International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 07, July-2018

Battery Investigation for Electric Vehicle

Kartik Arora
Electronics and Communication Engineering (UG),
Vellore Institute of Technology
Vellore-632014, Tamil Nadu, India

***Abstract* - This paper discusses different types of batteries available in market and finding a suitable one for Electric Vehicle (EV). The battery must be chosen in a way to provide maximum efficiency and power while having less load on the battery. The cost should be minimum and the battery should have long life span for customer attraction. This paper puts forward an overview of the battery that should be used in an EV based on the customer requirements that should also be at par with the safety due to growing atmospheric temperature. A rechargeable battery that could power the vehicle as well as the auxiliary systems concerned with it is the main focus of this paper. Increase in global warming pushes the need to use renewable energy sources like solar energy, wind energy to charge the battery and dissipating the current and power requirements for the vehicle using an efficient battery management system (BMS). This paper presents the advantages and disadvantages of using different batteries in an EV.**

Keywords— Electric Vehicle (EV), Li-ion Battery, state of heath, Nickel Manganese Cobalt Oxide (NMC), specific energy, specific power

I. INTRODUCTION

The technology is upgrading day by day and we are in an era where electric vehicles are making their way into the market. EV are no longer a future now and can be seen running on the roads. Since the 19th century when EV came into existence, enhanced technology has made a greater way for EV to be used commercially. It reduces the burden on non-renewable fossil fuels and emphasizes the need to use renewable sources of energy for a sustainable future.

The minimal availability of charging stations battery plays an important role in the running span and efficiency of the vehicle. Renewable sources of energy can be used to recharge the battery as when needed.

The research indicates the cost of energy of 0.1302$/kWh on ECVS (Electronic Vehicle Charging Station) with an operating cost of 56,000$ approximately. [1]

The need to shift on renewable sources of energy also arises a question to use battery efficiently and with a longer life span to decrease the operating cost of the vehicle.

The wide availability of batteries in the market arises a dilemma to choose a perfect battery according to society's requirement.

Various type of rechargeable batteries offered presently for commercial use include: - [2]

- Lead acid batteries
- Lithium-ion batteries (Li-ion)
- Nickel Cadmium batteries (Ni-Cd)
- Nickel Metal Hydride batteries

The various parameters affecting the operation of these batteries in an EV comprise of:-

- *Specific power*
  The power to mass ratio of the battery
- *Specific Energy*
  It is defined as the energy per unit mass of the battery. (J/kg)
- *Safety*
  A safe battery should be resistant to heat and work on atmospheric conditions without any restrictions
- *Lifespan*
  The battery life of a battery in years
- *Cost*
  The combined prices of cells used to make a battery, it's one of the most important factor for commercial market
- *Performance*
  The

II. BATTERY PACK PARAMETERS [3]

- Temperature
- Depth of discharge
- Operation current
- Energy density:- how much energy can be stored in 1kg or 1L
- Work cycles
- Battery capacity
- State of Charge (SOC)
- State of Health (SOH)

Ampere-hour (Ah) Capacity

It is the total charge that a battery can dissipate or lose from a fully charged battery under specified or required conditions. The Rated Ah capacity of a battery is the nominal capacity of a charged new battery under the conditions that a manufacturer defines. For example, can be defined as 20C and discharging at 1/20 C-rate.

Rated Wh Capacity = Rated Ah Capacity x Rated Battery Voltage

C-rate.

C represents the battery charge or discharge rate over a period of one hour.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 07, July-2018

For Example 1.6 Ah battery, C is equal to charge or discharge the battery at 1.6A. Therefore 0.1C is equivalent to 0.16 A, and 2C to charge or discharge a battery at 3.2 A.

Specific Energy
Specific energy is used to measure how much energy is stored in per unit mass of a battery.
Unit: Watthours per kilogram (Wh/kg) as

Specific Energy = Rated Wh Capacity/Battery Mass in kg

Specific energy of a battery is a very important parameter to determine the total battery weight for a given distance range for an electric vehicle.

Specific Power
Specific power defines the peak power per unit mass of a battery.
Unit: W/kg as
Specific Power = Rated Peak Power/Battery Mass in kg

Peak Power
P= 2Voc2/9R, R-internal resistance of battery

Depth of Discharge (DOD)
It indicate the percentage of the total battery capacity that has been discharged since the battery was fully charged. Any deep-cycle batteries can be discharged up to 80% or higher than its DOD.
DOD = 1 – SOC

State of Health (SOH)
It is the ratio of the level to which a battery can be charged at maximum aged with time to the capacity when the battery was new or unused. It is a key indicator of performance degradation of a battery and to estimate the remaining life of the battery.
SOH = Aged Energy Capacity / Rated Energy Capacity

Cycles
It is the no of charge-discharge cycle that a battery undergoes at a specific DOD before it's performance degrades.

A comparison of diff types of batteries.

Comparison	NiCd	NiMH	Lead Acid	Li-ion	Reusable Alkaline
Energy Density (Wh/kg)	45-80	60-120	30-50	110-180	80
Internal Resistance(m ohm)	100-200	200-300	<100	150-250	200-2000
Lifespan(80% of capacity)	1500	300-500	200-300	500-1000	50
Charge Time(hour)	1	2-4	8-10	2-4	2-3
Overcharge Tolerance	Moderate	Low	High	Very low	moderate
Self-Discharge(room temperature)	20%	30%	5%	10%	0.3%
Cell Voltage(volts)	1.25	1.25	2	3.6	1.5
Load Current	20C	5C	5C	>2C	0.5C
Operating temperature(degrees)	-40 to 60	-20 to 60	-20 to 60	-20 to 60	0 to 65
Maintenance Requirement (days)	30-60	60-90	90-150	Nor required	Not required
Typical Battery Cost($)	50	60	25	100	5
Cost Per cycle($)	0.04	0.12	0.1	0.14	0.1-0.5

The above table summarizes the fact to use Li-ion battery in obedience to their use in EV. [4] The fact of using Li-ion batteries in an EV brings forward another question of which Li-ion best suits the need of EV market.

III. BATTERY TYPES

Lead Acid batteries
Conventional lead acid batteries provide reliable solutions for automotive applications. It provide low cost per watt hour and is really simple to manufacture. These batteries provide an edge over the various rechargeable batteries in the consumer market because of their simple construction and low maintenance cost, moreover they establish a recycling chain. But the biggest demerit of this battery for their application in electric vehicles is the low energy density i.e. less energy per unit mass of the battery. [6]
Also they allow only a few and a limited no of cycle and only have a small window for partial state of charge and the deposition on negative electrodes degrade their life. [7]

Nickel Cadmium batteries (Ni-Cd)
Nickel Cadmium battery have been in use since a long time and find their application in most of the devices like AAA batteries, adapters etc. These batteries have a wide range availability depending on sizes and voltage requirements at very affordable prices. The easy and fast charging along with a long life time but has high discharge rate. [8]
With all these merits it has a few drawbacks that make it inefficient and unsuitable for electric vehicle market, the main demerit being the low energy density which is top priority for EVs and must be high. Also it contains toxic metals making it difficult to dispose of recycle after its lifetime.

The power supply and performance is also not met as per the electric vehicle requirements and hence we discard it.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 07, July-2018

Nickel Metal Hydride batteries (NiMH)

This type of rechargeable battery has been an important source of energy in the recent years, some electric vehicle manufactures have been using NiMH batteries to power their vehicle because of their low cost which turn out to be a merit for commercial use. At the same the electric vehicle need high specific energy for higher efficiency which NiMH fails to deliver, simultaneously it has a higher discharge rate of more than 50% than Ni-Cd as well and degradation in performance with rising temperatures which rules out its use in countries with high temperature. [9] [10]

IV. LITHIUM ION BATTERY

Li ion battery is one of the most widely used rechargeable battery in the market which involves the movement of li-ions from negative electrodes of the cells to their positive electrodes during the discharge and vice versa while charging.

The wide application of Li-ion cells include home appliances, portable electronics with high energy density and low discharge rate. The need of electric vehicle market is also being catered by the Li-ion cells because of their less weight, high energy density and increased lifespan and performance.

The average *specific energy* of various li-ion cells available in the market goes up to *100-265 Wh/kg* along with an *average power of 250-340 W/kg.* [5]

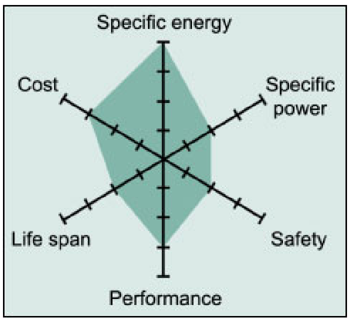
Self-discharge rate – 2% per month
Average charge-discharge cycles- 400-1200
Nominal Cell voltage- 3.6V

V. TYPES OF LI-ION BATTERY

- Lithium Cobalt Oxide
- Lithium Manganese Oxide
- Lithium Nickel Manganese Cobalt Oxide(NMC)
- Lithium Iron Phosphate (LiFePo4)
- Lithium Nickel Cobalt Aluminum Oxide
- Lithium Titanate
- Lithium Polymer

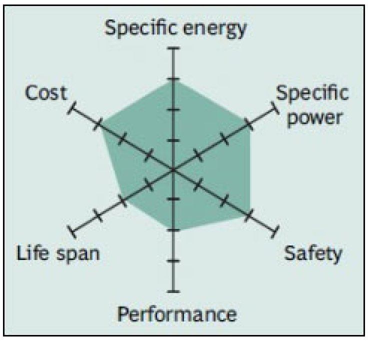
Lithium Cobalt Oxide

This type of Lithium ion battery offers high specific energy and is widely used in laptops and mobile phones. It is available at a low cost and with a moderate performance. It has a low specific power, low lifespan, and low safety which makes it unsuitable for EVs.



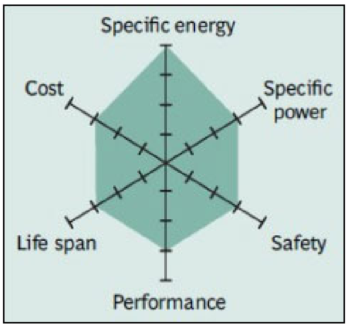
Lithium Manganese Oxide

It offers a moderate specific power, moderate specific energy, and a moderate level of safety when compared to the other types of Li-ion batteries. Though it's a low cost battery but because of low performance and low lifespan it is usually used in medical devices and power tools.



Lithium Nickel Manganese Cobalt Oxide (NMC)

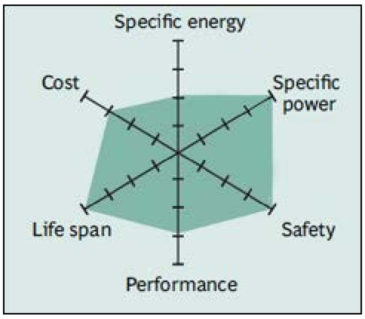
This type has two major advantages as compared to the other batteries, *high specific energy* which pushes its use in electric powertrains, electric vehicles and electric bikes. The second is its *low cost*. It offers moderate specific power, safety, lifespan and performance compared to the other lithium-ion batteries. It can be modified to either have a high specific power or a high specific energy.



Lithium Iron Phosphate (LiFePo4)

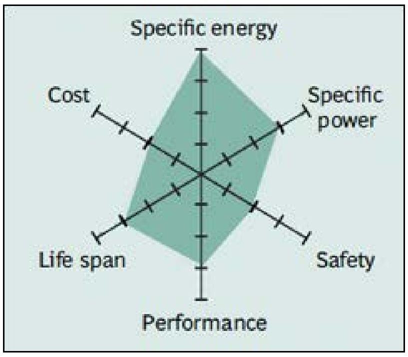
This battery has one major drawback as compared to other types of lithium-ion batteries and that is its low specific energy. Apart that it has a moderate to high rating in all the other characteristics. High specific power, High level of safety, High lifespan, low cost and moderate performance. It is being used in electric motorcycles and other applications that require a long lifespan and high level of safety. If a solution could be found to increase the specific energy of LiFePo4, it finds perfect application in the EVs.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 07, July-2018



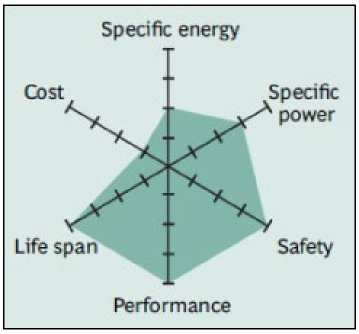
Lithium Nickel Cobalt Aluminum Oxide

It only offers high specific energy, apart from this it's safety is low, performs low but because of long lifespan it finds perfect application in power trains.



Lithium Titanate

Offers high safety, high performance and a high lifespan but its specific energy is low compared to the other lithium-ion batteries but it compensates this with a moderate specific power, also its high cost discards it for commercial use. This battery has remarkably fast recharge time and find perfect application for storing solar energy and creating smart grids.



Inference

Lithium ion battery types	Specific power	Specific Energy	safety	Lifespan	cost	performance
Lithium Cobalt Oxide	L	H	L	L	L	M
Lithium Manganese Oxide	M	M	M	L	L	L
Lithium Nickel Manganese Cobalt Oxide	M	H	M	M	L	M
Lithium Iron phosphate	H	L	H	H	L	M
Lithium Nickel Cobalt Aluminium Oxide	M	H	L	M	M	M
Lithium Titanate	M	L	H	H	H	H

H-high
M-Medium
L-Low

[11]As an inference from the table and battery description above the best suited Lithium ion battery should be *Lithium Nickel Manganese Cobalt Oxide with: -*

- *High specific Energy*
- *Low Battery Cost*
- *Moderate Performance*
- *Moderate lifespan of approx. 5-6 years*
- *Moderate safety*
- *Moderate Power supply*

VI. SAMPLE BATTERY PARAMERTER ESTIMATION

Assuming a battery of 24V, 100Ah Capacity ($LiFePO_4$)

Battery specs [12]

Nominal Voltage= 3V/cell for 24V, 8 cells in series

Rated capacity = 1.25 Ah/cell for 100Ah, *80 cells, 8 x 10 matrix*

Cell weight = 36g/ cell

80 cell, *weight*= 36g * 80 = 2.88 kg (battery mass)

Cell radius, r=0.915cm

Cell height, h=6.45cm

Cell Volume, V_1=pi * r^2 * h=3.14*0.915*0.915*6.45=16.9563 cm^3 = 0.01695 L

80 cell, *Volume*, V= 0.01695 * 80 = 1.3565 L (battery volume)

Specific Energy = Rated Wh Capacity/Battery Mass in kg

Cell Nominal V = 3V

Cell Capacity = 1.25 Ah

Cell Capacity = 3V * 1.25Ah = 3.75 Wh

80 cells, Capacity = 3.75 Wh * 80 = 300 Wh

Specific Energy = 300 Wh/ 2.88 kg = 104.167 Wh/kg

Peak Power. $P= 2V_{oc}^2/9R$

V_{oc} = 3.3V (>=3.3V)

R = 80 mohm (<=80 mohm)

1 cell, P = 2 * 3.3 *3.3/(9 * 0.08) = 30.25 W

80 cells, P= 30.25 * 80 = 2.42 kW

Specific Power = Rated Peak Power/Battery Mass in kg

S.P. = 2420 W/ 2.88 kg = 840.278 W/kg

Energy Density= battery energy / volume (Wh/l).

Energy Density = 300 Wh / 1.3565 L = 221.1574 Wh/L

Power Density= peak power / volume of a battery (W/l).

P.D. = 2420 W/ 1.3565 L = 1784.003 W/L

State of Charge, SOC = Remaining Capacity / Rated Capacity

Depth of Discharge (DOD) = 1 – SOC

State of Health, SOH = Aged Energy Capacity / Rated Energy Capacity

VII. CONCLUSION

The above discussion and finding on various types of rechargeable batteries available in the market based on the battery parameters and factors influencing their performance, Li-ion battery offers the best and well suited advantages to find use in electric vehicles. Despite some disadvantages of Li-ion battery which can be taken care of during its application this battery is in obedience with all the requirements of an EV.

Going deep in Li-ion battery and studying its types *Lithium Nickel Manganese Cobalt Oxide (NMC)* is well suited for electric vehicles. If the cost of Lithium Titanate Oxide could be reduced somehow it offers best properties for the application in this field.

All data conclude to one simple requirement of electric vehicle i.e. high energy density, high power density and high performance requirement. If any battery meets these 3 requirements other factors could be still altered to meet the need of the vehicle.

REFERENCES

[1] Ashish Kumar Karmaker, Md. Raju Ahmed, Md. Alamgir Hossain and Md. Mamun Sikder, “Feasibility Assessment & Design of Hybrid Renewable Energy Based Electric Vehicle Charging Station in Bangladesh,” Sustainable Cities and Society , Feb2018

[2] https://www.batterysolutions.com/recycling-information/battery-types/

[3] http://iopscience.iop.org/article/10.1088/1757-899X/211/1/012005/pdf http://iopscience.iop.org/article/10.1088/1757-899X/211/1/012005

[4] http://batteryuniversity.com/learn/archive/whats_the_best_battery

[5] https://en.wikipedia.org/wiki/Lithium-ion_battery

[6] http://sci-hub.tw/https://ieeexplore.ieee.org/document/8333717/

[7] Sandia National Laboratories, “Energy Storage Systems Program (ESS),” http://www.sandia.gov/ess/

[8] https://www.doityourself.com/stry/nicd-battery-advantages-and-disadvantages

[9] https://www.cobaltinstitute.org/nickel-metal-hydride-batteries.html

[10] http://www.mdpi.com:8080/2313-0105/4/1/9/pdf

[11] https://www.batteryspace.com/prod-specs/LFP18650.pdf

[12] http://batteryuniversity.com/learn/article/types_of_lithium_ion