

Session Thirteen Application of Lithium-ion batteries in Energy Storage Equipment

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Abstract: Different types of energy storage systems are currently available for the stationary power market such as capacitors, compressed air, pumped hydro, flywheels and rechargeable batteries. In this paper, we will emphasize on the comparison of different types of batteries and their characteristics. Furthermore, different types of battery management systems will also be discussed.

1- History of the Battery

Within the off-grid energy storage systems market, different types of batteries dominate the industry. Table 1 illustrates the history of the battery from 1800 up to 1999, when the Lithium ion polymer (polymer electrolyte/separator) was developed. In addition to this, the progress of battery development is shown in Fig 1 from 1800 to 2050 [1].

Table 1. History of Battery

Year	Type of Battery
1800	Voltaic pile: silver zinc
1836	Daniell cell: copper zinc
1859	Planté: rechargeable lead-acid cell
1868	Leclanché: carbon zinc wet cell
1888	Gassner: carbon zinc dry cell
1898	Commercial flashlight, D cell
1899	Junger: nickel cadmium cell
1946	Neumann: sealed NiCd
1960s	Alkaline, rechargeable NiCd
1970s	Lithium, sealed lead acid
1990	Nickel metal hydride (NiMH)
1991	Lithium ion
1992	Rechargeable alkaline
1999	Lithium ion polymer (polymer electrolyte/separator)

2- Important Parameters to select a Battery

One of the most important aspects of designing an energy storage system is selecting the correct type of battery. Based on research and application by Magellan for the past 20 years, the main parameters to select the battery types are:

- Size:
 - Physical
 - Energy density (watts per kg or cm^3)
- Longevity
 - Capacity (Ah, for drain of C/10 at 20°C)
 - Number of recharge cycles

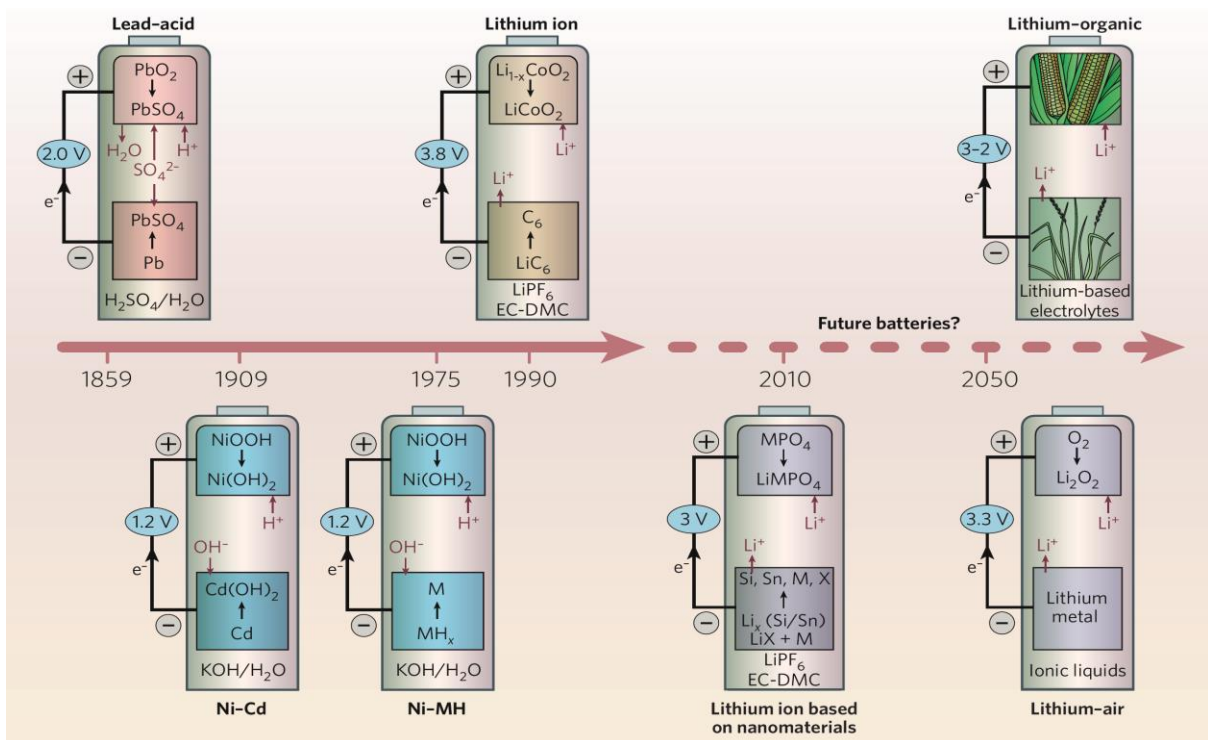


Fig 1. Progress of battery development

- Discharge characteristics
- Cost
- Operational factors
 - Temperature range (storage, operation)
 - Self-discharge
- Environmental factors
 - Leakage, gassing, toxicity

Table 2 and figures 2-4 show the comparison of three different types of batteries in terms of cell voltage, life cycle, safety, environmental, cost and working temperature. Based on this comparison, it can be seen that Lithium-ion has a significantly higher cycle life than lead acid in deep discharge applications. A factor not represented in the datasheets is that the battery systems are often housed in enclosures that see internal temperatures 10°C higher than the air temperature due to solar installation, which would further

decrease the performance. The average temperature is also not completely representative of how much time is spent at extreme temperatures where the degradation accelerates in lead acid systems (e.g. one hour spent at 40°C and one hour spent at 20°C has a worse impact on the battery compared to two hours spent at 30°C).

Table 2. Comparison of Lead Acid and Lithium batteries

Type	Voltage(V)	Cycle life	Safety	Environmental	Cost per cycle	Working Temperature (°C)
SLA	2.0	>400	Safe	Y	1	-20 to 40
LiFePO4	3.2	>2000	Safe	Y	0.3	0 to 60

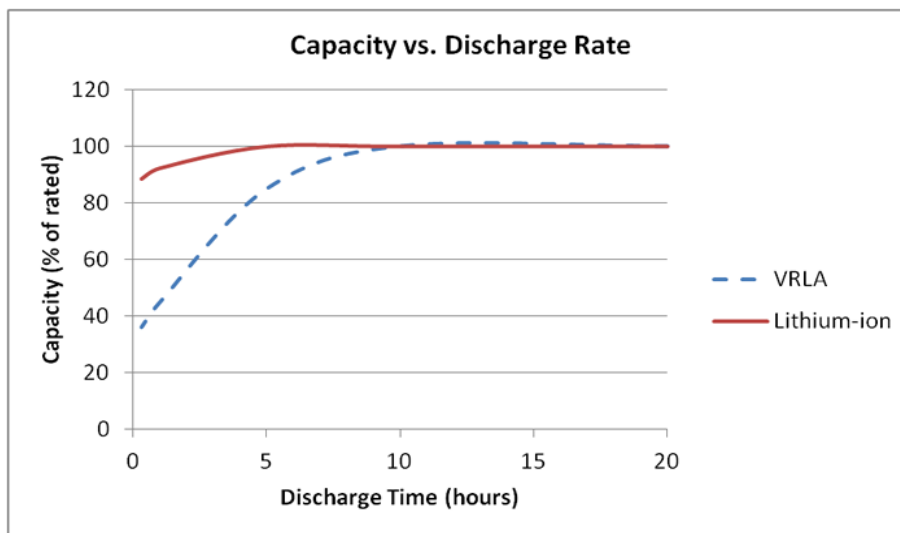


Figure 2: Capacity vs. Discharge Rate

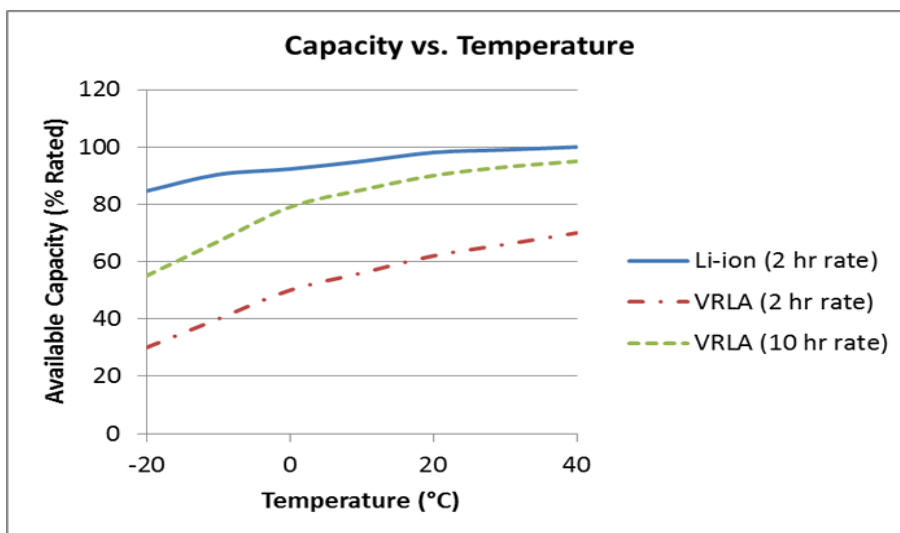


Figure 3: Capacity Available versus Temperature

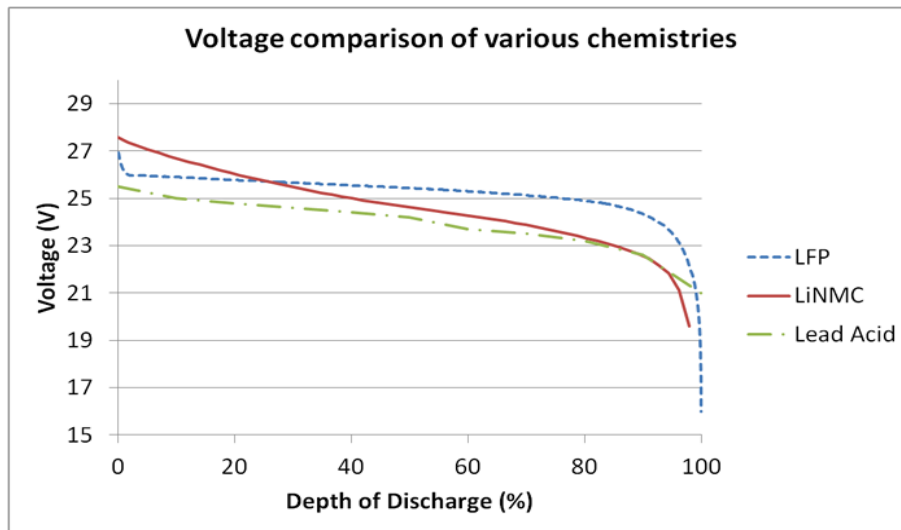


Figure 4: Voltage Comparison

3- Why LITHIUM-ION?

A lithium-ion battery (sometimes Li-ion battery or LIB) is a rechargeable battery where ions move from the anode to the cathode during discharge and back when charging. The main advantages of this type of battery are:

- Excellent cycle life (3-5 times the cyclic lifespan of lead acid batteries)
- Good calendar life
- Best specific energy
- Very high power density
- Excellent charging and discharging efficiency
- 1/3 the weight and size of lead acid batteries

It should be noted that there are some weaknesses as well, such as:

- Global cost of technology
- Compulsory electronic management
- High power chargeability at low temperature

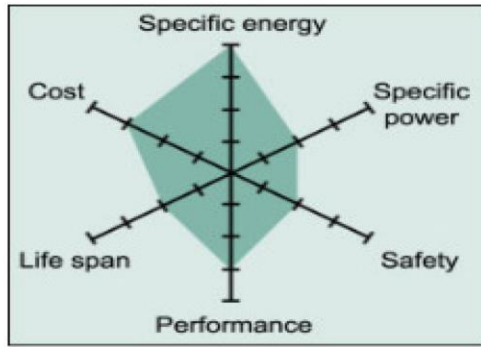
To overcome the above mentioned disadvantages, Magellan Power has designed two different battery management systems.

4- Types of Lithium-ion

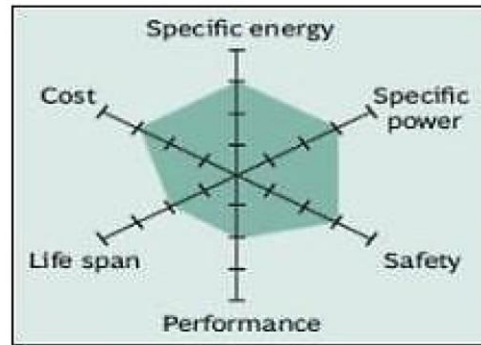
There are numerous types of lithium batteries, as followed:

- Lithium Cobalt Oxide
- Lithium Manganese Oxide
- Lithium Iron Phosphate
- Lithium Nickel Manganese Cobalt Aluminium Oxide
- Lithium Nickel Cobalt Oxide
- Lithium Titanate

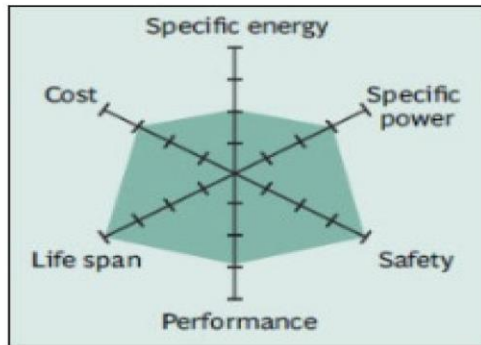
In Fig. 5, they are compared in terms of cost, specific energy, specific power, life span, performance and safety [2].



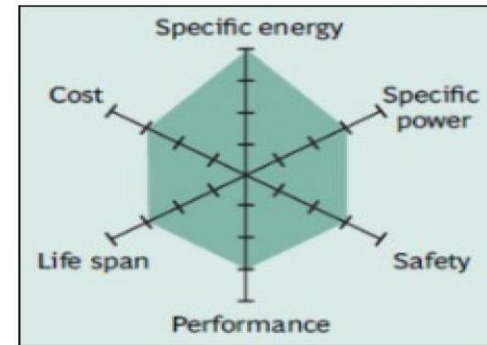
(a) Lithium Cobalt Oxide



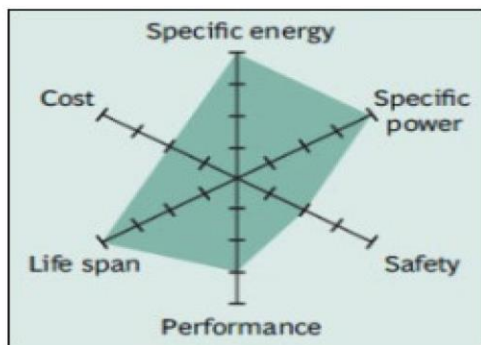
(b) Lithium Manganese Oxide



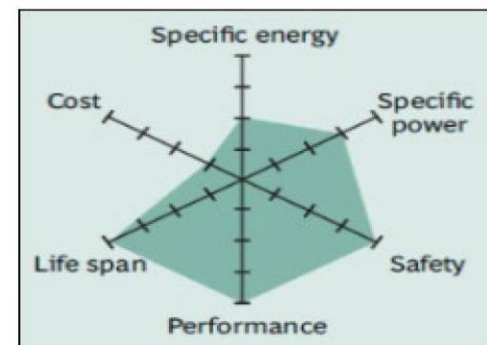
(f) Lithium Iron Phosphate



(c) Lithium Nickel Manganese Cobalt Oxide



(e) Lithium Nickel Cobalt Aluminium Oxide



(d) Lithium Titanate

Fig 5. Lithium Batteries comparison in terms of cost, specific energy, specific power, life span, performance and safety [2].

5- Battery Management System

As mentioned in section 3, to overcome the disadvantages of the Lithium batteries, a battery management system is necessary to balance the cells by transferring energy from or to individual cells, until the State of Charge of the cell with the lowest capacity is equal to the battery's SOC. It should be noted that without balancing, the cells can be easily overcharged and over-discharged with the BMS, and the battery cells will be monitored and protected from overcharging and over-discharging [3-4].

There are two different types of balancing methods:

- **Passive balancing:** Energy is drawn from the most charged cell and is wasted as heat, usually through resistors.

- **Active balancing:** Energy is drawn from the most charged cell and transferred to the least charged cells, usually through DC-DC converters.

In both of the battery management systems, the BMS monitors the following parameters [3]:

- Voltage: total voltage, voltages of individual cells
- Temperature: temperature of individual cells
- State of charge (SOC)
- Depth of discharge (DOD)
- Current: current in or out of the battery

In addition the BMS monitors and protects following parameters:

- Over-current
- Over-voltage (during charging)
- Under-voltage (during discharging)
- Over-temperature

Figure 6 and 7 show the passive and active Magellan Power BMS circuits, respectively.



Fig 6. Passive Magellan Power BMS circuits



Fig 7. Active Magellan Power BMS circuits

Conclusion

This study presents a comparison of two types of batteries, evaluating them in terms of cell voltage, life cycle, safety, environmental, cost and working temperature. Based on this comparison, it can be seen that Lithium-ion has significantly higher cycle life than lead acid in deep discharge applications. In addition, the advantages and disadvantages of the Lithium-ion batteries are presented and compared with them. Furthermore, two different types of battery management systems were presented to overcome the weaknesses of the Lithium-ion batteries.

References:

- [1] <http://www.nature.com/nature/journal/v451/n7179/full/451652a.html>
- [2] http://batteryuniversity.com/learn/article/lithium_based_batteries
- [3] <http://www.magellanpower.com.au/component/virtuemart/industrial-batteries/-lithium-iron-phosphate-lifepo4batteries-detail>
- [4] <http://www.magellanpower.com.au/component/virtuemart/industrial-batteries/lead-acid-batteries2012-09-19-00-57-045-detail>