CASE STUDY

Ultracapacitors Double Operational Life Of Wave Measurement Buoys

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Introduction

The world's oceans are constantly in motion, and a knowledge of the ocean waves is vital for safe shipping and to understand coastal erosion. Wave measurement and analysis is therefore of great importance.

To measure waves in remote locations or far offshore, the most common solution is to use buoys that contain measuring instruments, a power source, and the means to transmit measurements. Once put in position, it is desirable to be able to leave the buoys unattended with no maintenance for as long as possible, ideally a number of years.This means that the power source, or sources, of the buoy must have an extremely long lifetime, and be completely reliable. Buoys are often deployed in remote locations, and maintenance and service is difficult and expensive. Batteries have traditionally been the main power source, but recently a new solution using ultracapacitors has doubled the battery lifetime.

Powering the buoys

One of the world's leading suppliers of wave measurement buoys is Datawell BV of the Netherlands. Since its introduction in 1968, the company's Waverider (WR) buoy has been recognised as a standard wave data acquisition tool. The more recently-introduced Directional Waverider (DWR) buoy uses three accelerometers to measure wave height and wave direction, and also monitors sea surface temperature.

The buoy tracks its position using techniques based on the Global Positioning System (GPS), and transmits data using a high frequency transmitter at a range of up to 50km. Optional modules allow it to transmit datea via satellite telemetry or GSM mobile phone links.The Waverider has through its development used batteries as its main power source. In the early days there were no reliable alternatives, and work focused on achieving the lowest possible power consumption.

Continuous improvements in electronics have resulted today in a specified power consumption of less than 0.35 watts for a Directional Waverider (DWR) continuously measuring and transmitting wave data. Using primary cells, the 0.9 metre diameter Directional Waverider has an operational life of three years between battery changes and the 0.7-metre version achieves more than one year.

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While solar panels with accompanying rechargeable batteries might seem an obvious choice, until recently this has not been considered to be viable due to the increased vulnerability, complexity and costs associated with such modules.

However, the advantages of solar power are obvious. In sunny climates, solar energy can power a buoy for years without the need to ever change a single battery. In most regions however, while there is an abundance of solar energy during the summer months, the winter season normally provides insufficient recharging capacity.

This seasonal consideration has a major effect on the design of most solar systems for buoys with regards to both solar panels and batteries. The solar panels need to acquire as much energy as possible during low sunshine periods and the rechargeable batteries require sufficient capacity to carry forward the abundant summer energy into the winter period. This generally results in a large, cumbersome and expensive array.

The ultracapacitor solution

To overcome the problems associated with solar power, Datawell developed a triple source, hybrid power option for its Waverider buoy. The power module combines primary batteries, solar cells, and BOOSTCAP® ultracapacitors from Maxwell Technologies.

This approach optimises the solar energy system for the summer time, via the introduction of the ultracapacitors to store energy, and relies mainly on standard primary cells during the winter period. By adopting this hybrid concept the solar panel assembly can be kept small and only a small amount of energy needs to be stored in order to cover the hours of darkness.

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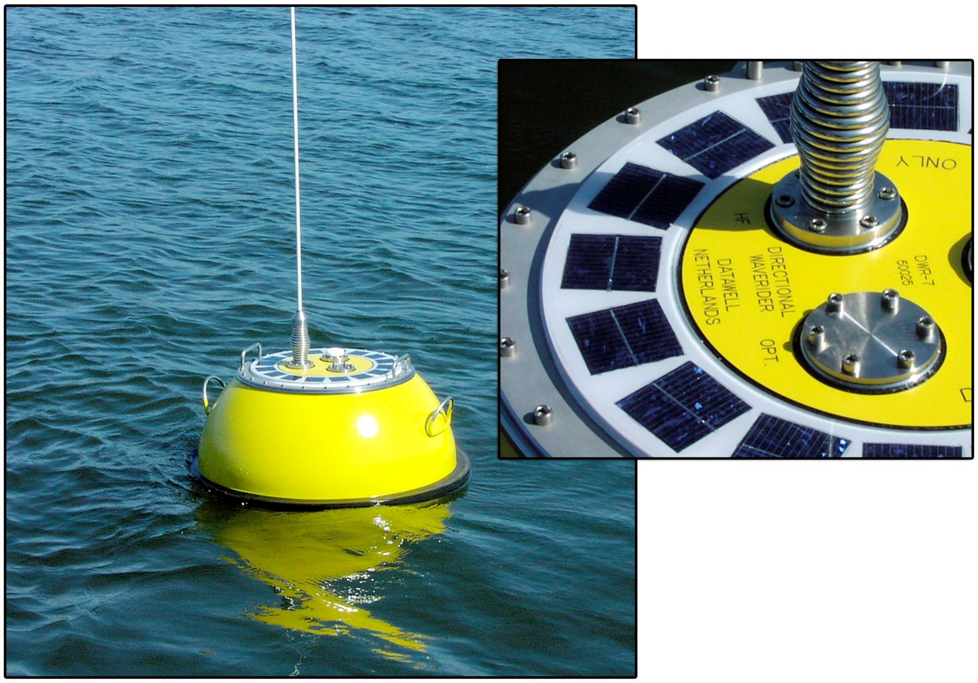

The Waverider buoy, showing the solar cells on top of the stainless steel hatch cover, protected by a layer of polycarbonate.

The advantages are obvious:

- The solar panel can be kept small and positioned in a mechanically safe place.
- The energy storage medium needs to only bridge around twelve hours a day and can thus be based on maintenance free solid state ultracapacitors.

This innovative approach to energy storage effectively eliminates power budget considerations as a factor in determining operational maintenance schedules while surmounting the vulnerabilities and complexities associated with traditional rechargeable battery usage. In particular, the ultracapacitors are not damaged when completely discharged – in contrast to lead acid batteries.

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The complete system

The recent introduction of BOOSTCAP ultracapacitors from Maxwell Technologies opened the door for the hybrid power option. These devices offer a capacity of hundreds of farads (at 2.5V) within a 60-gram cell. Around these ultracapacitors, Datawell has designed a hybrid energy system that combines the reliability and ease of primary cells with the lifetime generation offered by a solar system.

The hybrid energy system consists of three major components:

A dedicated solar panel array supplying energy to the buoy. It has a peak power equal to 15 times the energy consumption of the standard Directional Waverider using HF transmission.

A set of BOOSTCAP ultracapacitors storing, and supplying when needed, the surplus solar energy. The capacity equals the energy used by a Directional Waverider with HF transmission during 12 hours of operation.

Primary batteries for one year of operation of a Directional Waverider with HF transmission.

The primary batteries are used when needed, from day one or during the darker periods of the year, and solar energy is used whenever available. This means that the buoy is always ready for use and the finite energy content of the batteries is extended to a point where it is no longer a limiting factor for maintenance scheduling.

Figure 1 shows in more detail how the hybrid system works. There are three major components that set the Waverider "hybrid power module" apart from a primary cell powered buoy - the solar generator, the storage medium and the electronic power switch. The latter is used to automatically switch between solar

power and battery power in order to save as much battery power as possible. The buoy electronics keep track of the energy used from the primary cells. This information is incorporated within the data transmitted by the Waverider, allowing the user to remotely monitor system performance.

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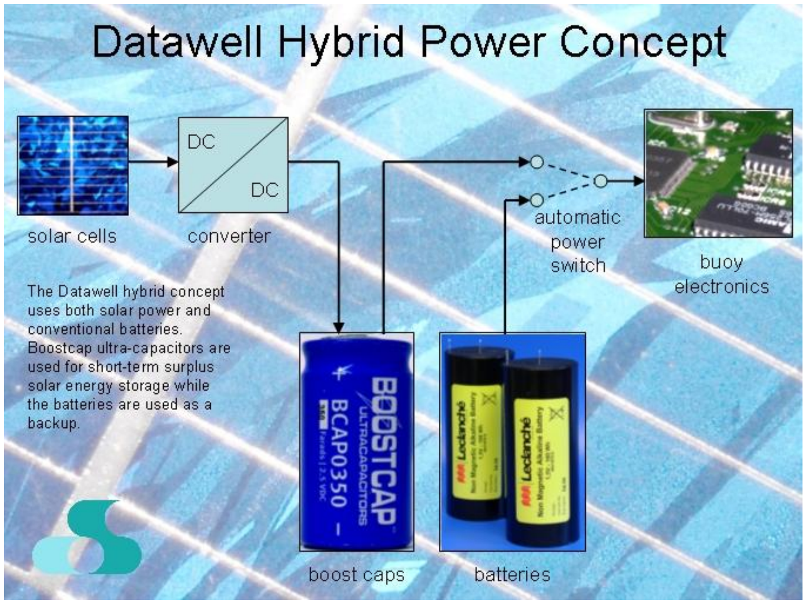
Figure 1. Hybrid power concept.



Solar panel construction

Due to the low power consumption of the Waverider only a small solar panel is required. The array comprises a flat circle of five-centimetre squared solar cells on top of the stainless steel hatch-cover and is protected by a layer of polycarbonate. This rugged construction, fully integrated within the original spherical design of the hull, makes the panel extremely robust. Using only 16 of these small cells, the array generates a peak power of 15 times the continuous power consumption of a Directional Waverider

Datawell has also designed a novel cell configuration to deal with any shadows, obscuring by barnacles or bird deposits, or damage to individual cells. By connecting the cells in a matrix, rather than in series, when any one cell is blocked, current can still flow through the neighbouring cells in the matrix.

Maintenance-free ultracapacitors

An array of ultracapacitors is used to store surplus solar energy during the day. Although the ultracapacitors do not store as much energy as lead-acid batteries, the efficient, low-power design of the Waverider ensures that enough energy can be stored to power the buoy through the night.

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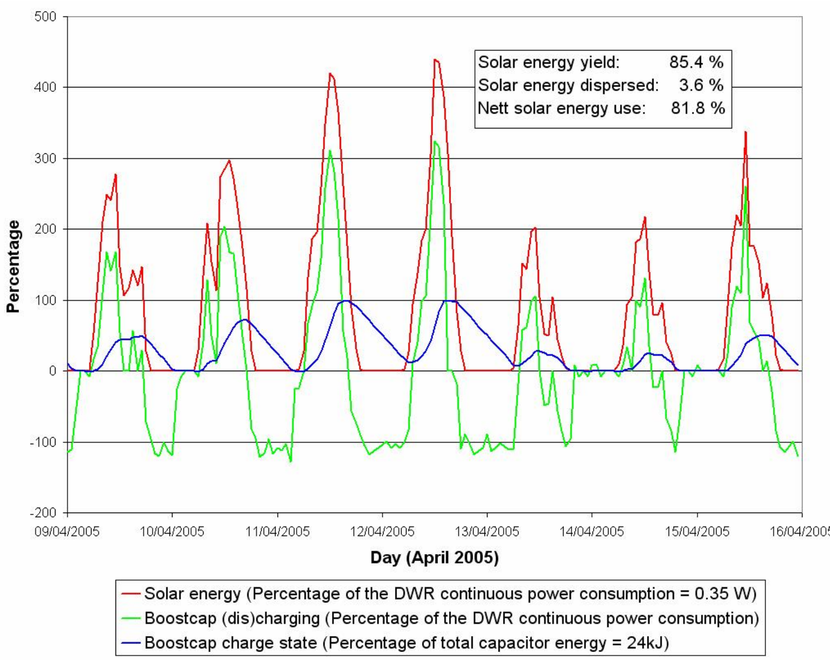
The ultracapacitor is a double-layer capacitor incorporating a metal/carbon electrode and an advanced non-aqueous electrolytic solution. As a potential is applied across the terminals, ions migrate to the high surface area electrodes. The combination of available surface area and proximity to the current collector provide an ultra-high capacitance for this electrostatic process. Unlike a battery, there are no chemical bonds made or broken in the process. The maximum voltage of the ultracapacitors is not temperature-dependent, and since there is no chemical reaction this voltage is not in fact critical. Another important advantage of the ultracapacitors over batteries in this application is their robustness. They are a completely maintenance-free component and can be charged and discharged up to a million times, compared to only a few thousand charging cycles for rechargeable batteries. This makes them ideally suitable for applications at sea.

First experimental results

The purpose of the hybrid power system is to reduce primary battery drainage. A typical result of this strategy can be seen in Figure 2. This data set is from a hybrid powered Waverider in Dutch waters (52°N latitude) during a sunny week in April.

Figure 2.



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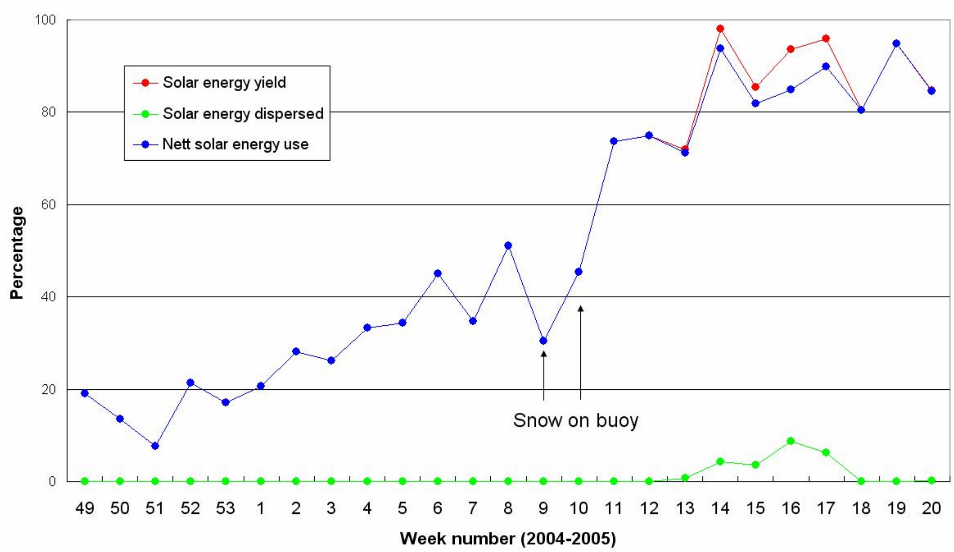
Experimental results of week 15, 2005. Solar energy yield and Boostcap (dis)charging are expressed as a percentage of the DWR continuous power consumption (0.35 watts). Charge state is a percentage of the total capacitor energy (24 kilojoules).

It can be seen that the solar panel produced up to 4.5 times the required power in this spring week. The excess energy was stored in the ultracapacitors and used during the night. Sometimes the ultracapacitors had expired before the sun rose again and sometimes, on better days, they were full before the sun went down and surplus energy was dispersed.

Overall, the Directional Waverider operated during this week for 82 per cent of the time on solar energy and four per cent of the generated solar energy was dispersed. During winter the percentage of solar energy in the total power consumption budget is less favourable, as can be seen in Figure 3. The graph spans a period from November until April (i.e. winter and spring).

Figure 3.



Experimental results from November 2004 until May 2005. All quantities are expressed as percentages of the DWR continuous power consumption (0.35 watts).

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Based on this graph it is estimated that the solar panel array will supply around 30 per cent of the energy consumption of the Directional Waverider during the darkest half of the year. During the rest of the year this figure will rise to 80 per cent. From these numbers, it is safe to say that, on average, battery drainage will be halved and, thus, battery life will be doubled. This doubling of the lifetime of the primary cells is what would be expected in regions with a pronounced difference between summer and winter. In regions with a more constant supply of sunshine (between the tropics) the battery lifetime will increase to an even greater extent.

Conclusion

In conclusion, the Datawell hybrid energy power system, combines the reliability of primary cells with the environmental and financial benefits of solar energy. The design makes no compromises in the important area of buoy design either with respect to vulnerability or functionality of the hatch, hatch cover and antennae. The design is suited for use in all climates and provides a "ready for action" buoy at all times.

This improvement has been made possible by the use of ultracapacitors, and in particular due to their maintenance-free operation and their extremely long lifetime of up to a million cycles. By working together with a primary battery, the ultracapacitors have helped to at least double its lifetime, which means that battery life no longer determines the service interval for the buoy.

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