
HIGH	EM	0.180	0.180	0.180
	EX (Standard)	0.016	0.250	0.250
	PE	0.150	0.150	0.150

*FT420 with analog output disabled

THE SOLAR PANEL

A 5 Watt solar panel is sufficient for powering the low- and medium-power Seametrics products listed in Table 1 in nearly all cases. In the case of medium-power meters installed at high latitudes, with continuous flow measurement through the winter, long periods of overcast weather or short days, a 10 Watt panel may be required. Remember that solar panels are fragile and especially vulnerable to damage during installation. If located near a road, where possible mount them where other structures will hide the panel or make it less noticeable.

During installation the most important adjustment is to make sure the panel faces due south in the northern hemisphere or due north in the southern hemisphere for maximum solar exposure with minimal shading. Solar panel shading should be avoided for at least the four hours before and after noon. For this type of application at locations below 50 degrees latitude it is not necessary to set the panel angle with respect to horizontal to other than the fixed 45-degree angle provided by the Seametrics RSP5 mounting bracket. (If the flow meter is to be powered through the winter at higher latitudes, system performance may be increased somewhat by pre-bending the bracket (before bolting it to the panel) so the angle to the horizontal equals approximately the latitude plus 15 degrees.)

In areas where there may be dust accumulation it may be necessary to periodically clean the glass surface of the panel if the dust becomes thick enough to reduce incident solar radiation. Likewise, snow and ice build-up may need to be removed if present for more than a few weeks.

The solar panel is best mounted on an electrically grounded metal pole or other structure whose highest point is at least 3 feet above the solar panel. There should be an eight-foot ground rod driven at the base of the structure and electrically bonded to it if there is risk of a lightning strike.

THE SOLAR CHARGE CONTROLLER

The purpose of the solar charge controller is (1) to charge the battery using the electrical energy coming from the solar panel with the most efficiency (least loss of solar energy) and (2) to maximize the useful life of the battery.[1] It cannot be overstated that the wrong choice of solar charge controller for a particular type of application will result in an unreliable system requiring much more frequent replacement of your expensive battery. With a properly selected solar charge controller, you should get five years of useful life from a correctly sized battery except in very hot climates. The only installation requirement is that the charge controller be located so that its temperature matches the battery temperature under all weather conditions to within +/-5 degrees C (+/-9 degrees F) during daylight hours. The most reliable means of accomplishing this is to mount the controller close to the battery and have both shaded from the sun to prevent unequal solar temperature gains. The cooler the battery is kept the longer its life. The solar charger supplied by Seametrics is lightning protected for severe lightning environments.

THE BATTERY

In nearly all solar installations, Lead-Acid batteries provide the lowest life-cycle cost. Good reliability is achievable under all but the hottest climatic conditions. Long battery life, however, requires proper selection, installation and maintenance of the battery.

Battery capacity (the amount of energy a battery can store) is measured in Amp-hours. Under typical conditions, a 20 Amp-hour battery will power a device requiring 1 Amp for 20 hours or 0.5A for 40 hours. To a good approximation, the Amp-hour capacity is the product of the battery discharge current in Amps (consumed by the flowmeter) and the number of hours it takes to fully discharge the battery. That is, Amps x hours = Amp-hours. (This relationship is nominally true for specified conditions but capacity will decrease at higher discharge currents and lower temperatures.) The battery capacity then determines how long the flowmeter will operate under dark and heavy overcast conditions when the solar panel is unable to recharge the battery. For example a 20 Amp-hour battery could power a Seametrics low power mechanical meter consuming 0.010 Amps for 2000 hours (~3 months) with little or no sunlight (since 0.010 Amps x 2000 hours = 20 Amp-hours.)

There are three types of lead-acid batteries from which we may choose. They are differentiated by their engine starting capability (obviously unimportant for flowmeter solar applications), depth-of-discharge (DOD) capability and cost. (Depth-of-discharge is defined as the ratio of the number of Amp-hours a battery has been discharged to its full capacity and is generally expressed as a percent.) Because names for these different battery types are inconsistently used, for our purposes we will refer to them as automotive, Marine/RV and VRSLA (for Valve Regulated Sealed Lead Acid[2].) Their differences are due to variations in the lead plate material and construction to accommodate the battery's primary application. Automotive batteries use porous lead plates to maximize cranking amperes for starting engines and VRSLAs use solid lead (or lead-calcium) to get the best DOD. Marine/RV batteries, a compromise between the other two, have a better DOD than automotive batteries but poorer engine starting ability for the same size. They are often advertised as "deep-cycle" batteries due to their improved DOD, but this can be misleading since their DOD is not nearly as good as VRSLA batteries.

Selecting a battery with a higher DOD in most solar applications allows the use of a smaller battery. For example, for medium power meters in Table 1, the required battery capacity using a VRSLA battery will be only one-fifth of that of an automotive battery for the same battery longevity. The reason is that the longevity of the battery depends on DOD (that is, how "deeply" you discharge it.) If you discharge an automotive battery by more than 10% of its capacity it will incrementally shorten its life each time you discharge more than 10%. How much its life is shortened depends on how much more than 10% you discharge it and how soon and how fast it is recharged after the 10% or greater discharge. For comparison, you can safely discharge a Marine/RV battery by up to 20% without significantly degrading it and for the VRSLA, up to 50%. Unfortunately, a VRSLA battery is much more expensive than the other two types for the same nameplate capacity. Essentially this means that the VRSLA has the most "useable" capacity for solar applications where you need to discharge the battery during extended cloudy periods without shortening its life due to excessive DOD. It also means that the battery choice that gives you the best lifetime cost depends on the DOD actually experienced with the model of meter you are installing in your particular climate.

You can make your own estimate of the optimum battery size (capacity) needed for each type of battery using the method in Appendix A. For most installations, some general battery selection recommendations can be made for the products listed in Table 1. For all but the cloudiest climates or for operation during high-latitude short winter days, a 20-25 Amp-hour VRSLA battery is a good choice for cost and longevity for the low power products in Table 1. In sunny climates a 40-50 Amp-hour automotive or preferably a Marine/RV battery may give the same longevity for less cost. For medium Power products use a 33-40 Amp-hour VRSLA. If you are uncertain, you should do the Appendix A calculation. (Do not substitute flooded deep-cycle marine/RV grade batteries as they will not perform much better than an automotive battery with medium power flowmeters.)

A specialty battery or solar system distributor is a good source for VRSLA batteries. Good quality VRSLA brands include Enersys, Hawker Energy, Panasonic, and Sonnenschein. Your distributor can recommend others besides these. Take advantage of their expertise and recommendations. With comparable batteries (having similar Amp-hour capacities) from the same distributor, a higher price generally means better quality and consequent longer life. Avoid the bottom end of the price range.

NOTE: Use caution when selecting a battery for use with applications using the FT420. Evaluate the application over all anticipated operations and insure the battery voltage does not, at any time, drop below the minimum specified voltage, as this will lead to unreliable operation and possible damage to the unit.

THE LOAD

The load is the device using the power generated by solar panel, in this case, the flow meter or flow sensor and its display (if separate) and other accessories.

WIRING AND INSTALLATION

Extreme temperatures are the enemy of lead-acid batteries. Extended periods of high temperatures (greater than 40 degrees C, 104 degrees F) can greatly shorten battery life. The battery should be installed in a location, which minimizes exposure to extreme hot or cold since both significantly affect battery performance and service life. A ventilated, non-flooding, non-freezing underground location would be ideal, but as a minimum the battery should be shaded from direct sunlight with the solar charge controller mounted close enough to be at nearly the same temperature. Also take measures to prevent moisture from accumulating on the connector surface of the battery due to precipitation that creates a conductive path that could discharge the battery. Similarly, protect against submersion due to flooding for the same reason.

For safety reasons do not install the battery in an electrical equipment enclosure without ventilation since even a sealed battery is capable of venting hydrogen gas, which could ignite if an electrical fault should occur. Also beware of the added temperature rise inside enclosures. If the enclosure is not shaded it should be painted gloss white to reduce the temperature rise due to solar absorption. Even a moderately light color like the standard enclosure ANSI 61 gray can raise the inside temperature by an additional 40 degrees F (22C) compared with only 10F for a white enclosure. The temperature difference due to color alone can shorten battery life by several years, especially in hot climates.

Always fuse the battery as close to the positive terminal as practicable since in the event of short circuited wiring the battery can deliver enough energy to melt insulation and ignite surrounding flammable materials. Use a 1A time-delay fuse installed as close to the positive terminal as practicable. Protect the fuse connections from corrosion using a moisture resistant fuse holder or other means.

Use only wire rated for outdoor sunlight and weather exposure. Connections exposed to weather should use sealed wiring devices such as gel-filled wire nuts. Exposed wiring should be supported at regular intervals to prevent wind and animal damage. Battery connections should be clean and secure to prevent corrosion. Use an anti-corrosion inhibitor on battery terminal connections having dissimilar metals. Be careful to observe polarity when connecting solar panel, load and battery wires.

MAINTENANCE

If the battery is removed for storage, be sure that it is fully charged. Unlike most other types of rechargeable batteries, a stored lead acid battery will deteriorate rapidly if it is left partially discharged. It will also self-discharge rapidly at higher temperatures. A disconnected battery stored in a hot or heated indoor location should be recharged every six months to prevent deterioration.

If the battery is discharged to less than 75% its capacity (25% DOD) it can be damaged by freezing electrolyte. At 50% DOD the battery electrolyte will freeze at -16F (-27C.) For this reason <u>never disconnect the battery from a charging system during the winter unless the load is also disconnected</u> and you assure that it is fully charged.

For automotive and Marine/RV batteries, unless they are of a sealed, “maintenance-free” type, check the electrolyte level at least once per/year.

Where necessary remember to remove snow and clean dust from the solar panel.

CHECKLIST

1. Is solar panel oriented for maximum solar exposure?
2. Has potential solar panel shading been checked, especially for low winter solar angles?
3. Have steps been taken to minimize vandalism (such as reducing panel visibility, raising it above easy reach if visible from road?)
4. Is the metallic structure supporting the solar panel properly earth grounded?
5. Is the solar panel support or other metallic structure sufficiently higher than panel to attract lightning away from solar panel?
6. Does the Solar Charge Controller provide the correct temperature-compensated charging voltage for “standby service”?
7. Is the Solar Charger Controller protected against lightning and overload?
8. Is the battery a recommended type and capacity for the load power requirement?
9. Are the battery and Solar Charge Controller co-located and shaded from the sun to minimize their temperature difference?
10. Have reasonable measures been taken to minimize the battery’s exposure to extreme temperatures for longer life?
11. Are battery and wiring connections safely above high water level in areas that experience periodic flooding?
12. Is the battery terminal surface protected against moisture accumulation from precipitation or irrigation that could discharge the battery?
13. Is the battery properly fused and the fuse holder connections protected against corrosion?
14. If the battery and Solar Charge Controller are located in an enclosure, does the enclosure maximally reflect solar radiation to minimize the temperature rise inside?
15. If the battery and Solar Charge Controller are located in an enclosure, is the enclosure vented?
16. Are exposed wiring materials resistant to the effects of water, sunlight (UV resistance) and temperature extremes?
17. Is exposed wiring protected from animal and wind damage?
18. Are wiring connections protected against corrosion?
19. Are maintenance processes followed to check battery electrolyte for unsealed batteries (at least annually) and replace battery (every 3-6 years) at prescribed intervals as determined by climate?
20. Are processes in place to monitor and clear dust, ice and snow from solar panel glass as necessary?
21. If disconnected for seasonal storage, will the battery be stored fully charged to prevent battery deterioration or freeze damage?

APPENDIX A

For estimating the minimum Amp-hour capacity of the battery for a given climate you can use the following procedure:

- Estimate the maximum number of consecutive winter days (Dmax) for which it is overcast for most of the day (that is, more than half of the daylight hours.)
- During this length of time estimate the fraction of time the flow meter will experience empty pipe conditions and multiply this by the Average Empty Pipe Current (in Amps) for the meter of interest in Table 1.
- During the same length of time estimate the fraction of time the flow meter will experience full pipe, no flow condition and multiply this by the Average Full Pipe Current (in Amps) for the meter of interest in Table 1.
- During the same length of time estimate the fraction of time the flow meter will experience flow conditions and multiply this by the Average Full Pipe Current With Flow (in Amps) for the meter of interest in Table 1.
- Make sure the fractions in the three cases above add up to 1.00.
- Add the three products calculated above to get the Average Current (Iave) for this period.
- Multiply the result by the length of the period in days estimated above (Dmax)
- Multiply this by 24 (the number of hours in a day)
- Divide the result by the maximum allowable depth-of discharge (DODmax) (0.1 for automotive batteries, 0.2 for Marine/RV "deep-cycle" batteries, or 0.5 for non- flooded sealed lead acid batteries.) The result is the estimated minimum Amp- hour capacity for the battery.
- If the flow meter is in the empty pipe condition for more than half of the year (as in some irrigation applications), the above calculation should be repeated for summer, spring and fall and the highest of the four results used to determine battery size.
- The formula for each season is:

  Battery capacity in Amp-hours = (Iave * Dmax * 24)/DODmax

EXAMPLE CALCULATION: An EX meter purchased with the low power option and a Seametrics FT420 remote display consumes 0.016A (from Table 1) when the pipe is empty, which for our example is 75% of the time in the winter. The other 25% of the time it is full pipe, and either flowing or not and using 0.044A. Therefore the average winter current is

(0.75 * 0.016) + (0.25 * 0.044) = 0.023A

The maximum duration of mostly cloudy days is estimated to be 14 and we wish to use a non-flooded SLA battery. Therefore:

Battery capacity (winter) = (0.023 * 14 * 24)/0.5 = 15.4 Amp-hours

Repeating the calculation for summer when the pipe is full all the time and we expect only seven consecutive cloudy days we get:

Battery capacity (summer) = (0.044 * 7 * 24)/0.5 = 14.7 Amp-hours

After also doing the spring and fall calculations (not shown), we conclude that winter requires the highest capacity. To be on the conservative side we size the battery up by 100% and order a 33 Amp-hour battery. One reason for this upsizing is that many assumptions have been made. We haven't taken into account the worst case minimum number of sunny days between cloudy periods and whether the 5 Watt panel will have time to recharge the battery sufficiently in that many days before the next long cloudy period (Think SE Alaska, for example). We haven't accounted for the fact that the battery does not charge or discharge as efficiently in the winter at temperatures below freezing. Furthermore, we may need to leave a depth-of discharge margin so that freezing at very low temperatures doesn't damage the battery. Our calculations allow a maximum DOD of 0.5 (50% discharge) but at this DOD the battery could be damaged if the temperature drops below –16 F (-27C.) A calculation that takes all these factors into account with any accuracy is beyond the scope of this application note. If in doubt, consult Seametrics technical support.

FOOTNOTES

1. The solar charge controller's ability to extend battery life is contingent on its ability to prevent both overcharging, undercharging and "deep cycling" the battery, all of which degrade battery life. In this application the requirements for the solar charge controller are that it (1) be temperature compensated for outdoor use with lead acid batteries, (2) has the correct "float" or finish charge voltage for the type of battery, and (3) is designed for the correct charge/discharge cycling regimen for the load. The charge controller currently sold by Seametrics is temperature compensated at –4.7mV/degree C/cell, a value acceptable for all types of lead acid batteries in this application. The float voltage is 14.1 V. Exceeding this voltage as in some controllers will shorten battery life by overcharging. Overcharging will also occur with multi-step controllers designed for cyclic service, so our controller is specified for standby service to extend battery life for our low power meters. It will work with solar panels up to 50 Watts. It employs series regulation for better efficiency, helping to prevent undercharging, is designed for outdoor applications, has an operating temperature range of –40 to +85 degrees C and is fully lightning protected. The solar charge controller also must also consume as little power as possible for its own use (< 2% of the solar panel's full power output) and cause negligible drain on the battery after dark (leakage current.) Many charge controllers will not be close enough to meeting these requirements to the degree necessary for flowmeter applications.

2. VRSLA batteries are also known as SLA (sealed lead acid) batteries but this confuses them with "maintenance free" automotive or Marine/RV batteries that are also sealed (no caps to add water.) VRSLA batteries are also referred to by the way the electrolyte is contained, such as non-flooded gelled or matted electrolyte ("dry") and flooded ("wet".)

3. Use caution when selecting a battery for use with applications using the FT420. Evaluate the application over all anticipated operations and insure the battery voltage does not, at any time, drop below the minimum specified voltage, as this will lead to unreliable operation and possible damage to the unit.