Investigation on Battery for Electric Vehicle Application

R. Revathy[*], *J.Visveswar*

Department of EEE, IFET College of Engineering, Villupuram, Tamilnadu, India

Abstract. Battery powered electric vehicles are becoming increasingly important in the automotive industry. It is hard to decide which battery meets all the most important characteristics from different perspectives such as energy storage efficiency, construction characteristics, cost price, safety and service life of today's Electric Vehicles. Investigation on different types of batteries are discussed in this paper. Among the most important components of a car is the battery. Only the stored electrical energy in the battery provides the power for BEVs which is the unique source of energy. Various types of batteries are used in electric cars depending on their systems. The lithium-ion battery is the most common electric car battery. A battery which is considered zero emission is abbreviated as ZEBRA. In this paper, we can gain knowledge over the different types of battery options available for electric vehicles, along with their characteristics.

Keywords*—Electric Vehicle, Batteries, Storage Efficiency, Cost Price, Lithium-ion Battery, ZEBRA, BEV*

I. Introduction

In a Battery Electric Vehicle (BEV) or hybrid electric vehicle, the electric motors are propelled by a battery, sometimes referred to as the traction battery. Typically, Lithium-ion batteries are designed to have high electric charge (or energy) capacities. Deep-cycle batteries are distinguished electric vehicle batteries, where ignition batteries are made to supply power for extended periods of time. Smaller and lighter batteries are preferred because they enable a vehicle to weigh less and run more effectively. Electric Vehicles are characterised by their comparatively high power-to-weight ratio, specific energy and energy density. The specific energy of the majority of today's batteries is lower than that of liquid fuels, which frequently affects the maximum all-electric range of vehicles. M. Broussely [1] examines the Battery Requirements for HEVs, PHEVs and EVs. Bloomberg NEF (BNEF) [2] depicts the Battery Pack Prices Cited Below $100/kWh without precedent for 2020, While Market Average Sits at $137/kWh. M. M. Whiston, I. et al [3] examines

[*]revakrishnan89@gmail.com

master appraisals of the expense and expected future execution of proton trade film energy units for vehicles. M. Franke et al [4] introduced empirical sulfation model for valve-directed lead-corrosive batteries under cycling activity. J. Wu et al [5] introduced a web-based technique for lithium-particle battery staying helpful life assessment utilizing significance inspecting and brain organizations. R. Xiong et al 6] proposes a twofold scale, molecule separating and energy state expectation calculation for lithium-particle batteries. Tie S.F. et al [7] portrays a survey of fuel sources and energy, the broad framework in electric vehicles. Youthful K et al [8] examines Electric Vehicle Battery Technologies in Electric Vehicle Integration into Modern Power Networks. Boribun et al [9] presents demonstrating and analysis of the Plug-in Electric Vehicles Charging in the Unbalanced Radial Distribution System. Y. Zhang et al [10] examines long transient memory repetitive brain network for staying valuable life expectation of lithium-particle batteries. Chang-sheng, F et al [11] examines design of the auto electric power framework regulator. Ziyad M. Salameh et al [12] presents Electrical Component Model for a Nickel-Cadmium Electric Vehicle Traction Battery. Z. Chen et al [13] proposes Battery Pack Grouping and Capacity Improvement for Electric Vehicles Based on a Genetic Algorithm.

Due to their high energy density in comparison to their weight, lithium-particle and lithium polymer batteries are the most popular battery types in modern electric vehicles. Lead-corrosive, nickel-cadmium and nickel-metal hydride are less frequently used, while zinc-air and sodium nickel chloride batteries are among the various battery-powered battery types used in electric cars. The amount of power stored in batteries such as electric charge is calculated in ampere hours or coulombs with the total energy typically calculated in kilowatt-hours (kWh).

II. Different Types of Batteries used in EV

a) Lead-Acid (SLA) Batteries

The oldest powered batteries are SLA (lead-corrosive) batteries. Lead-corrosive batteries have less capacity and are much heavier than lithium and NiMH batteries, but the price is quite low and they are safe. Large-capacity SLA electric vehicle batteries are under development however they are currently only used as an optional stockpiling system by commercial vehicles.

In EV applications lead-corrosive batteries end up making up a sizable portion (25%) of the final vehicle mass. Like other batteries, they have about 30–50 Wh/kg of explicit energy, which is less than oil fills in this case. The heavy batteries will typically result in larger masses when applied to vehicles with an average reach, even though the difference isn't as glaring as it first appears due to the lighter drive-train in an EV. Lower temperatures have a negative effect on the productivity (70–75%) and capacity limit of on-going deep cycle lead acid batteries and the ability to operate a warming loop in a different way can reduce efficiency and reach by up to 40%.

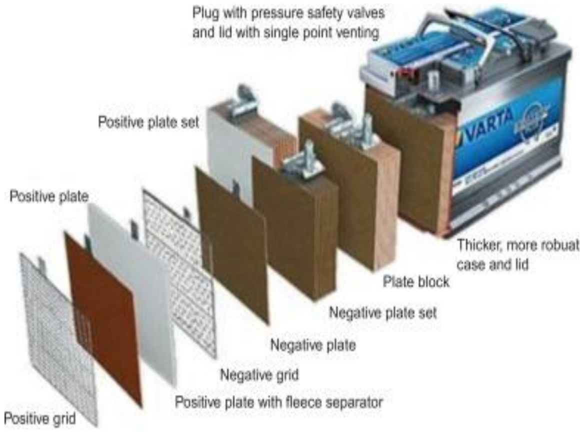


Fig.1. Lead-Acid Battery

b) HYBRID NICKEL-METAL (NIMH) BATTERIES

NiMH batteries are broadly utilized by crossover electric vehicles (HEV) but at the same time are utilized effectively in some BEV vehicles. This kind of crossover electric vehicle battery doesn't get power from outside (can be re-energized from an external wellspring of the vehicle framework). The re-energizing of crossover electric vehicle batteries relies upon motor speed, haggles slowing down. NiMH batteries have a more drawn-out life cycle than lithium-particle batteries or SLA batteries. NiMH batteries are protected and lenient towards utilization. The greatest impediments of NiMH batteries include:

- The cost is moderately more costly
- High self-release rate
- Produce critical intensity at high temperatures.

These inadequacies make NiMH less powerful as a battery for electric vehicles whose batteries should have the option to be re-energized from outside the framework. For this reason, the vehicle battery is the most generally applied by crossover vehicles.

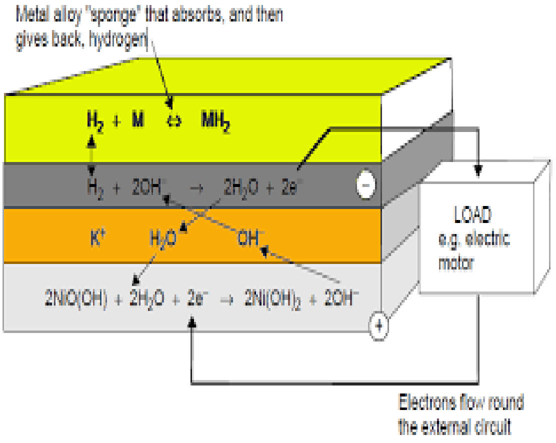


Fig.2.Nickel-Metal Battery

c) Solid-State Batteries

Solid state batteries are broadly promoted to be the following large forward leap in battery innovation. These wouldn't supplant lithium-particle in that capacity, however would utilize a strong as opposed to a fluid electrolyte. At the point when the innovation is idealized, there are various advantages to get from solid state batteries. Solid state batteries would be lighter and more minimal than current batteries with a fluid electrolyte, that implies the heaviness of the vehicle could be decreased or the capacity limit expanded. Solid state batteries would likewise be more impervious to fire if they are penetrated or affected, as they come up short on combustible fluid electrolyte.

Most extreme charging rates would likewise be extraordinarily improved with a full re-energize accomplished in barely 10 minutes. Almost certainly, they will have a significantly longer life expectancy. Scientists at Harvard have proactively planned a lithium-metal solid state battery that can be charged and released something like multiple times at a high current thickness. Strong state batteries have several drawbacks when contrasted with lithium-particle batteries. Producing solid state batteries at an enormous scope is troublesome. This is probable to a great extent because of the freshness of the innovation and the intricacy of going from lab information to large scale manufacturing.

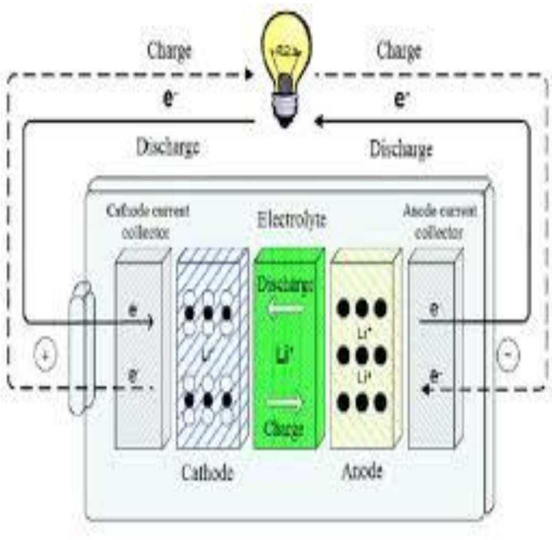


Fig.3.Solid-State Battery

d) ULTRA-CAPACITOR BATTERIES

The ultra-capacitor battery is not similar to the normal battery. As opposed to other electro-substance batteries, this sort of electric vehicle battery really stores spellbound fluid between the cathode and the electrolyte. As the surface region of the fluid expands, the energy stockpiling limit additionally increases. Like SLA batteries, ultra-capacitor batteries are entirely appropriate as optional stockpiling gadgets in electric vehicles. This is on the grounds that the ultra-capacitor helps electro-synthetic batteries increment their heap levels. Likewise, ultra-capacitor can give additional capacity to electric vehicles during speed increase and regenerative slowing down.

Fig.4.Ultra-Capacitor Battery

e) LITHIUM-ION BATTERIES

Lithium-particle batteries are the most well-known storage device, they release and re-energize as the electrolyte conveys emphatically charged lithium particles from the anode to the cathode as well as the other way around. Notwithstanding the materials utilized in the cathode can shift between lithium-particle batteries. LFP, NMC and NCA are three different sub-sciences of Lithium-particle batteries. LFP involves Lithium-phosphate as cathode material, NMC utilizes Lithium, Manganese, Cobalt and NCA utilizes Nickel, Cobalt and Aluminium.

Lithium is also the lightest of all metals. However, lithium-ion (Li-ion) batteries contain no lithium metal but they contain ions. For those wondering what an ion is, an ion is an atom or molecule with an electric charge caused by the loss or gain of one or more electrons. Lithium-ion batteries are also safer than many alternatives. Battery manufacturers have to ensure that safety measures are in place to protect consumers in the unlikely event of a battery failure. Li-ion batteries have a wide range of uses, including portable devices and home appliances with high energy density. The Li-ion cells are used to power electric vehicles because of their increased longevity, improved performance, high energy density and low weight. 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. Self-discharge rate is 2% per month and average charge-discharge cycles is 400-1200 and nominal Cell voltage is 3.6V.

Advantages of Lithium-particle batteries:

- Less expensive to deliver than NMC and NCA batteries.
- Longer life expectancy - convey 2,500-3,000 full charge/release cycles contrasted with 1,000 for NMC batteries.
- Produce less intensity during charging so it can support a higher pace of force longer into the large bend, prompting quicker charge without battery harm.
- Can be accused to 100 percent of little battery harm as it assists with adjusting the battery and give more exact reach gauges. Model 3 proprietors with a LFP battery are encouraged to keep as far as possible set to 100 percent.

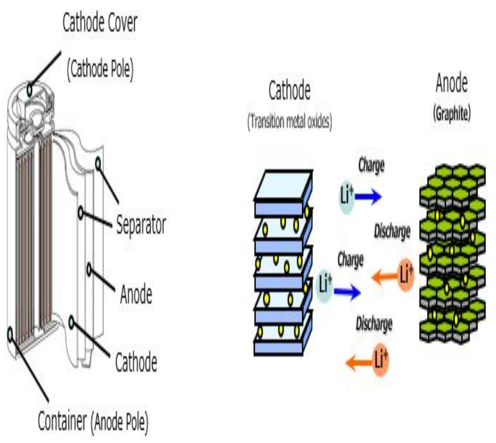


Fig.5.Lithium-ion Battery

III. INVESTIGATION ON BATTERY FOR ELECTRIC VEHICLE

The quantity and type of batteries are used to determine a BEV's range. As with the mileage of standard vehicles, the weight and kind of the vehicle, as well as the terrain, the weather and the driver's behaviour, all have an impact on the battery efficiency. Execution of the electric vehicle changeover is dependent on a number of factors, including battery science:

- The cheapest and most widely available batteries are lead-corrosive ones. Typically, the range of these alterations is between 30 and 80 kilometres (19-50 mi). EVs manufactured today are capable of travelling up to 130 kilometres (81 mi) on a single charge.

- Model EVs may travel up to 200 km (120 mi) with NiMH batteries, which contain more explicit energy than lead-corrosive batteries.

- New electric vehicles (EVs) equipped with lithium-ion batteries offer 320–480 km (200–300 mi) of range per charge. Additionally, lithium is less expensive than nickel.

Regenerative braking energy during slowing down can increase range by up to 50% under extreme traffic circumstances without completely stopping with an AC framework or high-level DC framework. However, depending on the region, the reach is generally extended by 10 to 15 percent when travelling in cities, but not at all when driving on throughways. Battery execution testing often includes the guarantee of:

- Province of Health (SOH)
- Territory of Charge (SOC)
- Energy Efficiency

During regenerative braking, mechanical energy is converted into electrical energy and stores it in a synthetic structure. At least one voltaic cell is present. A conductive electrolyte is linked in series to each voltaic cell's, one of which is the positive terminal (the anode) and the other is the negative terminal (the cathode). The electron exchanges that take place during redox reactions power the battery. Redox processes involve two simultaneous reactions that is oxidation at the anode and reduction at the cathode. To allow for redox reaction, various materials are used to make the electrodes. The electrolyte connects the two electrodes electrically, even when they are not in contact (solid or liquid).

In this proposed system the regenerative braking of an electric vehicle has been simulated using MATLAB software. The power circuit consists of DC-DC converter, Universal controller, BLDC motor, Battery circuit and Super capacitor circuit. Each component's output can be connected to a distinct scope and the system's input is a DC source from the battery.

The main battery pack serves as the system's source of power. The 100V is set as input voltage for the operation of motor. The BLDC motor has stator which is like in induction motor and stator which is like in normal DC shunt motor. So, the BLDC motor can operate in both AC and DC mode as per the requirements of the motor. The BLDC motor works here by AC voltage to improve the efficiency of the motor up to 10% and to run the electric vehicle with adequate speed by change in frequency and the controlling of motor can be easier which is possible by giving AC voltage at the input of the BLDC motor. However, the BLDC motor cannot be started with just 100 volts, so the input voltage is sent through DC/DC converter to increase the input voltage. Then the reference voltage set to 280V.

By the means of converter action, the input voltage from the battery can be improved and which is given to the input of the motor through universal bridge. At the time of motor action, the universal bridge act as a inverter to convert the DC supply into AC. The hall sensor checks the position of the BLDC motor and the input supply is taken from the battery through inverter circuit as the motor starts to run and during regenerative braking operation the motor will act as a generator which convert some mechanical energy into electrical energy due to brake applied. Then the converted energy is stored into the super capacitor by converter (at regenerative mode, the universal bridge act as a converter circuit, which convert ac into dc) and the stored energy is sent back from the super capacitor while battery gets drained. By this process the electric vehicle can go further more miles and the input voltage taken from the battery is also reduced by using DC/DC converter circuit.

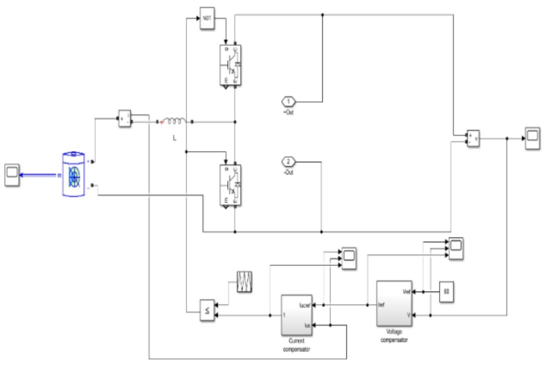


Fig.6.Simulation Circuit for Investigation on Battery for Electric Vehicle

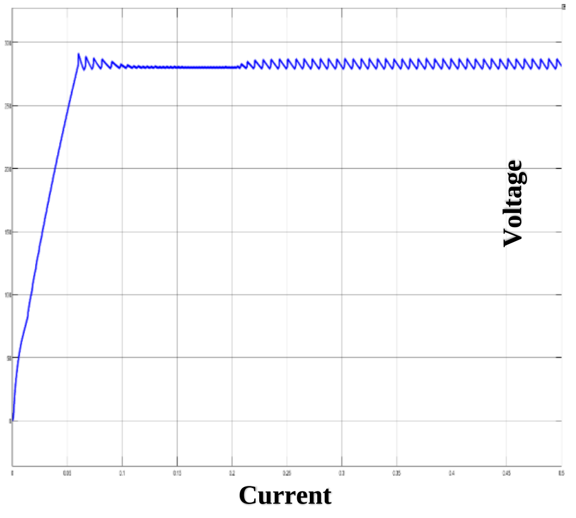
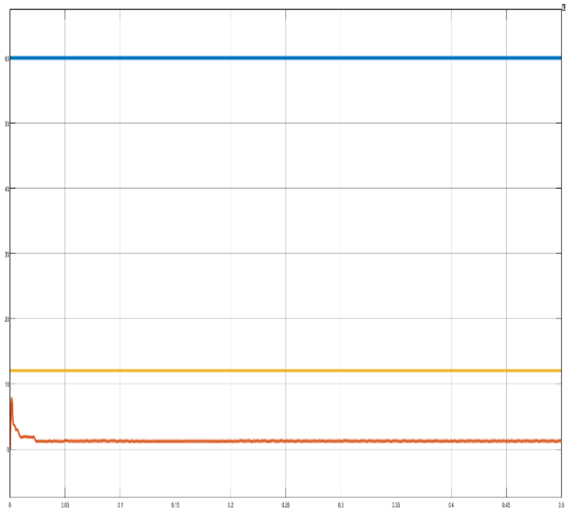


Fig.7.Simulation output of battery's output



Current

Fig.8. Simulation output of battery's input

TABLE.1 INVESTIGATION ON BATTERY FOR ELECTRIC VEHICLE

Sl.no	Types of batteries	Mass energy density	Volume energy density	Power density	Charging/ discharging efficiency
1	Lead acid battery	30-40 Wh/Kg	60-75 Wh/L	180 W/Kg	70-92%
2	Nickel-Metal battery	40-120 Wh/Kg	140-400 Wh/L	220 W/Kg	65-80%
3	Solid state battery	100 Wh/Kg	75-120 Wh/L	150 W/Kg	75-85%
4	Ultra-capacitor battery	120 Wh/Kg	100-140 Wh/L	200-275 W/Kg	60-70%
5	Lithium-ion battery	100-180 Wh/Kg	200-300 Wh/L	250-340 W/Kg	95-99%

IV. CONCLUSION

In this paper, we discussed five different kinds of batteries for electric vehicle application on various standards like energy stockpiling effectiveness, productive qualities, value, security and usage life. The Lithium-particle Battery is more productive while contrasting and different batteries since it has high effectiveness, high mass energy thickness, high volume thickness, high power thickness and furthermore less in weight and size. From this we realize that the lithium-particle battery has 95-almost 100% proficiency when contrast and different batteries. Along these lines, Lithium-particle battery is more reasonable for Electric Vehicle applications.

REFERENCES

[1] M. Broussely, "Battery Requirements for HEVs, PHEVs, and EVs: An Overview, pg. 307. In: Electric and Hybrid Vehicles, Power Sources, Models, Sustainability, Infrastructure and the Market", Chapter 13, pp. 305-345, Elsevier B.V., 2010.

[2] BloombergNEF (BNEF), "Battery Pack Prices Cited Below $100/kWh without precedent for 2020, While Market Average Sits at $137/kWh," Bloomberg, 2020.

[3] M. M. Whiston, I. L. Azevedo, S. Litster, K. S. Whitefoot, C. Samaras and J. F. Whitacre, "Master appraisals of the expense and expected future execution of proton trade film power devices for vehicles," Proc. Natl. Acad. Sci., vol. 116, no. 11, pp. 4899-4904, 2019, doi: 10.1073/pnas.1804221116..

[4] M. Franke, J. "Kowal, Empirical sulfation model for valve-directed lead-corrosive batteries under cycling activity, Journal of Power Sources", Volume 380, 2018, Pages 76-82, Feb. 2018.

[5] J. Wu, C. Zhang, and Z. Chen, "A web-based technique for lithium-particle battery staying helpful life assessment utilizing significance testing and brain organizations," Applied Energy, vol. 173, pp. 134-140, Jul. 2016.

[6] R. Xiong, Y. Zhang, H. He, X. Zhou and M. Pecht, "A twofold scale, molecule separating, energy state expectation calculation for lithium-particle batteries," IEEE Transactions on Industrial Electronics, vol. 65, no. 2, pp. 1526-1538, Feb. 2018.

[7] Tie S.F. also, C.W. Tan, "A survey of fuel sources and energy the board framework in electric vehicles, Inexhaustible and Sustainable Energy Reviews", 2013. 20: p. 82-102.

[8] Young K., et al., "Electric Vehicle Battery Technologies, in Electric Vehicle Integration into Modern Power Networks", R. Garcia-Valle and J.A. Peças Lopes, Editors. 2013, Springer New York. p. 15-56.

[9] P. Pao-la-or and B. Boribun, "Demonstrating and Analysis of the Plug-in Electric Vehicles Charging in the Unbalanced Radial Distribution System," Int. J. Electr. Electron. Eng. Telecommun., vol. 8, no.

[10] Y. Zhang, R. Xiong, H. He and M. Pecht, "Long transient memory intermittent brain network for staying valuable life expectation of lithium-particle batteries," IEEE Transactions on Vehicular Technology, vol. 67, no. 7, pp. 5695-5705, Jul. 2018.

[11] Chang-sheng. F and G. Yan-ling,” Design of the auto electric power guiding framework regulator Procedia Engineering”, 2012. 29: p. 3200-3206.

[12] W. A. Lynch, Ziyad M. Salameh, "Electrical Component Model for a Nickel-Cadmium Electric Vehicle Traction Battery", IEEE Annual Vehicular Technology Conference,Toronto, Canada. July 4-9, 2006.

[13] Z. Chen, N. Guo, X. Li, J. Shen, R. Xiao, S. Li,” Battery Pack Grouping and Capacity Improvement for Electric Vehicles Based on a Genetic Algorithm”, vol 10, issue 4, 2017.