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# A Realistic Take on Solar-Powered Traffic Beacons: Facts not Marketing

by Joseph Wise

Solar-powered traffic systems have been designed and manufactured in many variations since their commercial acceptance. In spite of various designs, the application of solar electric for these projects is an exercise in applied physics. The rules governing the design process have been proven conclusively for several decades.

An article (hereinafter referred to as "the article") by Andrew Evans of JSF ("A Modern Take on Solar Powered Traffic Beacons: Form Leads Function" *IMSA Journal*, July/August 2005, pp 28-30) presented a number of statements which implied these long-standing rules are no longer applicable. I, and many others in the solar community, have read this article and take issue with some of the statements. This article will serve as both a refresher of solar electric basics for Mr. Evans and a rebuttal to "the article."

**Standard solar electric design rules**

Solar power systems must be designed by following a set of design rules. Designing a solar power system is much like figuring out a simple budget: you must manage what goes out (expenses) against income (your paycheck) and the back up from the battery bank (your savings). You need to know three things for effective and reliable solar design:

1. Load: How much power the equipment draws and at what voltage

2. Duty Cycle: How much time each load draws power each day

3. Location: The geographical application site of the equipment

Using the *load* and *duty cycle* data, one can accurately determine the amount of power consumed daily. This value is similar to the kilowatt-hour values listed on your monthly electric bill showing the daily average power used at your home and equals the expense portion of the hypothetical budget.

The third item, *location*, allows the system designer to locate solar data for a particular area of the country. This determines how much solar energy is available at a specific location and is equivalent to the potential "income" available in this budget example.

Using these three values, a designer can determine the size and number of solar modules and batteries needed to provide a reliable system that will last for years. To reinforce these basic ideas, go to the DOE-associated agencies' Web sites for basic solar design details such as NREL or Sandia Labs. More information may be found at solar manufacturers and distributors Web sites listed in my references.

My associates and I – with more than **75** years of solar electric experience – ask: Is it possible a new wrinkle in physics has been found which alleviates the need for these "archaic" methods?

**Customer expectations**

The most common reasons for using a solar-powered beacon rather than a conventional AC-powered system is that the conventional type is too expensive or it takes too long to run AC power to a specific point (Wise, Joseph. "Solar Flashers: An Urban Alternative for Traffic Control" IMSA Journal January/February 2003). Customers' expectations of solar flashers are simple: they must be reliable, they must be as straightforward to apply as an AC beacon and cost no more to operate than an AC beacon.

Consequently, solar electric flashers have been deployed in the field for more than 15 years. Their reliability, and subsequent acceptance, has accelerated over the last 5 years due to the advent of LED lamps and their lower power draw resulting in lower system costs, smaller solar arrays and scaled-down battery banks.

The article claims solar beacons are "...finally meeting traffic engineer's design requirements." They actually have for many years prior to the introduction of any JSF product. As far as the claim of older systems being targets for vandalism, we, at Solar Traffic Controls, receive perhaps three calls annually to support vandalized systems. This is less than 1 percent of the number of systems we sell per year. Some manufacturers report they have had higher rates of vandalism but a great deal of this involves the areas where the equipment is installed: the location being problematic to begin with, not the equipment itself.

**Effectiveness: let there be light!**

Whether solar electric or AC, the effectiveness of flashing beacons is a well-established traffic engineering fact. The article leads the reader to believe that having the flasher solar powered makes it more effective than an AC-powered flasher. This statement is completely false as proven by a Torrance (California) Unified School District fifth grader who won the school science fair award for a study of driver behavior at 4-way stops with and without flashing beacons. It was proven that approximately 10 percent more people came to a full stop at the stop sign with the flashing light than the one without. In this case the light was AC powered.

It is not the power source which makes the light effective, it is the fact that there is a light.  Solar options make it affordable to add the light in situations where an AC connection would be cost prohibitive or time consuming to obtain (Wise, Joseph. "Solar Flashers: An Urban Alternative for Traffic Control" *IMSA Journal* January/February 2003).


*Figure 2: 40W solar flasher system at Phoenix, Arizona VA hospital.*

**Solar Modules: efficiency, tilt and temperature effects**

Solar modules come in various materials generally selected on criteria such as efficiency and costs. Module efficiency is a key factor in the size of a solar module. The more efficient a solar module is in converting sunlight to electrical energy the smaller its surface area.

In my previous article ("Solar Flashers: Solar Module Options" *IMSA Journal*, May/June 2003) crystalline, polycrystalline and thin-film (amorphous) silicon types of off-the-shelf modules were discussed. It was shown that amorphous modules are significantly larger than either of the other two technologies. Off-the-shelf polycrystalline and crystalline modules typically have efficiencies ranging from 12-15 percent. A member of the sales staff at Kyocera Solar recently reported a value of 14.5 percent as average for their production modules.

Pricing for these modules typically ranges around $5 to $7 per watt to end users. Cells with efficiencies of 16 percent have been produced for years. Assembling the cells into modules requires that they be sorted by output to obtain the optimal results in the module design, which is generally a compromise that uses a range of cell efficiencies to obtain the final module efficiency. It is possible, through additional testing and increased cost, to sort these cells by output and realize slightly higher efficiencies for a particular module.

There are other more efficient types of solar materials available as mentioned in the article. One such material is based on gallium arsenide typically used in space applications. According to Alain Chuzel of SunCat Solar, these solar cells routinely have efficiencies above 25 percent. The drawback for the solar electric industry is these cell types have installed costs in the hundreds of dollars per watt! It is true as the article stated that there are a number of new solar technologies with higher efficiencies on the horizon. However, as the article stated, many are years from being commercially viable; so it looks like silicon will continue to be the dominant material with its inherent pros and cons such as reduced voltage output at higher temperatures.

Voltage output degradation at higher temperatures in silicon solar modules is a well-understood physical property that has been compensated for by using enough cells in series to maintain adequate charging voltage output, typically 36 in series. Figure 1A shows the effects of temperature on the output of a 110W solar module. The article, under the section on Temperature Control, makes the statement, “High temperatures also impact solar panels, effectively shutting them down as temperatures soar at midday.” There was some truth to this with certain types of amorphous and self-regulating modules that used 33 cells in series instead of 36. However, all the major solar flasher providers that have been offering systems for the last few years use 36-cell modules.

One thing known to help keep modules cool, thereby maintaining output, is to allow free airflow around the back of the module. Manufacturers offering the so-called “older models” of solar flashers would be at a distinct power advantage over the enclosed modules shown in the article in a high temperature setting. Figure 2 shows one such “older model” solar flasher.

The issue of module tilt angle was also raised in the article as the author indicated recent developments make it unnecessary to tilt modules to increase output. Tilting a solar module allows sunlight to fall more directly onto the cells, thereby allowing more energy to be captured. Figure 1B shows the effects on the output of the solar module at various light levels: The upper curve representing full sun exposure and the lower ones the amount of light available with fewer direct sun angles or overcast conditions where the sunlight is some fraction of the maximum (Wise, Joseph. “Solar Flashers: Too Cloudy for You?” *IMSA Journal*, November/December 2002).

Obviously the less direct the sunlight, the less output from the solar module when equivalent solar materials are compared. Considering that the equipment discussed in the article is at a shallow angle the amount of solar radiation collected during a winter day would be severely impacted, not to mention the reduced ability to shed snow or accumulated dirt from snow plow operations.

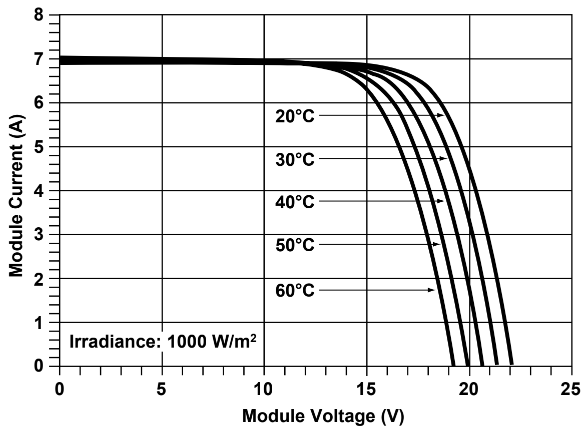



*Figure 1A: Typical 110W module temp curve. Voltage output drops with increasing temperature*

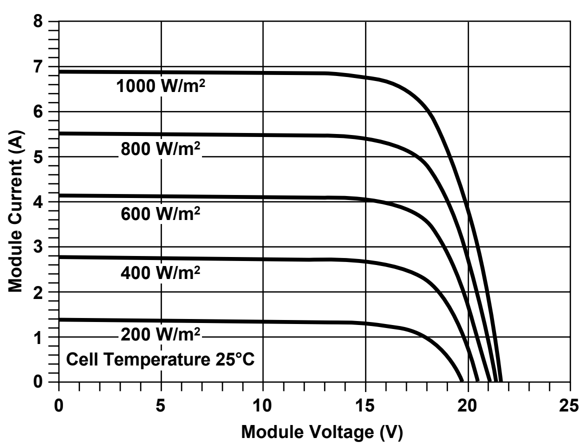



*Figure 1B: Typical 110W current/irradiance. Current output changes with incident light*

**Batteries: backup time, life cycle and temperature effects**

All solar flasher systems run off the battery bank. Some people mistakenly believe these systems run directly from the solar output. A good battery is critical to the success of any system and sealed lead-acid type batteries are the preferred – battery-due to cost and reliability. Autonomy, battery back-up for a project, is ultimately dependent on the weather patterns at the application site including the temperature and the depth of discharge limits set by the designer. The load draw is also important in calculating back-up, and it should be noted that red and amber LED lamps have significantly different power draws.

Before discussing specific claims in the article, it is important to look at key battery data as well as some disclaimers provided by battery manufacturers. Figure 3A is a graph of the number of cycles vs. depth of discharge (DOD). Both figures show that with a shallow DOD a battery experiences a greater the number of cycles. However, some key information must be noted on each diagram. The information for figure 3B shows this is only true for a battery that operates at a fixed temperature of 20C and both stipulate a limit on the discharge rate. All manufacturers are careful to provide disclaimers for battery service life. Enersys, manufacturer of the Cyclon brand of batteries, states in their battery application manual, Section 7.1:

*All batteries have extremely variable service life, depending on the type of cycle, environment and charge to which the cell or battery is subjected during its life. Cyclon products are no exception to this rule.*

Fully recharging the system battery is also an important factor in determining the life of the battery. A battery left in a discharged state for an extended period is subject to loss of capacity. Again the Enersys manual, Section 7.2, Cycle Life, goes on to point out:

*The quality of recharge is a critical determinant of the life of a battery in a given cyclic application. In contrast to float applications where more than adequate time is allowed for a full recharge, in cyclic applications a major concern is whether the batteries are being fully recharged in the time available between discharges.*

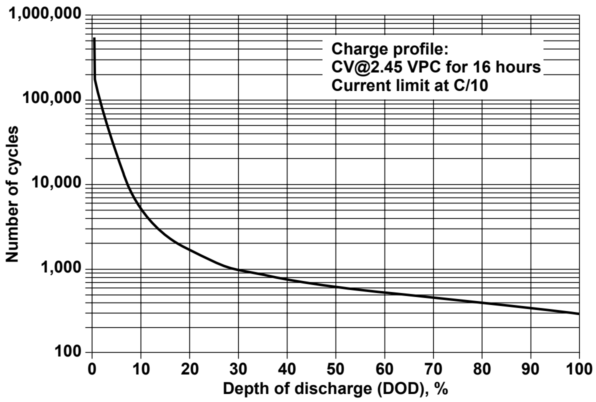
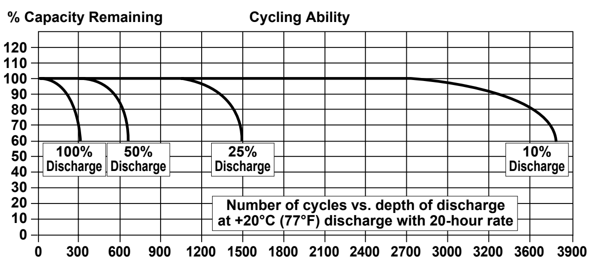



*Figure 3A: Cyclon battery life cycle vs. depth of discharge*




The solar battery excels in cycling applications.

Typical Cycling Performance*

| Capacity Withdrawn | Cycles |
|---|---|
| 100% | 300 |
| 50% | 650 |
| 25% | 1,500 |
| 10% | 3,800 |

*Dependent upon proper charging and ambient temperatures.

*Figure 3B: East Penn Deka series battery discharge cycles vs. depth of discharge*

The article claims that "Modern systems are using sealed lead, 2V, 25-amp hour" cells when in fact only the products coming from two Canadian manufacturers are equipped this way. All other systems on the market use 12V or 6V "car" sized batteries. The argument given for this "modern" design methodology is to hide the batteries in the signal head.

Under the subheading "Temperature Control," the article also makes the claim that the existing designs require heavily insulated enclosures and "solar powered Peletier Effect cooling plates" along with other cooling equipment or "the budget for battery replacement will become prohibitive" implying that existing designs suffer heat issues. This is incorrect and has been proven by both field results and empirical measurements. A former Econolite sales representative once said that the only environment harsher than a traffic cabinet in the Southwest was under the hood of a car in the Southwest. Due to the heat in Arizona most automotive batteries last only three years. Solar flasher batteries are lasting 5 to 6 years in the Southwest and some customers in northern parts of the U. S. have reached 7 years on their batteries.

The article indicates that system batteries are installed inside the closed signal head, which may actually be detrimental due to the lack of ventilation and insulation.[1] Table 1 shows the temperature inside a black 12" signal head and a lightly insulated battery enclosure with venting measured in Phoenix on August 5, 2004. Note that the temperature in the closed signal head was actually higher throughout the day. Both the signal head and the battery box did not have batteries in them for the test and the black signal head did not have a solar module over the top.

| Time | Enclosure | Signal Head |
|---|---|---|
| 11:32 | 117.1 | 125.5 |
| 12:08 | 116.1 | 130.8 |
| 12:16 | 118 | 128.4 |
| 12:28 | 115 | 125 |
| 13:10 | 121.5 | 129.6 |
| 13:55 | 120 | 132 |
| 14:30 | 114.9 | 128.4 |

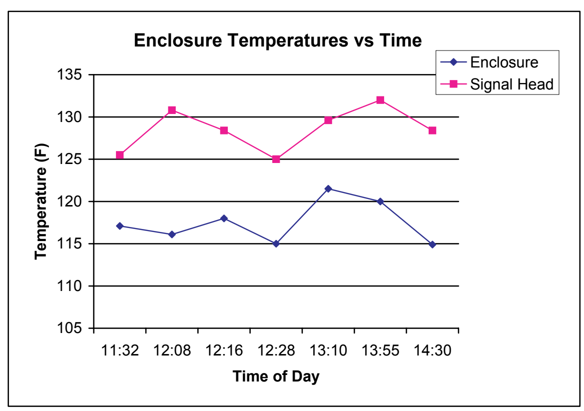



*Table 1: Temperature measurements vs. time, Phoenix, AZ August 5, 2004, clear and sunny with a light breeze*

[1] The ITE Interim LED Specification (replaced by the VTCSH LED Circular Signal Supplement) included a technical note on temperatures inside black signal housings. It concluded that using black signal heads in locations south of 30 degrees latitude and an ambient temperature of 120 degrees F or higher should be approached with caution. It is for this reason that Solar Traffic Controls houses the batteries and electronics for its solar-powered flashing beacons in vented enclosures and not in the signal housings.

**LED Lamps: intensity, control and availability**

It is true that high intensity LEDs have made solar flashers more affordable and reliable. It's also true LED lamps can be dimmed at night reducing the power draw at night by as much as 65% in some lamps without degradation of performance. It should be noted that amber LEDs are less efficient at converting electrical energy to light energy and draw more power than red LEDs. Production DC LED lamps are available from a number of sources such as Gelcore, Dialight, Cooper Lighting and Precision Solar Controls and, while more expensive than AC LED lamps, are still very affordable. Replacement lamps are readily available from a number of U. S. distributors with relatively short lead-times.

The future also looks promising as semiconductor manufacturers find new ways to boost efficiencies in conversion of electrical energy to light energy. However, like solar cell efficiencies, LED efficiency comes with a higher price but continues to decrease with improvements in technology.

One of the key things to be aware of when selecting a DC LED is whether or not it meets the industry guidelines for intensity and viewing angle. Comparisons of lamps from different manufacturers will show that some lamps meet neither. In many cases, lamps are selected solely on price and the power draw that provides the smallest solar power system, not on what industry standards require. In an effort to boost perceived output, some manufacturers will sacrifice viewing angle for a brighter output on center through lensing techniques.

Controls for solar flashers need to be smart but they also need to perform within the MUTCD guidelines for public safety. The 2003 MUTCD, Chapter 4K states that a flashing beacon must "... be flashed at a rate of not less than 50, nor more than 60 flashes per minute" and have an "…illuminated period of not less than one-half and not more than two-thirds of the total cycle." In the latter part of the article, the author indicates that an intelligent system "will adjust the flash brightness and duration so that the beacon continues to function." It is stated that this change is needed to provide a visual warning to "catch the attention of a passing traffic engineer" as well as to prolong system operation.

This condition appears to be based on the battery state-of-charge not necessarily the ambient light, which implies that the flasher may be allowed to run in a mode of operation that contradicts the MUTCD standards for flash rates and also operate with a reduced optical output on a sunny day. Older style systems rely solely on the ambient light levels to determine lamp intensity and duty cycle is not compromised as it is defined by industry guidelines.

**Conclusions**

While improvements to existing technologies and concepts will always take place it is important to ensure that such changes conform to tried and true engineering principles.

When dealing with solar-powered equipment, remember the basics of solar: 1. Load, 2. Location, and 3. Duty Cycle. You must produce enough electrical power from the solar energy resources available to meet your daily energy consumption and allow for a margin of safety. Plan your electrical loads for worst-case scenario not optimistic projections.

Remember the basics for flashers as defined in the MUTCD: 50-60 flashes per minute and not less than one-half the duty cycle for the illuminated period. The fact that a flasher has been added to a traffic situation can be a significant safety enhancement regardless of a power source. Solar-powered flashers can offer a cost effective and expedient option to AC-powered systems to realize the necessary safety enhancement.

Finally, for any solar application, let the electrical load and duty cycle drive the design of the system not a marketing or packaging concept.

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