Photos: REAPsystems Ltd.

Dr. John Low, Dr. Doerffel, Researcher Phil Yue Wu and Dr. Carlos Ponce de Leon Albarran discussing test plans on top of the University roof where the solar system is located.

Advancing Li-ion

Lithium-ion batteries: Whether for off-grid applications or for self-consumption micro-grid systems, lithium battery storage technologies have steadily expanded their application scope and efficiency. REAPsystems together with the University of Southampton conducted research on a new version that can potentially increase efficiency and reduce cost.

Today, power utilities in countries like Germany are arguing that the grid is unable to integrate intermittent power generated by solar and wind efficiently. Counter-arguments exist, as SMA Solar Technology's Felix Kever explains, that PV plants "put a relatively small load on the power distribution grid" quoting a survey by the German Solar Industry Association that showed that a "further expansion of PV will not have a significant impact on the German power grid." That aside, the decision makers sitting in parliament still decided not to take 'risks' with the grid.

Hence, all the more reason storage technology needs to step up. Storage technologies can only further enhance the potential of PV power by enabling load shifting, peak shaving and dispatchability.

Companies like BYD, Hitachi Group, Mitsubishi, Saft, Samsung and Sanyo are already part of the growing range of lithium battery suppliers for smart storage solutions. Research is growing in the field as well, not just for conventional off-grid usage but also on-grid solutions, which have recently been growing in importance. Storage becomes a big theme especially when FITs get cut, like in the current scenario in Germany.

Traditional off-grid

Traditionally, lead-acid batteries were the prime choice for off-grid PV applications as a storage means. Lead-acid solutions have been around since the mid-19th century. Despite their long existence

and widespread usage, lead-acid batteries have pretty much remained one of the lowest energy-to-weight and energy-to-volume battery designs. In essence, this means they are too big and heavy for the energy they provide. Their prime advantage is that they are cheaper.

Dennis Doerffel , Founder of REAPsystems Ltd says, "for off-grid systems, energy storage devices (batteries) have been used for many years in conjunction with solar PV. They usually use lead-acid batteries. Lead-acid batteries are proven in these systems and available at a low cost. However, the off-grid systems are a niche application and their numbers are in decline."

The need for storage solutions is growing and lithium-ion (Li-ion) batteries have emerged over the last few years as one of the preferred methods. However, they are more often regarded as the power sources for mobile phones and laptops. Additionally, they are still quite new to the market and price is another issue that comes into play. Li-ion batteries for PV power storage still entail high capital and operating expenditures (CAPEX and OPEX). However, Matthias Vetter of Fraunhofer's Electrical Energy Systems Division tells **pv magazine** that he expects prices of better battery solutions like Li-ion to fall (see **pv magazine** 02/2012, p.p. 78-81).

Different Li-ion options exist in the market right now, in the form of lithium manganese oxide, lithium nickel manganese cobalt and other forms. Whether containerized solutions that are transportable or stationary battery packs, the industry is heading in the right direction with the Li-ion evolution. Doerffel highlights the advantages Li-ion has over, for

LI-ION IN THE FUTURE

Lux Research recently released a report: Grid storage under the microscope: Using local knowledge to forecast global demand. In the report, Lux evaluates application requirements and the price and performance of eight energy storage technologies in 44 countries and all 50 U.S. states. Looking at Li-ion technologies, Lux forecasts Li-ion taking an early lead, capturing 37 percent of the market in 2012, or about 20 GWh of capacity. However, they state that they see the technology losing out to cheaper alternatives long-term. The reasons they cite are cheaper alternatives like flow batteries coming onto the scene.

Lux predicts that Li-ion batteries will only capture 13 percent of the demand by 2017 with the rest occupied by vanadium redox, sodium sulfur, sodium nickel chloride and zinc bromine flow batteries at 33, 19, 15 and 19 percent respectively. This implies a need for Li-ion battery manufacturers to reduce costs.

Lux Research says that Li-ion batteries for transport are energy dense storage options and stationary storage projects rarely value this metric. This leads to wasted value for grid-tied Li-ion storage systems. The lion's share of the grid storage market, therefore, will go to the technologies that manage to integrate lower costs and higher resource availability together in the next few years. Nevertheless, research is on-going intensively in the Li-ion storage solution sector and work is underway to lower the cost of production, and thereby end cost. The research undertaken by REAPsystems and the University of Southampton is one example of working on the enhancement of the Li-ion storage option.

University researcher Phil Yue Wu and Dr. Doerffel of REAPsystems Ltd preparing the Li-ion test battery.

SANDIA NATIONAL LABORATORIES COST AND PERFORMANCE ASSUMPTIONS

Technology (battery type)	Power subsystem cost $/kW	Energy storage sub-system cost $/kW	Round-trip efficiency %	Cycles
Advanced lead-acid	400	330	80	2,000
Sodium/sulfur	350	350	75	3,000
Lead-acid with carbon enhanced electrodes	400	330	75	20,000
Zinc/bromine	400	400	70	3,000
Vanadium redox	400	600	65	5,000
Li-ion (large)	400	600	85	4,000
Flywheels (high speed composite)	600	1,600	95	25,000
Supercapacitators	500	10,000	95	25,000

** The costs in the table are based on certain standard assumptions for the applications and technologies considered, and on expert opinion. They are meant to be used for comparative purposes. The actual costs of any storage system depend on many factors and the assumptions and the means of calculating some of the values are subjective and continue to be debated, even among experts in the field.*

Source: Sandia National Laboratories

example, lead-acid batteries. "The energy is stored and released more efficiently. We have seen charge-discharge efficiencies above 90 percent." Furthermore, he points out the following advantages: Li-ion batteries can remain at any state of charge (SOC) for any length of time without accelerated degradation; the self-discharge rate is very low; the cycle life is very high; there is no hydrogen gassing; they have a high discharge rate capability without sacrificing efficiency as much as lead-acid batteries; they have a lower weight and smaller size.

The research

The University of Southampton and lithium battery technology company REAPsystems worked together on researching the use of lithium batteries as an energy storage solution for PV installations. The research brought to light a new battery type that held the potential to improve efficiency and at the same time, reduce the cost of PV power.

The way the research went about was quite novel. Doerffel tells **pv magazine** that they adopted a systems approach. The researchers from the universities were all from a variety of fields from artificial intelligence to power electronics and this infused well with the practical and commercial expertise of REAPsystems who brought in the experience with large battery systems.

Data was gathered on lithium iron phosphate (LiFePO4) batteries with regards to their storage function coupled with PV. Lead research student from the university Phil Yue Wu says, "lead acid batteries are traditionally the energy storage device used for most photovoltaic systems. However, as an energy storage device, lithium batteries, especially the LiFePO4 batteries we used, have more favorable characteristics."

How this was determined was by collecting the data from a LiFePO4 battery that was connected to a PV system in one of the university buildings using a specially designed REAPsystems battery management system. The research led to the finding that the lithium battery had an energy efficiency of 95 percent while the lead-acid batteries in common use achieve about 80 percent.

REAPsystem's Doerffel further elaborates, "The LiFePO4 type of Li-ion battery specifically offers higher intrinsic safety and lower production cost when com-

pared with other Li-ion battery types. The lithium-titanate (LTO) batteries offer even higher intrinsic safety, very high power capabilities and very high cycle life." He also stressed that these solutions are in the early days in terms of deployment. Moreover, both the LiFePO4 and LTO have some issues that need to ironed out before they are ready for commercial production.

Doerffel lists the following as the challenges:

- The SOC is more difficult to determine than for any other type of Li-ion cell.
- The system cost is still high.
- Lifetime and optimal usage parameters for real-world applications are not very well understood.
- The lifetime cost per kilowatt hour (kWh) is not very well known.

Li-ion batteries, especially LiFePO4 and LTO cells offer high cycling capability. This leads to long life for load leveling and frequency control. Doerffel explains, "This is because the Li-ions are just moving between the positive and negative electrodes and intercalating into electrode material. Theoretically, there are no significant changes to the electrode structures during charging and discharging." This phenomenon is different in lead-acid batteries and gives Li-ion cells the edge over them in terms of higher cycle life – at least three times higher.

REAPsystems also works closely with cell manufacturers who produce the solutions and are the key to lowering costs of energy storage. A performance guarantee of at least 10 years in real applications – maybe even twenty – will provide long-term cost savings, a benefit to end users. "I can see pension funds investing in energy storage devices with LTO cells. However, even for Li-ion cells, this is not easy to achieve and even more difficult to prove. So, this requires research," Doerffel adds.

The aim is to offer scalable energy storage systems. The range, Doerffel says, can range from a small one kilowatt hour system to those that are in excess of one megawatt hour. "There is no real limit to the total battery capacity. However, above a certain size it may be more cost effective to employ other energy storage solutions, such as flow batteries or pumping stations or fuel-cell based solutions," says the REAPsystems founder.

He stresses that the research undertaken is very much applied. "Our aim is not to conduct blue-sky research in order to find a revolutionary energy storage solution. Our aim is to find answers to many smaller questions, which prevent us from making this battery type available and attractive to a wider customer base. There is still a lot of work to do in this exciting field and the industry, including REAPsystems, is looking for enthusiastic, capable engineers and applied researchers."

Hence, it is still too early to write off Li-ion batteries as cost-effective and efficient long-term energy storage solutions in favor of newer emerging technologies. ◆

Habib Ali/ Shamsiah Ali-Oettinger

Lux Research's reports, including the one on Grid storage under the microscope: Using local knowledge to forecast global demand can be found on the website: http://bit.ly/Hr3Jdx.