Sun Wize

Solar Electric Systems – Power Reliability for 24/7 Operation

By John DeBoever

Understanding the load, DC or AC, is essential for solar system reliability. With the variety of applications on the market using solar as the primary power source for remote installations, solar designers need to review critical factors regarding power quality. Let's review those factors.

Determining Continuous Power Demand

Load Configuration

When defining the total load at one site, it is important to specify the power consumption of each piece of equipment being powered (see figure 1). This information provides accurate calculation of the continuous average power demand per day at the site. Missing one piece of equipment will have dramatic consequences. Designers also recommend using more than one source for equipment load information. Manufacturers may not provide information on product data sheets related to normal use. For instance, a manufacturer of a data logger may specify maximum power with all channels under short circuit limit. This is a UL or similar agency requirement to insure correct wire sizing and fusing, representing a correct peak or maximum load, but not the steady state load required for the solar system design.

Operating Voltage

AC or DC Loads & Voltage Tolerance

DC or AC Loads - All solar operates on DC technology. If AC voltage is specified, check with the original equipment manufacturer to see if the equipment will also run on DC power. Since AC is typically rectified to DC in electronics, this will eliminate the need to double convert the power and will reduce the system size. The penalty paid for AC is a 20-30% larger system.

DC Load Voltage Tolerances - While newer equipment accepts a wide voltage tolerance, it is important to check if the load

requires operating at a tighter tolerance (i.e.+/-5%). The battery of a typical solar electric system operates over a range of voltages during discharging and charging modes. For a 12 volt (V) system, as the battery discharges, voltage can drop as low as 11.8V before the system cuts off the load to protect the battery. As the system recharges, the battery voltage can reach as high as 15V. For a 24V system these figures are doubled and for a 48V system quadrupled. This means a nominal 12V system has a voltage tolerance of 12V +/-25%. For equipment with tighter voltage tolerance requirements, the appropriate power solution includes highly efficient DC to DC converters to generate tightly regulated power. Since the DC/DC converter adds losses to the system, the designer takes these losses (typically about 5% to 15%) into account when sizing the system.

Load Duty Cycle

Multi-Stage Operation & Transients or Peaks

Multi-Stage Operation - Some equipment operates on a 24 hour, 7 days per week basis, others cycle on and off. Some equipment such as radios go through multi-stages of operation,

Figure 1 Load Configuration Worksheet

DC LOADS	Voltage VDC	Current (ADC) OR	Power (WATTS)	Duty Cyle 1-100%	Voltage Tolerance %, +/-
Load 1	24		27	75%	N/A
	DESCRIPTION: Radio				
Load 2	12		18	100%	_+10%
	DESCRIPTION: Flow meter /sensor				
Load 3					
	DESCRIPTION:				

each with its own power consumption level, i.e. transmitting (Tx), receiving (Rx) and standby (Sb). This information is critical for accurate calculation of the continuous average power demand per day at the site.

Transients or Peak - When the load cycles on/off, the resulting continuous average power demand per day is smaller than the nominal power rating of the load. The designer considers the average power information for sizing the module array, solar regulation and battery capacity. The transient or peak current is used for the appropriate sizing of electrical circuitries to comply with NEC requirements.

A standard DC system employs the controller's low voltage disconnect (LVD) feature to disconnect the load should the battery reach a low state-of-charge. As a result, the load current capacity for the system is dictated by the controller's LVD current capacity. This is often not an issue as most draw currents are many times smaller than the LVD set point.

However, when the load is designed to cycle on/off, the load transient or peak current may exceed the LVD current capacity. This is typical for pump or motor applications where the motor only operates a few minutes a day, but the operation power is much bigger than the load it represents when averaged over time. The designer can decide to connect the appropriate relays for a pump low voltage disconnect or connect the pump directly to the battery bank. For AC loads, similar considerations must be made if a high inductive load requires a low power factor drive capability.

Correctly Sizing a System

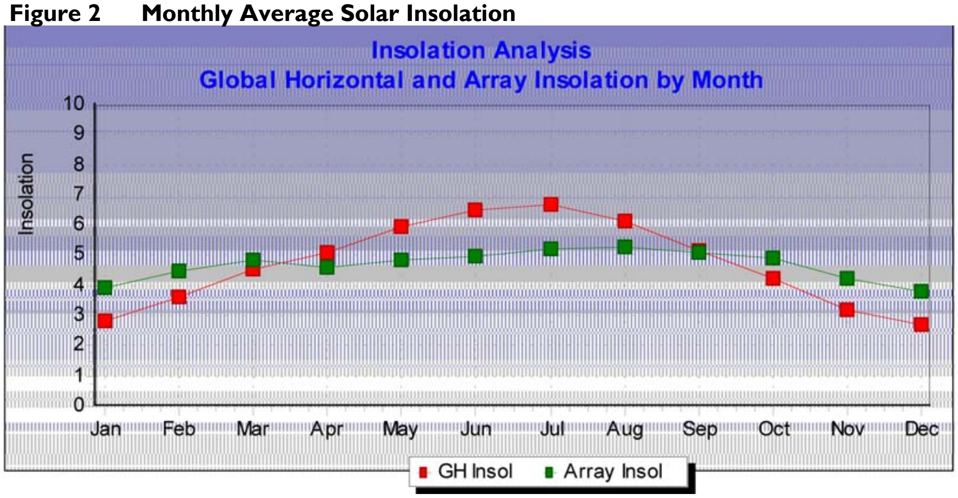
Sizing a solar powered system can be a deceptively complex process. Solar power is derived from the understanding that the system will fail statistically. The experience the solar designer provides is they are able to quantify how and when the system will fail, and provide a reliable design at an acceptable price. The solar designer uses information such as regional weather conditions (i.e. seasonal temperature, sun availability, snow, rain) and the load parameters to plan a system.

Sizing Standards

PV Array - A minimum array to load ratio (ALR) of 1.11—The solar array current depends on monthly average solar insolation (see figure 2). Good design begins with over sizing the solar array current by 11% to compensate for variance in the solar insolation. ALR is the over sizing factor of the solar array current versus load current demand.

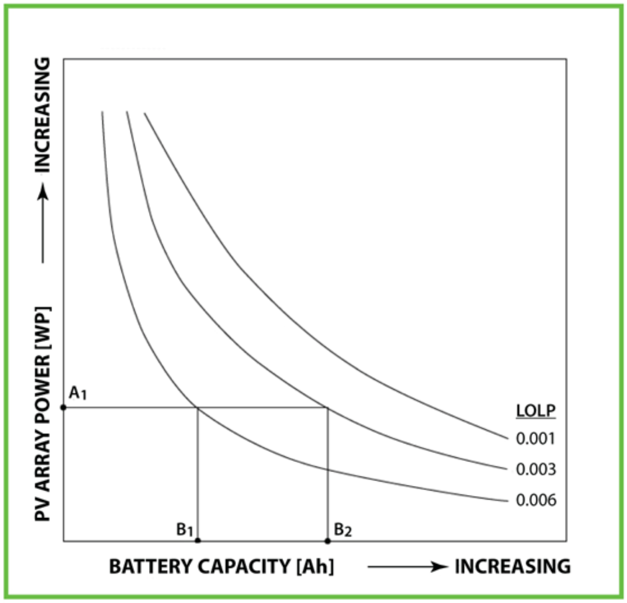
Battery - A minimum battery autonomy of 5-days—Battery capacity depends on monthly average temperature. US manufacturers define nominal battery capacities at 25ºC. Good design begins de-rating battery capacity at 10ºC.

Figure 2 Monthly Average Solar Insolation



Sometimes it is tempting to change one aspect of the system, such as battery capacity. It may be perceived as a benefit to use 3 days instead of 5 to save cost. Changing the battery autonomy to less time will drastically reduce the reliability because solar is not an on demand power source. The battery powers the load through predictable blackout periods (every night) and unpredictable blackout periods (rain or overcast days). A 3-day capacity will cause the battery to cycle too often, shortening battery life.

Figure 3 Loss of Load Probability (LOLP)



Since nature is difficult to predict, the correct capacity is always required to insure reliable performance. Adding more time, 10 days instead of 5, may appear to have true benefit but may not be the case. Since a system is balanced to provide power to the load and power to charge the battery, the 5 days is not an accident. It is required to achieve a minimum of 99.95% yearly average power availability or better when using reasonable array to load ratios.

Adding too much battery without increasing the solar array would lead to a battery that may never be properly charged. Should the battery be needed for seven days or more, it would indeed maintain the load. However, when sun returns, the battery may take too long to fully reach its full optimal charge, resulting in battery degradation. Undercharging a battery is as harmful as overcharging a battery, leading to poor system life.

System Performance

The result is a power supply performance, provided by software analysis, showing yearly power availability (PA). PA is typically better than 99.95% for the entire year. This translates to a probability of less than 1 loss of load every 5 years, also known as Loss of Load Probability (LOLP) (see figure 3).

Installing the System

Good system planning, packaging and documentation eliminate most installation issues. System planning and packaging coordination with the solar designer is critical to installing the system in a timely and organized manner.

- Consider the shelf life of components such as batteries so that the batteries are fully charged when they arrive at the site for installation.
- Maximize energy harvesting by reviewing the shading, tilt angle and directional orientation of the PV array. Shade issues should be taken into account if there are known obstacles such as fences, towers or trees which obstruct a clear view of the sky.
- Make sure the manufacturer provides documentation and pre-assembled subsystems to eliminate wiring issues and to facilitate installation. Factory pre-commissioned controls dramatically reduce site commissioning as well.

As you can see, working closely with the solar designer in the beginning of the design process results in a trouble free system providing years of reliable power.

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