VOLTABOX®
OF TEXAS INC. • A PARAGON COMPANY

Seven Things Your Team Should Know about Converting Your Fleet to Green Energy

Capitalizing on Green Energy Series

Capitalizing on Green Energy Series

VOLTABOX® OF TEXAS INC. • A PARAGON COMPANY

Seven Things Your Team Should Know about Converting Your Fleet to Green Energy

While "going green" makes perfect sense from an environmental stewardship perspective, the reality is that many green alternative energy sources can be very costly, often times not even paying for themselves, and can even create environmental hazards. Lithium ion (Li-ion) battery technology offers a number of advantages over other sources of energy for motive applications including ground support equipment (GSE), by reducing costs, improving safety, providing longer long life cycles and enhancing productivity. It also offers additional cost advantages over diesel and lead acid technology when issues such as maintenance, required infrastructure, and performance in extreme temperature are considered. Voltabox of Texas, Inc., a Li-Ion battery system design and manufacturing company, has found that many teams exploring green energy options fail to evaluate the total cost equation. To fully understand whether or not Li-Ion battery technology makes sense for your application, seven areas should be considered:

- Regulations
- Cost
- Performance
- Reliability
- Safety
- Intelligent Energy Systems
- Environmental Considerations

First off, it is important to understand that there is no one Li-Ion solution that is perfect for all power applications. Li-Ion technology offers several different chemistries and until recently, Li-Ion technology was primarily used in small portable consumer applications such as cell phones and computers. However, three chemistries are well-suited for motive applications: Lithium Iron Phosphate (LFP), Lithium Titinate Oxide (LTO) and Nickel Manganese Cobalt Oxide (NMC). There are other lithium chemistries currently being used for their very high energy density but these come with some disadvantages, the most notable being the possibility for a thermal event to occur. The three chemistries mentioned above are all very safe, especially when compared to lead acid technology, and do not lend themselves to uncontrolled thermal events. While there is no chemistry that is perfect for all solutions, there are guidelines that help companies determine which chemistry is best suited for a particular application. Below is a chart comparing some key attributes of the three chemistries mentioned:

VOLTABOX® OF TEXAS INC. • A PARAGON COMPANY

Figure 1. Comparison of Tradeoffs in Li-Ion Chemistries.

Chemistry	Cycle Life	Safety	Energy Density	Power Density
NMC	Better	Good	Best	Good
LFP	Good	Better	Better	Best
LTO	Best	Best	Good	Better

Regulations

Agencies such as EPA, OSHA, MSHA, FAA, ICAO, and many others are imposing ever stricter regulations on industries and companies year over year in an effort to reduce pollution and environmental impact, while increasing safety and reducing energy usage. Compliance can be costly, particularly with older, less environmentally friendly technologies. When combined with a properly engineered Li-Ion battery system, advance Li-Ion technology delivers a solution that addresses many (if not all) of these costly regulatory mandates for most motive applications minimizing or even eliminating their overall financial impact.

Cost

The most important question when looking at adoption of a new technology is: “Is the technology commercially viable?” Often when discussing “Green Technology”, “Alternative Technology” or even “Advanced” technology, the emphasis is more on helping the environment than it is on how it effect on the bottom line. With a properly designed and constructed Li-Ion battery system that is tailored specifically to the application, commercial viability is not only possible but in most cases this new technology provides bottom line improvements.

Another challenge inherent in new rapidly advancing technologies is future proofing. Battery management systems manufactured by battery cell manufacturers are locked into their technology,

VOLTABOX® OF TEXAS INC. • A PARAGON COMPANY

good or bad. If a battery manufacturer decides to exit the business as technology changes, customers have limited support options. Comparatively, Voltabox's parent company, paragon AG, has been increasing its investments in the development of leading edge electric vehicle applications for a decade. Strategies such as module or system level "pod" scalability offers application possibilities that were not achievable even a few years ago.

Voltabox's team is expert in developing battery management systems that work with multiple battery brands. In short, because Voltabox is cell agnostic, the team works to find the best chemistry and cell option for a specific application instead of trying to make the application "fit" a specific cell solution.

Lastly, the flipside of the regulatory discussion above is that there are many Federal, State, and Municipal grants available for those who wish to pursue improved fuel economy, reductions in noise, emissions, environmental impact, etc. Grants such as the Voluntary Airport Low Emissions (VALE), Zero Emissions Airport Vehicles and Infrastructure (ZEV), and AIP Buy America Preference Requirements are available to all who wish to pursue this new technology. Many of these grants pay 50 percent of the total conversion cost or 75 percent of the incremental cost to switch to this new technology. This factored in with the added cost savings that this technology offers makes it almost imperative that companies investigate this further.

Most applications have specific requirements for cycle life, safety, energy density, power density, etc. Voltabox's configuration software tool provides fast "what if" analysis relative to costs and specific characteristics of each of these choices. Traditional analysis that normally takes weeks or even months can now be performed in mere hours. The end result is the ability to determine the best chemistry, cell option, and system architecture based on the specific requirements of the application. This broad range of choices can also help broaden the range of retrofit options.

Performance

The motive power of a Li-Ion cell is high. Commercially available cells can discharge at up to 48 times their capacity (or 48 C) for up to 10 seconds, ensuring that any activity involving moving up elevated ramps is not a problem. Continuous discharging rates can be as high as 10 C with proper thermal management. Additionally, electric vehicles experience no performance loss in high attitudes or various climatic conditions since the air aspiration required for a combustion engine is not a factor.

In terms of performance, Li-Ion provides a constant (very flat) voltage curve which translates to consistent power delivery. There is immediate power and torque when the operator requires it. Comparatively, lead acid has an immediate voltage drop and diesel does not provide an immediate transfer of power. Li-Ion battery systems also weigh one quarter to one third less than lead acid battery systems at the same power output.

VOLTABOX® OF TEXAS INC. • A PARAGON COMPANY

Capitalizing on Green Energy Series

Li-ion battery systems are up to three times more energy dense than their lead acid counterparts. In terms of power density relative to diesel, a typical cell has 2600W/kg of power, while a Cummins V8 diesel has only 650W/kg of power.

Advanced Li-Ion technology also allows for capturing of regenerative braking energy. Voltabox's battery system design includes regenerative capabilities. When a vehicle is in a braking mode, regenerative capabilities allows for capturing kinetic energy that is normally lost with mechanical or lead acid drive trains. Properly configured Li-Ion systems take full advantage capturing this energy very efficiently from the moment the breaking event occurs. Consequently, vehicles which need to go up and down ramps or break often are more efficient than their diesel or lead acid counterparts which have no regenerative capability. This "free energy" has the potential to save significant money on energy and maintenance costs throughout the life of the vehicle.

Quick charging is also another major advantage of a properly developed Li-Ion battery system. With current lead acid technology it takes up to 8 hours to charge and 8 hours to cool after charging. Comparatively, Li-ion's LTO chemistry can charge 80 percent of the battery's total capacity in less than 10 minutes. Diesel takes 5-10 minutes to fuel. Both diesel and compressed natural gas (CNG) require storage tanks for their fuel. Comparatively, Li-ion battery systems utilize the existing electric grid for recharging. This eliminates the need for very large and expensive battery storage and charging areas. Infrastructure and maintenance costs in these areas can be reduced to zero.

Another option possible with Li-ion systems is inductive charging. Inductive charging pads can be installed in areas where vehicles are likely to rest between service activities. With this system, 15 minutes of idle time periodically during the day translates to a continuous full charge state, minimizing vehicle downtime and/or the number of vehicles required to support daily operations. This also reduces the size of the battery system which directly translates into an even smaller initial investment.

Reliability

The key advantage of Li-Ion over diesel from a fleet management perspective is that diesel engines have a lot of moving parts that require periodic maintenance. Li-ion battery systems have no moving parts and require no periodic maintenance. Additionally, Li-ion battery systems tolerate low temperature extremes better than either diesel engines or lead-acid batteries, ensuring that support equipment is still ready to run when temperatures drop.

Voltabox's Li-ion battery management system adds another advantage to an industry where fleet status is critical - fleet availability monitoring. The operator will see the state of charge, state of health, and other critical information needed for optimal and safe equipment performance. The battery management system can also send status, safety, and performance information to an operations

monitoring person/department (see Intelligent Energy Systems section below). Comparatively, diesel systems don't provide either engine state of health or fuel levels remotely nor do lead acid battery systems.

A key advantage of diesel engines is that they typically have a life cycle of at least 8-10 years. That is not the case with most current battery technologies. However, as an example, LTO Li-ion technology does have a comparable 8-10 year or longer life cycle for motive applications. It delivers 30,000 recharge cycles before dropping to 80 percent depth of discharge. LFP and NMC Li-ion chemistries provide up to 6,000 cycles before reaching 80 percent depth of discharge. Comparatively, lead acid chemistry life is typically only providing hundreds of cycles.

This technology holds true to the adage of "You get what you pay for!" There are companies that are willing to sell very inexpensive units/systems but this comes at a price with regards to reliability, performance, lifetime and safety. The robustness of the design, quality of materials and construction are key attributes that must always be carefully evaluated.

There is little to no maintenance required with a well-constructed battery system that is properly configured for a particular application. This in and of itself is a testament to the improved reliability that one can achieve with this technology. Examples of additional reliability benefits at the application level include the fact that with regenerative braking (where the electrical drive system brakes the vehicle thereby capturing free energy in the process) there is much less wear and tear on the mechanical braking system, significantly extending its life and reducing costly required maintenance.

Redundancy with a properly configured module/pod strategy also offers benefits of vehicle reliability and performance. If for any reason a particular section or battery string were to become nonfunctional, the battery would still be fully operational and would only lose a portion of its overall capacity available until a repair is made.

With multiple thermal management solutions available to these systems, operation in harsh environments poses little if any problems. Be it in Nome, Alaska or Death Valley, CA, proper active thermal management will ensure maximum performance and maximum life out of the battery system.

Safety

In terms of safety, there are three levels to consider: the cell, module, and system level. All three Li-ion chemistries (LTO, LFP and NMC) are safer than lead-acid systems. At the cell level, melting fuses, over-pressure devices, advanced separator technology and highly automated production processes ensure consistent quality and safety. Additional safety features are placed at the module level, monitored by a slave battery management system (BMS) to stop overvoltage or overheating situations by shutting the module down in critical situations. These slave BMSs are in direct communication to the Master BMS

controlling the complete system. At the system level, the BMS will also shut down the system if widespread overvoltage or overheating is detected or anything occurs outside safety parameters. Discussion areas to cover with your battery system developer should include: over pressure devices, internal fuses, advanced construction materials, thermal management and phase changing material, on board BMS and remote communications, IP ratings, energy management, and optimal sizing. Additionally, there are other key safety considerations including no off gassing in normal use and surviving catastrophic events including system penetration by foreign objects. Finally, there are built-in mechanisms to ensure that in the event of abuse, there will be no immediate thermal event or explosion.

Voltabox's software configuration tool addresses each of these key characteristics and configures the proper solution for each customer's specific application. This process is as easy as answering the prompted questions, pushing a button and viewing the generated output. This assures that all key attributes are taken into consideration when developing a battery system and also ensures that the solution is tailored specific to the application's needs.

Intelligent Energy Systems

Li-Ion battery systems lend themselves to advanced monitoring and management technology, which can also be used to increase productivity. Voltabox's Li-ion battery management system adds an advantage to an industry where fleet status is critical: fleet performance monitoring. This enables fleet managers to continuously monitor the state of charge, state of health, battery usage data, energy consumption, detailed load cycles, charging times, usage times, operation times and service notifications. In addition, the operator monitoring the state of charge and health of the battery the battery system can also send status along with other performance and operational information to the operations center. Automated daily, weekly, and monthly reports are also available, supporting efficient service scheduling, vehicle availability optimization, costs of operations monitoring, protection against usage abuse, etc. Gone are the days of manual logbook and spreadsheet management. Since operations personnel have the ability to monitor all these metrics in real time, it becomes easy to optimize charging activity or maintenance and repair activities to minimize fleet or vehicle performance impact. This ability alone has the potential to save millions of dollars per year across domestic fleets. Communication interfaces include WiFi, Bluetooth, Cellular, Radio Frequency, and direct connection while charging.

Environmental Considerations

Electric vehicles offer a number of advantages over their diesel counterparts. First, they are by far quieter than internal combustion engine systems. No noise is generated, which helps minimize the amount of noise pollution to which workers are subjected.

Capitalizing on Green Energy Series

Li-ion batteries have no outgassing or emissions during normal operations as do their lead acid counterparts. This makes them ideal for applications that may involve some transit time indoors or where air quality is a concern. Lead-acid batteries vent dangerous hydrogen gas and require special infrastructure and designated areas to address this adding additional costs of operation even in outdoor applications. There are no emission whatsoever with the proper use of Li-Ion technology.

Li-Ion offers a near perfect technology for alternate energy storage to be commercially viable. At 70 percent depth of discharge a Li-Ion battery is considered near end-of-life for motive applications, however, it still has many years of life left for stationary applications such as storing solar, wind, or even traditional grid energy. Consequently, choosing Li-ion technology not only drops calendar aging on your fleet's energy source to one percent per year, it also provides a path where end-of-life cells can either be repurposed to your stationary energy storage needs or sent to a remanufacturer for continued life in the stationary energy market.

In short, Li-ion technology offers a number of cost and performance benefits beyond the fact that it is an environmentally responsible power source. Reduction in fleet maintenance costs, number of vehicles required, energy savings, and unscheduled downtime are just a few of the ways this technology can reduce cost. There are additional advantages to fleets located in areas that have extreme weather conditions or are located at high attitudes. Keeping in mind that there is not a one size fits all solution to a specific application emphasizes why partnering with a battery systems supplier, who is able to understand specific requirements and quickly present options for configurations that best meet your unique requirements, provides improved bottom line performance over current technology while concurrently providing an environmentally responsible energy solution!

About Voltabox of Texas, Inc.

Voltabox of Texas, Inc.'s headquarters and manufacturing facility are located right outside Austin in Cedar Park, Texas. Our German-based parent company, paragon AG, is an international leader in automotive and motive technology. Our innovative, custom-configured battery packs are currently used in a wide range of motive applications throughout Europe and the U.S. Selecting Voltabox will not only provide your team with a cost-competitive solution tailored specifically to your needs, it will also help sustain and create U.S. jobs. The systems manufactured in our Texas facility also fulfill the requirements of the Buy America Act of 2009.

1500 Volta Drive, Cedar Park, TX 78641 Tel: 1-512-814-3699 www.voltabox.com