Pre-integrated Energy Storage
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White Paper

Selecting the Best Fit Cell Chemistry and Battery Module for Energy Storage Systems

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Summary

Clients often look to gain perspective on the selection of which lithium-ion chemistry is the best fit for use in stationary energy storage systems. This application note presents some important criteria to selecting a battery for Battery Energy Storage (BES) systems. This application note will also present some information explaining why LiFePO4 is the right chemistry for stationary storage installations.

Battery Requirements:
6 Key Criteria

There are 6 key criteria when considering which battery chemistry to use for a specific application. The 6 factors are Safety, Cost, Specific Energy, Specific Power, Life, and Performance. Each of these factors are important when choosing a battery chemistry, but the requirements of the application determine which factors are more important than others. For example, in an application for an electric aircraft, such as an eVTOL (electric Vertical Take-Off and Landing) vehicle, the Specific Energy of the battery pack is critical since any extra weight reduces flight range. In a stationary Battery Energy Storage System (BESS) this factor is less important than Life. A brief explanation of each factor is below.

Safety

This is the most important criteria in all applications. The safety of the battery chemistry is paramount to ensuring the success of the application. Traditional chemistries, such as Lead-Acid batteries, although not without their own incidents, are widely accepted and well understood. Lithium Ion batteries have a much briefer history, and there have been very public incidents which have marred the reputation of this technology. However, what is not as well understood is that there are several different types of Li-ion chemistries, some of which are extremely safe.

Cost

The cost of a battery system is typically considered to be the upfront purchase cost. However, total cost of ownership in battery energy storage systems is a very important metric. BES systems have lifespans of 10-20 years, and the cost of replacing batteries can severely reduce the return on investment over the life of the installation.

Specific Energy

Specific energy is the amount of energy that the batteries can deliver per unit of mass. It is expressed as Wh/kg. This factor is a key driver in the physical size of the BES system. For stationary battery systems, this factor is typically only important if there is a limited space for installation.

Specific Power

Specific power is the amount of power that the batteries can deliver per unit of mass. It is usually expressed as W/kg. This is an important factor if a system needs to provide a large amount of power quickly. This factor is important in hybrid vehicle systems, where acceleration, or start-stop systems require a small amount of energy to be delivered very quickly. In stationary storage systems, the specific power requirements are not usually a key driver, however, if there are loads with large startup power requirements, such as motors with across-the-line starters then these loads should be taken into consideration.

Life

The life of batteries is measured in two ways, the overall age in years, and the cycle life. The cycle life is the number of times the battery can be charged and discharged until the ability to store charge degrades to 80% of the original storage capacity. The overall age in years can be affected by a few factors, but the primary driver of ageing is ambient temperature. This is a vital factor for BES systems, as it a key driver of total lifetime cost of the application.

Performance

Performance of batteries is measured by the rates at which they can store energy or release stored energy under all operating conditions. The expectation for BES systems is that they will deliver and store energy when required, regardless of the environmental conditions.

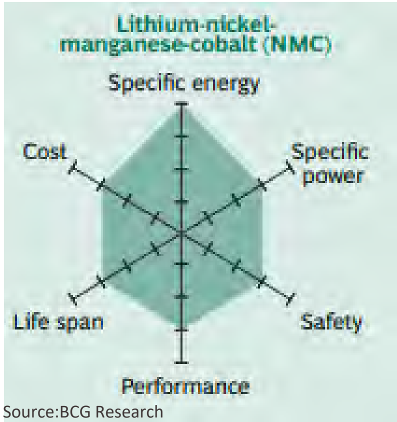
Common Li-ion Battery Chemistry Types for Energy Storage Systems

Lead Acid - Flooded/Absorbent Glass Metal/Gel

There are three typical types of lead-acid battery used in BES systems. These are flooded batteries, Absorbent Glass Mat sealed batteries, and Gel-filled sealed batteries. The lead acid is the oldest of rechargeable battery technologies. There are some advantages to using lead acid batteries in BES systems, and they are typically used in UPSs due to their low initial cost. Flooded lead acid batteries have the lowest up-front cost, but require balancing with distilled water, and have high maintenance requirements. They also must be stored upright due to the potential to spill the high corrosive acid electrolyte. AGM and gel batteries solve this problem by trapping the electrolyte in layers of woven glass fabric, or by using a gelling compound to solidify the electrolyte. Both applications are sealed and have much lower maintenance requirements than flooded batteries. Lead acid batteries have high specific power, and work well in cold and sub-freezing conditions. However, they have power specific energy, are extremely heavy due to the lead composition, and require slow charging. There have been some recent innovations over the past decade, but ultimately, the lead acid battery does not have a long life when used in deep cycle applications (where the depth of discharge can exceed 80% of the capacity of the battery).

NMC – Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2)

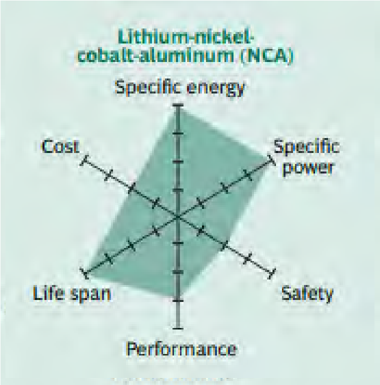
The NMC composition is one of the most popular and widely used Li-ion chemistries. By combining Cobalt, Nickel, and Manganese in the cathode, the chemistry allows for low internal resistance, high specific energy, and good specific power. NMC batteries are used in many applications. Some examples are power tools, laptops, electric bikes, the Tesla Power Wall, and electric power trains, such as the BMW i3. However, there are some drawbacks to the NMC chemistry which are high cost due to the Cobalt, and moderate-poor life due to relatively high thermal degradation. Even though the NMC chemistry is safer than NCA and LCO compositions, it still has a low thermal runaway temperature of 210°C(410°F).



Source:BCG Research

NCA - Lithium Nickel Cobalt Aluminum Oxide
($LiNiCoAlO_2$)

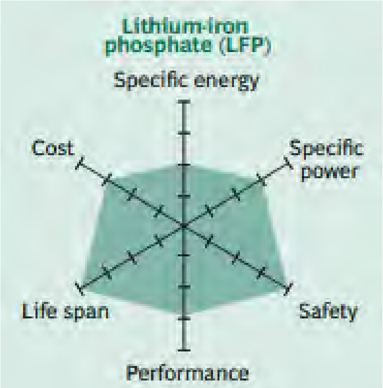
The NCA composition has the highest specific power and specific energy of all Li-ion battery chemistries, which is why it is a prime candidate for electric powertrain applications. Although NCA contains Cobalt, it is a relatively small amount, and NCA cost has greatly come down due to economies of scale, so it is one of the lower cost compositions. However, NCA has poor life due to thermal degradation. In addition, it is one of the more dangerous chemistries, and requires sophisticated battery management to prevent thermal runaway, as well as advanced manufacturing techniques to build battery packs.



Source:BCG Research

LFP - Lithium Iron Phosphate
($LiFePO_4$)

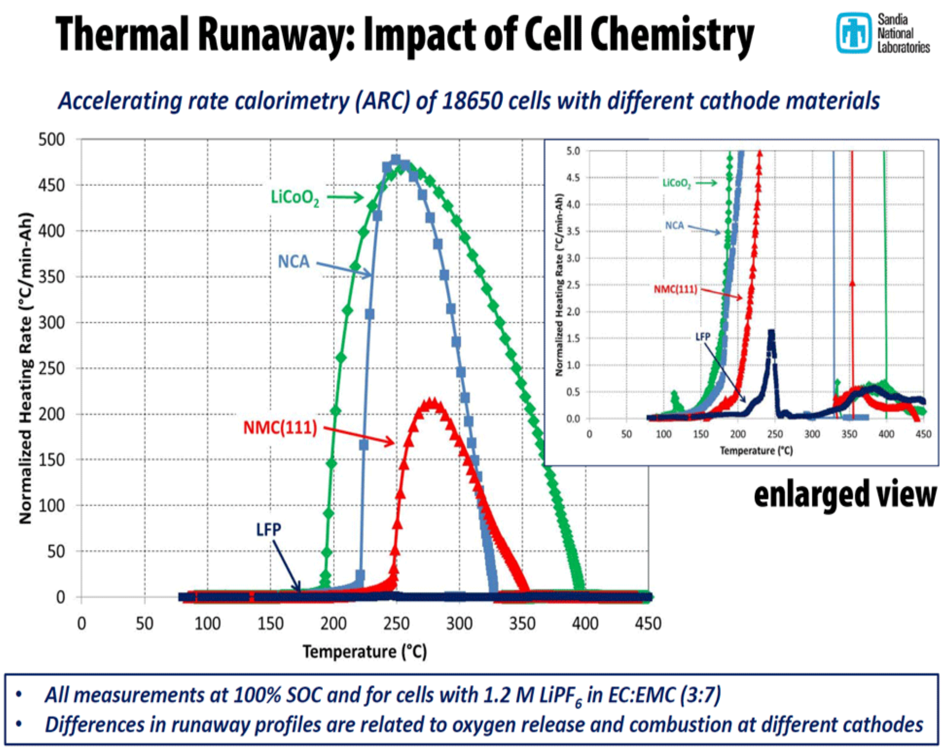
The LFP chemistry avoids the use of Cobalt in the cathode, and instead utilizes Iron Phosphate, which provides some protection against overcharge, and increased thermal stability. Even though it does not have the energy density or specific power of some of the other Li-ion chemistries, it has a very long life span, and is not subject to some of the thermal degradation mechanisms that are present in the other Li-ion types. LFP is by far the safest of the battery chemistries, which is one of the reasons it is recommended for use in stationary BES systems. Due to this increased safety factor, LFP is also use in several electric vehicle applications, such as the Chevy Spark. LFP has long life span and works very well in deep discharge applications. e-ON's documented forced failure point is 580 degrees Fahrenheit, and average of 3 times higher than NMC and other compounds.



Source:BCG Research

Battery Safety

Battery safety is critical for BESS applications. The primary concern with Li-ion battery systems is thermal runaway, which is a condition in which the temperature inside the cell creates a chemical reaction that causes additional heat to be generated. This frequently results in a catastrophic failure of the battery system. This failure can be highly energetic and can present a risk to life and property. The figure to the right demonstrates one of the key benefits of the LFP chemistry. As can be seen, the self-heating inside of the cell is extremely low. This means that thermal runaway is nearly impossible in LFP battery systems. Our electrolyte contains a proprietary additive that is designed to "de-oxygenize" active lithium particles, in the case of thermal failure leading to an off-gassing stage. This process is why our cells deliver a thick, black, non- flammable, non-toxic smoke, but no flame when set in to forced failure by UL, and documented in our UL1973 testing video.



Conclusion

An explanation of important criteria for selection of the correct battery chemistry has been presented. As can be seen in the previously presented information, the LFP battery chemistry has the best combination of safety, cost, and life to handle the challenges presented in stationary energy storage systems. With e-ON's extensive safety record established, the e-ON LFP battery systems are the right choice for BESS applications.

NMC's have a lower thermal ignition point than needed to activate the needed electrolyte additive.

The popularity of Battery Energy Storage Systems (BESS) is on the rise around the world. According to research from Wood Mackenzie Power & Renewables, global BESS deployment is projected to grow 13 times in MWh over the next six years (2019-2025). Given this growth trend, it is important to understand how lithium-ion battery chemistries compare in key performance criteria.

e-On Batteries

e-On Batteries is a prominent technological player in the development of lithium iron phosphate (LiFePO4) based energy storage systems with a focus on product safety. The company's UL 1973 listed 6.4kWh module is engineered as a scalable building block to enable larger systems, and its 19" rack-mounted modular systems are easily configured from 12.8kWh residential systems to 4.8MWh container-based systems and more. With over 20 million deployed calls and zero catastrophic failures, combined with cell-level BMS monitoring and control systems, expert engineering liaison and certified installers, e-On Batteries provides full value to you.

Product Certifications

Battery Cells

UL 1642: Standard for Lithium Batteries

UN 38.3: UN Transportation Test for Lithium Batteries, Sixth Revised Edition

6.4kWh Battery Modules

UL 1973: Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications

IEC62619: Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications including stationary applications