Smart Grid Energy Storage

While the current electrical grid is a modern marvel, there is a general consensus that it needs to be upgraded to a Smart Grid with grid storage. Energy storage is, in fact, a vital component of the coming Smart Grid, and NanoMarkets predicts that new materials and systems for chemical batteries and supercapacitors for Smart Grid electrical storage applications represent a significant opportunity.

Even though pumped hydro is the most efficient means for storing generated power for later use, NanoMarkets believes that chemical batteries and supercapacitors represent the biggest growth opportunity for most applications, as they are not limited to certain geological locations and do not have the potential environmental impact issues of pumped hydro.

The near-term opportunities for quality and load leveling storage are clear. Approximately 90 percent of power outages in advanced economies last two seconds or less, and 98 percent of outages last 30 seconds or less, but their economic effects are large. In the U.S. alone, the impact of power interruptions due to lost time, lost commerce, and damage to equipment is estimated to range from $75 to $200 billion per year.

Supercapacitors are well-suited to many short-term (less than a minute) load leveling and quality applications, because they have an extremely fast discharge and charging response, a high current capacity, and can be cycled hundreds of thousands of times without degradation to their storage ability.

While there is currently a large growth market for supercapacitors in uninterruptible power supply (UPS) battery systems for protecting critical infrastructure, improvements in capacity and cost are creating new markets for them as well, particularly in new high-tech industrial applications.

Chemical batteries, meanwhile, are ideal candidates for longer-term (minutes or hours) power quality applications and for peak-shaving applications, because they have higher energy densities and, for many types of batteries, have long service lifetimes.

They represent a critical component of several Smart Grid applications at several levels along the value chain. Bulk price arbitrage, central generation capacity efficiency improvement (peak shaving), transmission capacity/transmission congestion relief, and the integration of variable output sources, such as wind and solar, are all crucial storage applications for chemical batteries in a successful Smart Grid.

The need for storage that can integrate solar and wind cannot be over emphasized. In the U.S., 30 states have renewable energy mandates that average 17 percent integration of renewable energy sources by 2012 to 2025. Only with a significant amount of electrical storage can this level of wind and solar be integrated into a stable electrical grid, so the value proposition for new forms of electrical storage is difficult to overestimate.

In China, for example, generating capacity is not keeping up with increased demand, and storage is being examined as a means to balance load and demand. China also has several provinces where up to 20 percent of their electrical power comes from wind. Electrical storage will be needed in these areas to provide higher power quality.

Current Grid Storage Landscape

The term “Smart Grid” is a still-evolving, catch-all term to describe all of the improvements currently being made and proposed to the current electrical grid that will increase efficiency, reliability, and security, while reducing costs.

While it has been one of the least talked about requirements for achieving the desired Smart Grid, electrical storage is now being recognized as a crucial piece of the Smart Grid puzzle. Growth in the near term will be dominated by two applications.

- The first application is power quality in advanced markets. The growth of advanced manufacturing facilities and the pervasive application of electronics require that short-term storage become a standard feature for enabling advanced electronics equipment to ride through short-term (from a few cycles to a few seconds) power quality issues.
- The second is to provide power leveling in areas with significant percentages of intermittent generating sources (wind and solar) on the grid. The intermittent nature of these generating resources requires stored energy that can be released to the grid at a moment’s notice. Significant energy storage will be necessary if the 2030 renewable energy state and federal mandates are to be met.

Near-Term Applications for Chemical Storage on the Smart Grid

Energy storage: Currently, the most pervasive use of large-scale chemical energy storage has been for power quality in the form of uninterrupted power supplies. A UPS is used to protect expensive electrical assets, such as computer data centers and critical infrastructure, and represents a worldwide $10 billion/year market.

The requirements for such systems do not include high energy content, as most power outages are less than a minute in length. Lead-acid and metal hydride batteries are the mainstays of this industry, but it is an application where supercapacitors and integrated supercapacitor/battery backup systems may make significant inroads, because they have significantly quicker response times than batteries alone.

Until recently, there has been limited availability of high-priced supercapacitors As power quality requirements have increased and the demand for supercapacitors has grown, however, improved manufacturing techniques and higher volume manufacturing have reduced prices. In fact, the cost of supercapacitors dropped 96 percent between 1980 and today, and planned manufacturing improvements are predicted to reduce the costs another 50 percent in the next 10 years.

As these cost reductions become reality, more pervasive applications of the technology will become economical, particularly in combination with batteries, such that supercapacitor markets will expand beyond data centers and certain mission critical applications (e.g., hospitals and utilities) to include the protection of electronic assets for retailers, office buildings, and manufacturing facilities, and ultimately will find applications in new home construction.

Peak shaving: While power quality will be the first wide-scale application of electrical storage in the Smart Grid, peak shaving will be the next application of Smart Grid storage to experience rapid growth. Peak shaving amounts to storing energy generated or purchased during low demand time periods at low prices and either using or selling the stored energy at times of high demand and high prices.

To be economically viable for peak shaving, however, electrical grid storage will need to be cheaper than local generation, which is currently the peak shaving method of choice for many industrial facilities.

In addition to peak shaving, storage will also be crucial for efficiently managing the transmission capacity necessary for realization of worldwide wind and solar energy goals. Energy storage will allow wind and solar generators to sell for maximum profit at peak usage periods and move the electricity to market, on lower-capacity transmission lines.

Currently, lead-acid and sodium sulfur systems have the most extensive track record for peak shaving. While early lead-acid trials for peak shaving were not very successful, new advanced lead-acid batteries look to be up to the challenge. Sodium sulfur systems have been quite successful as well, although their use has been mostly limited to Japan, where currently over 200 MW of sodium sulfur capacity is being used for peak shaving and critical infrastructure, such as hospitals and high-tech manufacturing.

Future Advantages of Chemical Storage on the Smart Grid

There are several materials advances that are likely to become readily available in the next three to eight years that paint an attractive future for grid energy storage.

Flow batteries: Beyond lead-acid and sodium sulfur, flow batteries, such as those based on vanadium and ZnBr, show great promise. Flow batteries have good efficiencies (over 75 percent) and long lifetimes (over 10,000 charge-discharge cycles), and are scalable (battery size is determined by the electrolyte holding tank size). Vanadium flow batteries of 100 kW to 1.5 MW have been successfully demonstrated in UPS's for semiconductor manufacturing, island grid capacity firming, and grid peak shaving applications. Several ZnBr systems in the 200 to 500 kW range have also been demonstrated for peak shaving and island grid applications.

While the current cost of such flow batteries is high compared to lead-acid devices, there are ample opportunities for cost reductions with these new technologies compared to mature technologies, where most cost reduction opportunities have already been realized. Industrial applications, in particular, will greatly increase.

Zebra batteries: Alkali metal chloride batteries, or Zebra batteries, are another technology for grid storage that is quite likely to experience significant growth. GE announced in May 2009 an initial investment in a zebra battery plant in New York state that opened in July 2012 and supplies sodium halide batteries with a capacity of 900 MW hours/year for hybrid freight train, telecom infrastructure, and utility load leveling applications.

At the opening ceremony, GE announced a $70-million planned addition to the $100-million plant based on early demand which will double capacity. The initial customer is Megatron Federal of South Africa, which will use the batteries to improve the efficiency of cell-phone towers that are currently diesel powered. In September of 2012, GE announced $63 million in orders for its new batteries.

However, while a promising grid storage technology, zebra batteries, like the sodium sulfur system, operate at high temperature (~ 300 °C) and contain molten sodium. While maintaining the high temperature adds slightly to the cost, there is a safety issue if containment of the battery is breached, because the sodium metal in the batteries is pyrophoric. While the safety record is good so far, there was one NaS battery fire in Japan in 2011 that took two weeks to burn itself out. NGK stopped battery production for a year to redesign the cells with improved containment and fuses to improve safety

Lithium ion batteries: One technology that has been the darling of the energy storage sector over the past five years has been lithium-ion battery technology. NanoMarkets is less enthusiastic about this technology for grid storage applications than most due to its high cost and immaturity.

The A123 system provides a good example of the challenges associated with production of large Li ion modules in significant volumes. Despite $70 million in backing from GE and $249 million from the U.S. government, the company has run out of money due to a manufacturing recall and lack of demand at the current price point for their Li ion modules. A123 is currently in Chapter 11 bankruptcy. Its assets will be purchased by Wanxiang Group. Other Li-ion battery companies have also had their struggles over the past five years, and this technology has thus not proven to be the break out technology for energy storage.

Because the stationary lithium-ion battery manufacturers have been so heavily subsided, in the near term, there will still be decent growth for lithium-ion batteries, but our opinion is that once the subsidies are gone, lithium ion costs will be higher than the alternatives such as NaS and Zebra batteries and will begin to fade as a choice for grid storage except where they are part of a vertically integrated corporation such as Johnson Controls which has committed to lithium ion and both manufacturers cells and sells integrated grid storage solutions such as smart buildings.

Liquid metal batteries: Further out on the horizon, liquid metal batteries are another exciting concept that may provide up to 10x the capacity of current batteries in a simple system that can best be described as an extension of the sodium sulfur system, where a molten salt electrolyte is sandwiched between two different metals in a liquid state.

Like the sodium sulfur battery, it is a high temperature stationary solution, but if the current storage capacity is as high as reported, it may be a lower cost, more durable solution that could potentially be commercialized within the time period covered by this report. Originally developed at MIT, it has moved out of the lab and is being commercialized by AMBRI. The company has raised level-B funding of $15 million, and NanoMarkets considers it to be an innovative firm that should be watched to see if it can meet its initial expectations.

Aquion Systems approach: Another interesting and novel solution comes from Aquion Systems, which was formed in 2007 out of research labs at Carnegie Mellon University. On the positive side, they are taking a cost conscious approach by using activated carbon for the anode and an alkali ion intercalated manganese oxide as the cathode. The components are cheap and initial data looks promising. However, more data from early customer demos is necessary before a determination can be made as to whether this technology is as promising as advertised.

Supercapacitors: The supercapacitor roadmap also looks exciting through the length of the forecast period. Beyond the refinement and cost reductions associated with manufacturing improvements and volume production of current activated carbon-based supercapacitors, several new materials warrant close examination. Supercapacitors based on nano-structured metal oxides, perovoskites, nanotubes and graphenes are currently under investigation. These materials are reported to increase supercapacitor capacity 5 to 10 times compared to current activated carbon supercapacitors.

Ultrabatteries: Of the advanced lead-acid solutions, one of the most promising technologies is the combination of supercapacitors and lead-acid batteries in what CSIRO (Commonwealth Scientific and Industrial Research Organisation) in Australia refers to as an ultrabattery. Its ultrabattery hybrid electric car has already demonstrated over 100,000 miles on one set of ultrabatteries. It has been licensed by both Furukawa battery and East Penn Battery. Maxwell Technologies is also working on integrated supercapacitor/battery ultrabatteries

*See www.nanomarkets.net for additional details about the NanoMarkets report****, Batteries and Supercapacitors for the Smart Grid-*****2013**