The Forecast for Battery-Powered Energy Harvesting is Sunny

A real-world example of power generation demonstrates how the combined use of energy harvesting and industrial grade rechargeable Lithium-ion batteries can increase return on investment.

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Across the Industrial Internet of Things (IIoT), there is a growing demand for battery-powered solutions that combine energy harvesting with industrial grade rechargeable Lithium-ion (Li-ion) cells to power two-way wireless communications. This combination is especially important for applications that draw micro-amps of average current—enough to prematurely exhaust a primary lithium battery.

Ashalim Solar Thermal Power Station in Israel's Negev desert supplies 121 MW of clean, renewable energy to meet the daily needs of more than 120,000 households. The power station was constructed by Bright-Source Energy Inc. in partnership with General Electric and the NOY Infrastructure and Energy Investment Fund.

This power station plays a critical role in fulfilling the country's commitment to supplying more than 10% of its total electricity needs using renewable energy. The Ashilim power station features 50,000 flat, sun-tracking mirrors, also known as heliostats, that continually reposition themselves throughout a 3.15-square-kilometer solar field to redirect maximum sunlight towards a solar receiver/boiler sitting atop a 787-foot tower. Each mirror measures 4 x 5.2 meters.

Concentrated sunlight strikes the receiver, heating a transfer fluid to very high temperatures, which is circulated to produce superheated steam of up to 540° C to power a steam turbine or be stored to produce electricity day or night. This concentrated solar power (CSP) station requires a relatively small footprint of just 5-10 acres of land per MW of capacity. Even greater economies of space can be achieved by CSPs that generate 100 MW or more.

The rotation and tilt of each mirror is controlled by a battery-powered dual-axis tracking system capable of 360° positioning. Each heliostat motor is powered by a small battery pack using six TLI Series AA-size industrial-grade rechargeable Li-ion batteries that harvest energy from photovoltaic (PV) panels incorporated into the mirrors. These industrial grade rechargeable Li-ion batteries deliver the high pulses (5A for a AA-size cell) required to power two-way wireless communications for SCADA functionality.

Using Li-ion batteries to wirelessly connect all 50,000 heliostats represents a money-saving solution that eliminates the need for miles of cabling and wiring, resulting in an 85% reduction in such needs versus previous solutions. Wireless networking also sped the pace of construction while improving system reliability.

Why industrial grade Li-ion batteries are required

Due to the extreme environmental conditions of the Negev desert, consumer grade Li-ion rechargeable batteries were unsuitable. Consumer-grade Li-ion cells have severe shortcomings for industrial applications, including a short life expectancy (fewer than five years), a low maximum cycle life (500 full recharge cycles), high annual self-discharge (up to 60% per year), a limited temperature range (0° C to 60° C), and the inability to generate the high pulses required for two-way wireless communications.

Industrial-grade Li-ion batteries can operate for up to 20 years and support 5,000 full recharge cycles. Such extended battery life serves to reduce the total cost of ownership, as a system-wide battery change-out to replace 50,000 consumer-grade batteries every 5 years would be an enormous undertaking, far exceeding any initial savings achieved by using less expensive consumer batteries.

Industrial grade Li-ion cells also offer an extended temperature range (-40° C to 85° C), and feature a precision-welded hermetic seal, whereas consumer-grade batteries use crimped seals that can leak.

Comparing Li-ion batteries to supercapacitors

In determining the ideal power management solution for the Ashalim project, industrial-grade batteries were compared to bulkier supercapacitors (also known as ultra-capacitors or electric double-layer capacitors).

Supercapacitors—which are used to provide memory backup for mobile phones, laptops, digital cameras, and other consumer devices—store energy in an electrostatic field rather than in a chemical state (a process known as pseudocapacitance). Using an electrolyte along with an insulator that is very thin and often made of cardboard or paper means that supercapacitors can only deliver low voltage, as higher voltage requirements would cause the electrolyte to break down. Other drawbacks include short duration power, linear discharge characteristics that do not allow for use of all the available energy, low capacity, and high self-discharge (up to 60% per year). Additionally, when multiple supercapacitors are linked in series, expensive and bulky cell balancing circuits are required that drain additional current.

Supercapacitors are far bulkier than comparable industrial-grade Li-ion batteries. For example, three large packs of supercapacitors consisting of six D-size cells each (or 18 cells total) can be replaced by a much smaller battery pack consisting of six AA-size TLI Series rechargeable Li-ion batteries.

Industrial grade Li-ion battery packs offer additional performance advantages over supercapacitors, including:

- Higher practical capacity: 330 mAh (the equivalent pseudocapacitance is 1200 F). A supercapacitor having the same volume has about 10 F maximum (3.6V).
- Lower self-discharge: 1 to 2uA of self-discharge current compared to 20 to 50uA of discharge current for a supercapacitor having the same external volume. Self-discharge is the normal voltage drop experienced over time when a cell is not subjected to a load. Batteries experience a fairly constant voltage drop over time, while supercapacitors experience a more severe drop in voltage as they discharge stored energy.
- Higher number of cycles: a AA-size Li-ion cell can be charged and discharged for 35,000 cycles between 2.8V and 3.9V (80% depth of discharge).
- Higher cell voltage than a supercapacitor under the high-current pulse needed to power two-way communications for system control.

A concentrated solar power station.