2UCD401195

Article
Power conditioning - Applications and opportunities for new generation energy storage

New storage technologies and power electronics create opportunities in power protection, renewables, integration and grid support.

Storing electrical energy cheaply and efficiently has always been a vital goal for designers of cars, buses, uninterruptible power supplies, and the alternative energy community. Historically, lead acid batteries have dominated the energy storage market. They are cheap and effective but have many limitations. New generation batteries, such as Lithium-Ion and ultra capacitor energy storage technologies, are providing a breakthrough in cost-effectiveness and efficiency.

Energy can be stored in many ways, such as potential energy in water dams (pumped storage), kinetic energy in flywheels, as heat, chemically and as static charge. Much of the world now runs on electric power and many energy storage challenges involve efficiently and cost effectively converting electrical energy into stored energy. Stored energy must also be converted back to the current and voltage required by the particular load. This is where batteries and ultra capacitors become an attractive option, as they can store energy in the form of direct current (DC). When partnered with power electronics, this DC energy can be converted to the alternating current (AC) that most loads require.

Historically, battery technology has been dominated by lead acid battery designs. In recent decades, significant advances in lead acid battery design have occurred, most particularly in Valve Regulated Sealed Lead Acid (VRLA) designs. These batteries have become relatively cheap and have become the technology of choice for most uninterruptible power supply and other static and dynamic energy storage applications.

Relatively new advances, such as thin plate pure lead designs, have increased power delivery capability and energy density, and have become attractive for many short discharge time applications, typically for one to 15 minutes.

Despite all of the advances in lead acid battery technology and their suitability for many applications, they do have drawbacks, such as:

- Real application lifetimes are relatively short (typically three to 10 years, greatly reduced in environments with elevated temperatures)
- Reliability issues for higher voltage strings with many cells in series. Cell failure impacts on performance and can damage the complete string if not detected and corrected quickly
- Weight, as lead is a very heavy element
- Limited deep cycle performance capability
- High maintenance costs, as regular manual checking of batteries, or even automated checking, results in a relatively high ongoing cost of ownership
- Environmental concerns with lead and associated recycling costs

Despite all of these limitations, VRLA batteries continue to offer low initial capital costs and so will continue to be the technology of choice for most commodity static storage applications, such as UPSs, in the foreseeable future.

The huge commercial push for cost-effective electric cars has seen large-scale investment in new generation battery

LS Mtron ultra capacitor module installed in PCS100 UPS-I Industrial UPSs

A PCS100 UPS-I installation with ultra capacitor storage in a semiconductor facility

designs. Many technologies have shown potential but, at this point variations variants of Lithium-Ion technology are the most promising. With their light weight, good deep cycle performance, good acceptance and high rate discharge performance, and relatively high tolerance to elevated temperature, they tick many of the boxes in areas where VRLA batteries struggle. However, cost continues to be a challenge along with safety – particularly the risk of fire. Fortunately, the scale of demand for Lithium-Ion batteries, due to vehicle manufacture, continues to push costs down and improve safety performance. For other applications, such as demanding static and dynamic energy storage in the one minute to a few hours range, Lithium-Ion batteries are now a very promising technology.

Other interesting battery technologies are also appearing, such as flow batteries. Energy is stored in tanks of electrolyte and passes through cells to charge and discharge. Applications also exist for high power storage in the sub one minute autonomy range, and this is where ultra capacitors come into their own. Rather than storing energy chemically, ultra capacitors use static charge more directly. The advantage is very high peak power capability and round trip efficiency (minimal power loss in the charge/discharge cycle). These capacitors are now available in modular format, including the necessary voltage balancing and protection circuitry, as found in the LS Mtron battery shown in the photo above.

What are the opportunities?

Reduced Autonomy times

UPSs make extensive use of batteries, but the loads and requirements are progressively changing over time. A primary application for larger scale UPSs is within data centers, and the view on what is an acceptable battery autonomy time has changed dramatically. Historically, data center operators typically insisted on autonomy times at UPS full load operation of 30 minutes to one hour. As actual data center loads were much lower than this (typically half) and hold up depended on the real power loading on the batteries, real autonomies were very long. This would allow operators to identify a problem, investigate, and then shut down servers in a timely manner.

Today, data center operators typically expect much shorter autonomies because:

- If back-up diesel generators do not start first or second try, they are unlikely to be started within any reasonable autonomy time
- Applications such as cloud computing and redundant computing configurations have reduced the impact of unplanned power outages
- Cost pressures and space constraints have increased, so there is pressure to reduce battery size
- The real costs of battery ownership and maintenance have become clear and larger battery systems have a larger ongoing cost of ownership
- Many tier three and four data centers have dual redundant reticulated uninterruptible power, with each UPS loaded at significantly less than half loading – often around 25 percent. This means extended full load autonomy specifications are unnecessary

These factors have meant significant cost and space can be saved by selecting a battery designed to supply high levels of power efficiently, typically with a low internal resistance. VRLA pure lead batteries meet this requirement and are cost effective but, as already discussed, there are drawbacks. New generation Lithium-Ion batteries, although having a higher capital cost, offer a much better power density, operational life and tolerance to increased ambient temperature. The increased temperature capability can allow for significant savings in air-conditioning capital and ongoing costs.

Very large mega data centers or large industrial applications,

PCS100 ESS successfully applied with a zinc bromide flow battery at Redflow in Australia

such as semiconductor fabrication plants, are often closely connected to the high voltage transmission grid with high reliability. The more common problems, therefore, are very short outages, such as switching changeovers between redundant feds or very deep voltage sags caused by network faults and weather events. In these cases, autonomies in the order of seconds can be practical, and the reliable and power-dense ultra capacitor technology comes into its own.

ABB have supplied many hundreds of megawatts of ultra capacitor backed industrial grade UPSs with full load autonomies of two to three seconds, and the trend towards this technology is increasing.

Grid Support

There is increasing demand for battery energy storage systems (BESS) for electricity grid support applications. Electrical power can be stored and then supplied back to the grid as needed to support grid frequency, integrate renewables, and offset peak demand or shift demand from day to night. ABB's PCS100 Energy Storage System converters have been widely applied to interface the AC electricity grid to DC Lithium-Ion battery strings.

Not only can ABB's PCS100 ESS product shift real and reactive power to and from the grid on demand, but advanced features allow the power electronic grid interface to look like a virtual generator – much like other more conventional rotating electrical generators as found in power stations. The system can support the grid when connected and even detect grid loss, disconnect from the grid and then continue to support any local loads in island mode. This offers huge potential for advanced micro-grid development, including the integration of UPS functionality.

In fact there appears to be a convergence of UPS function and grid support function for many applications. Some customers want their UPSs to be able to support the grid with load shedding features and in some grid support applications a level of UPS function is requested. With advances in convertor technology, along with advanced energy storage, all of these outcomes become possible.

New energy storage technology and the development of advanced power electronic converters allow signficant advances in power protection, grid support and renewable power integration.

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