Innovative energy management and advanced solar modelling techniques for solar-powered aids to navigation systems

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Solar-powered aids to navigation systems
Proven to be very effective in remote marine applications where visibility and durability are vital, the pairing of LEDs with solar power produces a marine navigational aid that offers significant advantages over its grid-tie counterparts. These advantages include improved light quality, durability, flexibility, and cost. When developing self-contained solar-powered aids to navigation, there are several base components to consider, including solar panels, batteries, light emitting diodes (LEDs), lenses, charging/energy management circuitry, and the mechanical enclosure.

Figure 1 illustrates the components of a typical solar-powered aid to navigation. The decisive factor that differentiates solar aids to navigation on the market today involves design and engineering, particularly with regards to energy management.

Considerations for energy management
The primary considerations in sizing solar panels and battery capacity are location, optical output, and flash pattern. Since these parameters are variable, it is vital to incorporate a solar modelling methodology that allows designers and end users to determine if a particular aid to navigation will function to the required specifications in a particular location. For typical aids to navigation that are intended to operate year round in a wide range of geographical locations, proper solar sizing is essential. Accurate sizing ensures that solar-powered aids to navigation meet the wide range of operating specifications while maintaining a lightweight and cost effective design.

The effective radiation (sunlight) incident on the solar panels, and hence the energy collected and stored in the batteries, depends on the geographical location, weather, seasonal insolation variations, and the design of the fixture. It is critical that the energy collected by the solar panels is efficiently stored in a high quality battery that functions as an energy reserve for periods of minimal insolation. The ability to collect and store solar energy also depends on factors such as temperature, solar panel collection efficiency, battery charging efficiency, and degradation of the system components over time.

The energy consumed by the LEDs depends on the specified output, or range, as well as the effective duty cycle or flash pattern chosen. For example, if for a specified output (candela) the LEDs consume 4W of energy in a steady-on state (100 per cent duty cycle), and a repeating flash pattern of 0.5 seconds on, and 2.0 seconds off is selected, then the effective duty cycle becomes 20 per cent. Therefore, the effective energy consumption is 20 per cent of 4W, or 0.8W. Typical aids to navigation require selection of up to 256 flash patterns with duty cycles ranging from five per cent to 50 per cent.

Solar modelling methods
Ideally, solar modelling is used to determine the product performance capability for each specified application. The inputs include location (latitude, longitude), solar panel specifications (current, voltage), battery storage capacity (amp-hours), energy consumed by the light, flash pattern, output (candela) and of course, the solar radiation data for the selected location.

Solar radiation data is available from a number of sources including NASA’s Surface Meteorology and Solar Energy database. This resource provides the 10-year average and minimum daily insolation on a horizontal surface (kWh/m²/day). Using both the 10-year average and 10-year minimum values in the solar model allows the designer to establish safe and reasonable specification limits. For each of the solar panels on the lighting fixture, the horizontal radiation data, combined with the known size and geometry of each solar panel (slope and azimuth), is used to determine the effective energy produced by each panel.

Figure 2 demonstrates the battery performance versus time for use in Portland, ME for a typical marine aid to navigation, such as those produced by Carmanah Technologies Corp. The aid to navigation is set to provide a three nautical mile range with a code 129 flash pattern (30 per cent duty cycle).

As the chart indicates, a portion of the battery charge is depleted each night when the aids to navigations are flashing, and during the day the solar panels fully replenish the battery charge. The exception is during a one month period in December when there is a slight deficit in charging due to fewer sunlight hours during winter months. Despite this solar shortage, the battery has more than enough capacity to withstand this period and fully recovers a full state of charge by January. Figure 3 further illustrates this point.

As Figure 3 reveals, there is a surplus of energy available for all months except December when there is a decline in energy...
storage. Selecting the appropriate solar ‘engine’ size and battery capacity allows navigational aids to function effectively regardless of location or duty cycle.

**Battery performance**

A critical performance factor, directly related to battery capacity, is the autonomy of an aid to navigation. Autonomy involves a straightforward calculation of the number of night time hours the light functions without any solar charging. For example, if the batteries have a fully charged capacity of 50 amp-hours, and the aids to navigation consumes two amp-hours per night, then the rated autonomy is 25 nights. Autonomy is important given that unexpected weather conditions can potentially reduce the effective charging from the solar panels. Temperature and battery degradation over time are also a consideration in autonomy calculations. Typically batteries should be ‘de-rated’ for the average temperature and expected lifetime. The expected operating life depends on several factors including depth of discharge, temperature, and charging method. For operating temperature extremes ranging between -10°C to 35°C, the battery capacity is de-rated to 80 per cent for high quality lead-acid batteries.

A cyclic application is essentially an application where the discharge and recharge of the battery are approximately the same. The cycle life of a battery is defined as the number of cycles a battery delivers before its capacity falls below the acceptable level, usually defined as 80 per cent of rated capacity. The depth of discharge (DOD) is an important variable affecting cycle life. For high quality lead-acid batteries, cycle life expectancy is approximately 300 cycles, assuming 100 per cent DOD. Generally the DOD is very low, with the exception of winter months and also conditional on location and output. For a well designed aid to navigation, the maximum DOD in winter months is approximately 20 to 30 per cent, which yields a life expectancy of at least 1,000 cycles. Therefore, for typical applications, averaging the DOD over time, the battery will last for a minimum of five years.

**Energy management**

Intelligent energy management is critical for optimising overall performance. Using specialised electronics and temperature-compensated charging software, energy management technology optimises the battery charge levels over the course of each day using the available solar power. Carmanah Technologies developed its patented MICROSOURCE™ energy management system to not only maximise product performance capabilities and reliability, but to also extend the battery operating life.

As one of the primary components in Carmanah’s patented MICROSOURCE™ suite of integration technologies, Automatic Light Control (ALC) is a critical innovation for solar-powered LED lighting. This patented technology allows products to ‘read’ solar conditions and automatically adapt to the solar environment where they are installed. This greatly improves performance and reliability while allowing for a reduction in component size and associated cost.

The ALC component of Carmanah’s proprietary MICROSOURCE™ technology uses a control scheme to monitor the charge received by its batteries over the course of the day via the solar panel(s). Through a sophisticated algorithm,
ALC recognises any trend in the battery voltage levels to develop an approximate understanding of its installation location and/or prevailing weather conditions. It then determines if solar conditions are suitable to maintain its current light output, or if it should dynamically adjust its output level to ensure its battery levels will remain optimal for continuous, reliable operation. This self-configuring capability enables Carmanah’s products to operate reliably at nearly any location on earth. As an added feature, ALC modes can be disabled for applications where lowering the light output level is not desirable.

Summary
Solar modelling has become an extremely important tool for designers of aids to navigation. The use of sophisticated solar models permits designers and engineers to quickly determine the performance capability of their products for a wide variety of operating specifications. It is vital that the assumptions made in modelling systems account for environmental effects and aging of all components in the system, with particular attention to battery capacity and life expectancy. The highest quality marine aids to navigation incorporate advanced technology to optimise the solar collection, light output, and battery charging efficiency and lifetime.

With advanced energy management technology readily available and continually improving, users now have the advantage of receiving an analysis of an aid to navigation’s energy management and optical output prior to purchasing an aid to navigation system. This ensures a specific aid meets the user’s requirements with a consideration for the operating location, visibility range, autonomy, and flash patterns required for the application.