A Comparative study and Recent Research of Battery Technologies

Siriyala Trilochana[#1], C.N.Sangeetha [*2]

Electrical and Electronics Engineering, St.Martin's Engineering College

[1]trilochanaeee@smec.ac.in

[2]sangeethaeee@smec.ac.in

Abstract **— The growth of electric vehicle market in India is inferior compared to other countries. The main issues facing by EV market are lack of charging stations, the maximum components and batteries are exported from other countries which increasing the cost of EV, which acts as a main obstacle of EV growth in India, anxiety on vehicle fuel that they can reach destination or not and irregular policies. These issues are limiting the growth of EV market. However research is going on in a great extent to fabricate battery with as high power and energy densities as possible but these batteries costs high. But once the battery technology advances in such a way that it is feasible to apply in all application where presently maximum usage of batteries are lead acid batteries, their prices comes down automatically. This paper gives comparative study and recent advances of different battery technologies. This study gives the knowledge over the factors to consider before using in EV or hybrid electric vehicle (HEV).**

Keywords: **Electric Vehicle (EV), Battery, Energy Density, Coulombic Efficiency, Voltage Efficiency**

I. INTRODUCTION

The Automobile industry of the whole world is showing keen interest in use of electricity to drive vehicles. In addition they want to satisfy customers by providing a high performance and ease to maintain car. The objective is to reduce environmental pollution and to reduce the use of petroleum products. In most of the HEVs and PHEVs [1–3], battery acts as the source of electrical energy. However, it is seen that none of the present day battery technologies are capable of providing a range higher than what the modern IC engines can provide, considering equal weights of batteries and fuel tank full of petrol or diesel. This is the reason why automobile manufacturers are reluctant to leave IC engines completely as a source of vehicle drive. Considerable research is being carried out towards utilizing the unused potential of modern and advanced battery technologies like Lithium ion battery or its variants.

II. FACTORS TO BE CONSIDERED TO CHOOSE A BATTERY

Battery is a storage device of electrical energy, which gives DC output [4–8]. As a lot of Research is going in battery technologies, it gives certain factors to be considered for opting the right battery for a given PHEV:

a. Load Requirement of the vehicle

Battery Capacity required for a PHEV is decided by the gross load demand on the vehicle. The battery selected must be able of reach the peak load on the vehicle for maximum time. For the same weight, the type which can deliver maximum power is usually the best choice. The lighter the battery, the better it is. But there are certain other factors also to be considered.

b. Power or Energy Density

Power Density in Watts/kg and energy density (Specific Energy) in Wh/kg is also a good criterion for selection of battery type. A maximum value for any of the above parameters indicates that the battery can support a given load for greater time than other battery types with lower values of specific energy or power density.

c. Efficiency

Battery efficiency is another indicator of how best a battery can meet a given load. The net efficiency of a battery is identified in two ways :a) the Coulombic Efficiency and b) the Voltage Efficiency.

Coulombic efficiency (CE), also called current efficiency or faradaic efficiency, it illustrates the charge efficiency by rate of electrons transmitting in batteries. It describes how much amount of charge is withdrawn with respect to the charge deposited into the battery over a full cycle. Li-ion is one of the high CE rating rechargeable batteries with more than 99% efficiency. This is feasible only when the battery is charged with in temperature limits at moderate current. Once battery is charged in Ultra-fast mode it reduces CE rating because of losses due to charge acceptance and heat.

Voltage efficiency is another way to measure battery efficiency, which describes how much amount of average is discharged with respect to amount of average voltage charged. The dependence of the battery voltage on BSOC will therefore impact voltage efficiency. Other factors being equal, a battery during which the voltage varies linearly with BSOC will have a lower efficiency than one during which the voltage is actually constant with BSOC.

For the same ampere-hour rating, higher the efficiency better is the battery.

d. Vehicle Range

Another obvious way of choosing the best battery is by selecting the one which provides greater drive range [9] between two consecutive full charges.

e. Battery Cost

Irrespective of the above performance indicators, the battery cost is also another important criterion which affects the final choice of battery. In most cases the final choice is made by finding a best compromise between the above parameters and the battery cost.

f. Maturity of Technology

Although, today there are many battery technologies available, but not all of them are ready to be deployed in vehicles on a commercial scale [10,11]. This will require further research, before it can be successfully incorporated in vehicles in an economic manner.

g. Other Limitations

Besides the above performance indices, each battery technology will have its own specific drawbacks like issues with operations at wide temperature range, risk of fire hazards etc. This should also be kept in mind before making the final choice of the battery.

III. COMPARISON BETWEEN VARIOUS BATTERY TECHNOLOGIES

Table I [5, 12] shows a comparison of various battery technologies with respect to the performance indices discussed above. Certain other relevant features of those battery types are discussed below

Amongst the various types discussed below Sealed Lead Acid Battery is the oldest and widely used battery type in most vehicles. But there are certain other advanced battery technologies which have specific advantages over the Sealed Lead Acid Battery. The extent to which these battery types can be employed in HEVs or PHEVs is discussed below.

a. Sealed Lead Acid Battery

Advantages:

i. Life Free maintenance

ii. Good low and high temperature performance

iii. Availability is more

iv. Per watt-hour cost is less

v. 500–800 cycles durability.

vi. Well established battery technology and widely used in all types of automobiles

Disadvantages:

i. Their construction, use, disposal or recycling shows impact on environment.

ii. It occupies (25–50%) portion of final mass of the vehicle.

iii. The energy density is lower than petroleum fuels—in this case, 30–40 Wh/kg.

iv. Storage capacity of the current generation of common deep cycle lead acid batteries decreases with lower temperatures and Efficiency (70–75%).

v. The power transferred to run a heating coil reduces efficiency which ranges up to 40%.

vi. 3–20% self-discharge rate/month.

b. Nickel Metal Hydride Battery

Advantages:

i. Energy density of 30–80 Wh/kg (far higher than lead-acid).

ii. Exceptionally long lives (above 160,000 km).

iii. High reputed companies such as Toyota and Nissan, uses these batteries for their line of HEV's

Disadvantages:

i. Do not have sufficient cycle stability.

ii. Less efficient (60–70%) in charging and discharging than even lead-acid. Its added weight would negatively impact the efficiency of the HEV.

iii. Self-discharge is more

iv. Inferior performance in cold weather.

v. High cost.

vi. The usage of these batteries are limited due patent restrictions.

c. Zinc Air Cells

Advantages [7]:

i. Significantly high energy density

ii. Prototype of such a battery has been made.

Disadvantages:

i. A multiple increase in the approx. 100 charging cycles required before wide scale future applications.

ii. This storage technology has not evolved to an extend that it can be widely used in HEVs or PHEVs.

d. Sodium Sulphur Battery

Advantages:

i. inexpensive cost.

ii. Raw materials are available easily

Disadvantages:

i. safe to use

ii. High operating temperatures of 300 °C, resulting in thermal self-discharge in vehicles that are not in operation for longer periods.

iii. Low power electrolyte.

e. Sodium Nickel Chloride Battery (Zebra Battery)

Advantages:

i. Relatively mature technology.

ii. An energy density of 120Wh/kg.

iii. Reasonable series resistance.

iv. It gives good operation in Cold weather.

v. Can last for a few thousand charge cycles.

vi. Are nontoxic.

vii. Prototypes of Mercedes A-Class were built. Since 2006 these products entered in commercial vehicles.

viii. Only FZ Sonick SA, part of Italian automotive supplier FIAMM Group, still supplies a niche market with small electric vehicles fitted with sodium nickel chloride batteries.

Disadvantages:

i. Increasing heating costs especially in cold weather.

ii. Power density is less (<300 W/kg).

iii. Not widely used. Renaissance of this battery not in sight at the moment.

f. Lithium Ion Battery

Advantages:

i. Lithium has most negative redox potential of all elements, thus allowing high voltages to the cathode.

ii. Low weight.

iii. High energy densities. Impressive 200+ Wh/kg energy density and good power density.

iv. 80 to 90% charge/discharge efficiency.

v. Potential for about 30% improvements in Energy Density of batteries.

vi. The maturity of this technology is moderate.

vii. Lithium-ion (and similar lithium polymer) batteries, widely known through their use in laptops and consumer electronics, dominate the most recent group of EVs in development.

viii. Most other EVs are utilizing new variations (phosphates, titanates, spinels, etc.) on lithium-ion chemistry that sacrifice energy and power density to provide fire resistance, environmental friendliness, very rapid charges (as low as a few minutes), and very long life spans.

Disadvantages:

i. It is expensive which costs 400 Euro/kWh.

ii. Short cycle lives (hundreds to a few thousand charge cycles).

iii. degradation with age. Cathode is also somewhat toxic.

iv. Can pose a fire safety risk if punctured or charged improperly.

v. Cannot accept or supply charge in cold conditions. Expensive and energy efficient systems are necessary to warm them up.

g. Lithium Air Battery

Advantages:

i. Theoretical achievable range is 11,000 Wh/kg. (without considering mass of oxygen).

Disadvantages:

i. Research is ongoing. At present they are present only in Labs, and not widely used in HEVs or PHEVs.

TABLE I
BATTERY OPTIONS.

Sl. No	**Type of Battery**	**Coulombic Efficiency**	**Range obtainable in vehicle for a battery weight of 350kg.**	**Wh/kg**	**W/kg**	**Cost in $ (current cost + future cost + environmental cost)**
1	Sealed Lead Acid Battery	78% - Chloride (Flooded Lead Acid) 97% - Delco (Sealed Lead Acid)	<100 km	30–40 (60–75 Wh/ltrs)	180 (412 for advanced lead acid batteries)	100+100+low with recycling
2	Nickel Metal Hydride Battery	88% - Ovonice 80% - Panasonic	Between 100 and 150 km.	60–120	220	1000+200+low
3	Zinc Air Cells	Is said to have high efficiency but not widely used	60000 km (tested for a 20 kW battery system by General motors)	More than 300 (non-rechargeable)	100	300+100+low
4	Sodium based energy storage solutions	Not widely used	Approx. 150 km for both Sodium Sulphur Battery and Sodium Nickel Chloride Battery (Zebra Battery)	• Theoretically 792for Sodium Sulphur Battery • Theoretically 787for Sodium Nickel Chloride Battery (Zebra Battery)	100 for Sodium Nickel Chloride Battery (Zebra Battery)	X+300+X for Sodium Nickel Chloride Battery (Zebra Battery)
5	Lithium Ion Battery	80–90%	>200km (approx. 250 km)	120–130.(Up to 250)	315 or more	X+X+low

h. Lithium Sulphur Battery

Advantages:

i. Theoretical achievable range is 3350 Wh/kg. (so far only 350Wh/kg achieved).

ii. Prototype made.

Disadvantages:

i. Security issues due to dendritic lithium deposits.

ii. Minimum conductivity of Sulphur electrode.

iii. Battery can only be recharged 50 times.

iv. One more 15 years before they become accessible for series production.

V. Recent Research in Battery Technology of 2019

Lithium-ion Batteries:

If we charge a battery more than its temperature limits it leads to the reduction in lifespan and degrading. But If we charge a battery carefully beyond the temperature limits we will have many benefits, like shorter plug in time and high efficiency.

A researchers team of Penn state university illustrated a novel battery which can hold the heat. Generally when a battery charges at around 60° C (140° F) temperature, Scientists consider this limit as "forbidden". But this novel battery technology reaches this temperature limit in 10 minutes and cools down slowly prior to the deleterious effects take hold.

In this novel battery a thin nickel foil is attached to the battery's negative terminal, once the electrons flows through it , it allows to warm up quickly. Before it cool down again. These results a safe charging of battery is possible at these temperatures across 1700 cycles. This is done at high efficiency, by these results the researchers says that 10 minutes charging of a battery gives a electric vehicle for a range of 200- to 300-mile range (320 to 480 km)

CO_2 battery goes fully rechargable:

As researchers described that a lithium carbon dioxide battery have seven time more energy density capacity than a lithium-ion battery, but recharging a lithium carbon dioxide battery is so difficult, because while charging, an unwanted carbon gets deposits on battery's catalyst. But this problem is rectified by using a combination of materials of "nanoflakes” of molybdenum disulfide built into the cathode, along with a hybrid electrolyte consisting of ionic liquid and dimethyl sulfoxide. This combination material prevents the carbon dioxide to accumulate on the catalyst, and permits the battery to charge for 500 Consecutive cycles.

VI. CONCLUSION

Hence, it can be concluded that for applications where efficiency is of prime importance either NiMH or Lithium Ion Battery can be used as they have high energy densities. But in applications where cost is of much concern than efficiency, Lead Acid Battery may be an ideal choice. But there are several applications where both efficiency and overall system costs are constraints of equal importance. In such cases a hybrid battery pack can be employed where both lead acid and Lithium Ion cells (or NiMH cells) are used in optimal numbers so that the load is met with highest possible efficiency at an affordable cost.

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