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Future of Flow Batteries in Electric Vehicle Applications

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***Abstract:** Electric vehicles are used nowadays to reduce carbon emissions and green house gases. The main challenge in the electric vehicles is the energy storage systems. For battery operated vehicles, the increase in charging time is the major concern and range of the vehicles for a single charge is not satisfied. This leads to restrict the commercialization of electric vehicles. To overcome this, researchers and industry peoples has developed a hybrid vehicle technology which contains both electric and internal combustion engines. The efficiency of the hybrid vehicle is increased when it is incorporated with IC engines. But still the energy storage issues are censorious. Now the potential area in the energy storage systems is flow batteries. The main advantage of the flow batteries is fast charging tendency. Refuelling is possible only in case of flow batteries among all energy storage devices used in electric vehicles. This paper provides the study of flow batteries used in electric vehicles and comparison of different flow batteries for electric vehicle applications.*

***Keywords:** Energy efficiency, Flow Batteries, Electric Vehicles, Redox Batteries*

I. INTRODUCTION

To reduce the carbon emissions and green house gases from the transportation the researchers have more concern about the electric vehicles. Even though the internal combustion engine vehicles have high efficiency, the pollution caused by the vehicles is not accepted. Hence the electric vehicle technology provides pollution less transportation. Also the shortage of the fossil fuels in recent days leads to improvement in the electric vehicle manufacturing industries. Various types of electric vehicles such as battery operated electric vehicles, hybrid electric vehicles, plug in hybrid electric vehicles. The main challenge in the electric vehicles is the energy storage technology. There is lot of research works in the area of energy storage devices used in electric vehicles. The major concern about the batteries is the charging time and its efficiency in all operated conditions. The researchers work on the field of charging time reduction for batteries. In olden days lead acid batteries are the major resource for the electric vehicle applications. It provides good efficiency in all operated conditions, excellent life span and provides good reliability for the transportation application. The energy density of the lead acid batteries is about 30-40 Wh/Kg [1]. But the lead acid battery has some limitations such as maintenance and high cost and weight of batteries are much higher when compared with all other devices.

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The next era of the energy storage device is lithium batteries. This type of batteries is most commonly used batteries in electric vehicle applications. It has a main advantage as less weight compared with lead acid batteries. The energy and power density of the lithium batteries are higher enough for the electric vehicle applications. The energy density of the lithium ion batteries is about 110-160 Wh/Kg [1],[2]. But the cost of the lithium batteries is high. The charging time of the lithium batteries are not satisfied for transportation. To reduce the charging time flow batteries are used in electric vehicles. The advantages of the flow batteries are moderate cost, modularity, transportability and flexible operation. Flow batteries allow a degree of separation of power and energy components. The electrolyte used on the flow batteries is liquid electrolytes. The flexibility operation gives the optimization of electric vehicles and very much useful in electric vehicle design [2]. This paper provides the chemistry of the flow batteries and considerations for electric vehicles and efficiency comparison of flow batteries.

II. CHEMISTRY OF FLOW BATTERIES

The flow batteries are used to convert chemical energy into electrical energy in which the power and storage capacity can be largely decoupled. The power handling capacity of the flow type energy storage device is depends on the modelling of cells and its stacks. The storage capacity depends on the size the storage tank, amount of electrolyte present in the tank and the concentration of the chemicals used in the flow batteries. Figure 1 shows the general diagram for flow batteries. It consists of two electrochemical cells which are divided from a whole cell. One part is taken as positive and another one is taken as negative cell. These two cells are separated by the ion exchange membrane. The electrolyte is pumped via the pump. The electrochemical redox reactions occur in the two electrodes. The ion exchange membrane transports the proton between the electrodes and it is essential for maintaining electrical neutrality and balance of electrolyte but it leads to lower the transport of reactive elements between positive and negative electrodes in a minimum manner.
Hence the electron flows through the load and the battery gets discharged. The both positive (P) and negative (N) ions are illustrated in figure 1 [2],[3].
In this type of flow batteries, after complete discharge of the battery it can be easily recharged or replaced the electrolytes by fully charged electrolytes. That is refuelling is possible in case of flow batteries and it is similar to the petrol/diesel filling of conventional IC engine vehicles. In general the acceleration of the vehicle is based on the power handling capacity and the energy level is based on the range of vehicle travelled.

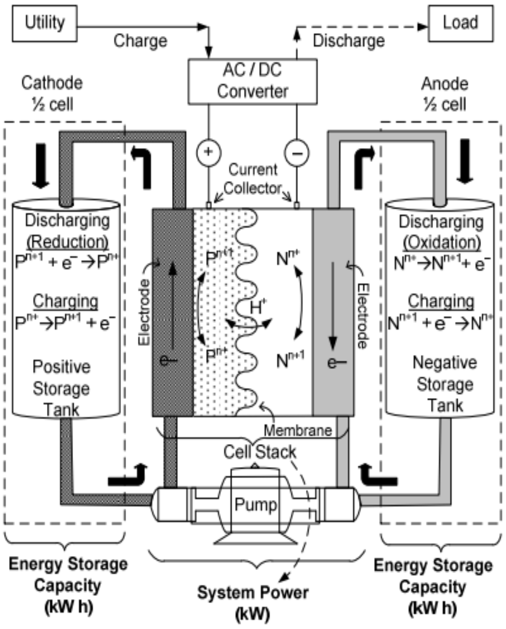

Figure 1: Single stack showing principle of flow batteries [2]

In flow batteries these two parameters are decoupled and this provides freedom for the vehicle designer. The major factor in the flow batteries is the storage tanks. The physical structure and sizing of the tanks have more flexible to the designers to meet out the required specifications of the vehicles. In normal batteries power and capacity is directly coupled so there is flexibility for the design of electric vehicles. Hence the volume of electrolyte storage is increased then the energy capacity is increased.

Flow batteries have an option of refuelling electrolyte; large charged electrolyte tanks can be placed in the charging stations and refuelling or swapping of discharged electrolyte to charged electrolyte at very fast rate that is short duration of time at the charging station. In charging stations also discharge electrolyte can be charged at the peak less time of the grid. Therefore the grid stability will be increased [3],[8].

III. RESULTS AND DISCUSSIONS

Based on the survey, flow batteries will be suited for Electric vehicles. The electric vehicle should have low weight batteries and good efficient batteries. Charging and discharging also the major concern or electric vehicles. The table 1 shows the comparison o flow batteries.

Table 1: A comparison of flow batteries [2]

Batteries	% Energy	% voltage	% Wh/Lit	% W/Lit
Bromine-polysulphi-de	77	75	20-35	60
Vanadium-vanadium	73	81	20-35	60-100
Iron-chromium	66	82	20-35	60-100
Vanadium-bromine	-	80	20--35	50
Zinc-/bromine	80	-	20-35	40
Zinc-cerium	83	-	20-35	50

The figure 2 shows the two different energy densities of commonly used electric vehicle batteries. The X axis shows the Energy density in Wh/Litre and Y axis shows the Wh/Kg. The electrolyte of the flow battery is water and ordinary liquids. Hence the flow battery will give good efficiency and it decreases the charging rate when compared with all other batteries.

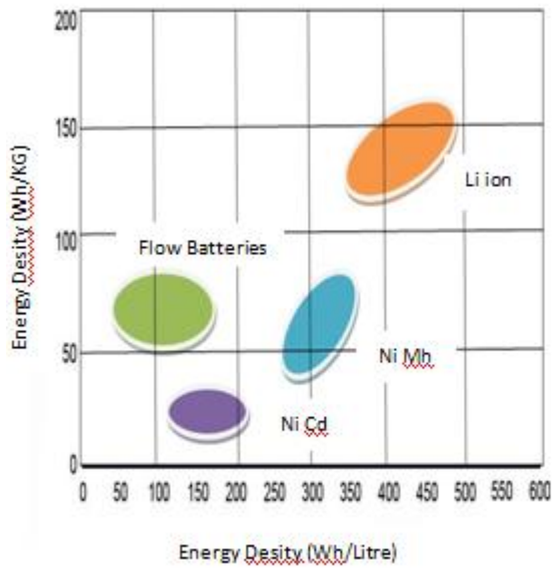

Figure 2: Energy Density comparison of all batteries

IV. LIMITATIONS

A. Flow rate

The count of the reactions takes place in the both positive and negative half cells will be affected by the flow rate of the electrolyte and afterwards the State of charge of the battery. Suppose the flow rate is increased, then the reactions will be increased and hence the State of charge will goes down. For a low flow rate the state of charge gets increased. At very low flow Ni Mh ie protons will be accun d in the membrane. Hence the flow rate should be o for high Ni Cd cy applications like electric vehic... At low flow rate the protons are deposited in the membrane and thus the efficiency of the battery gets reduced [4],[5].

B. Increasing Energy and power density

The electrolyte used in the flow batteries is completely depends on the temperature. The energy depends on the concentration of the electrolyte. For higher temperature the concentration of the electrolyte is increased and therefore the vehicle design should withstand the higher temperature. The spacing of the cells is the limiting factor for the power density [6],[9].

C. Economic Aspects

The depleted electrolytes can be easily refilled or changed in case of flow batteries. The time taken for the refuelling is almost similar to the petrol/diesel refuelling.

The constraint in this method is that the recharging setup electrolyte and the vehicle should be from one firm. Otherwise there is possibility for electrolyte mismatch. Hence the recharging system should be properly defined. Another important constraint is corrosion caused by electrolyte in the tanks [7],[10].

V. CONCLUSION

Flow batteries are more advantages when compared with other energy storage devices for electric vehicle application. It has the property which decouples the power and energy density so that the vehicle design is quite simple and flexible. Even though it has less energy density compared with all other batteries, the rate of charging is quite easy and it will be used or electric vehicles. However, still development of systems which contains temperature precautions and maintenance of electrolyte in charging stations. To get better efficiency for electric vehicle applications more research works and developments needs to be done to enhance the efficiency and proper utilization of batteries. After successful installation of the flow batteries, new business models could be developed for proper utilization of energy. The charging station ensures the electrolyte maintenance and low environmental issues. Also efficient recycling and disposing of the electrolyte could be done in the charging stations.

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V. Vaideeswaran working as assistant professor and pursing PhD in the field of electric vehicles. He received BE degree in Anna University in 2016. He received ME degree in Anna University in 2018. Active member in SAE India organization and participated in Electric Two Wheeler design competition and secured fourth Place in National level contest. Currently he is working on Battery management systems and electric vehicle batteries.

Senthil Kumar R, was born in Tamilnadu, India, on November 2, 1966. He received the B.E degree in Electrical and Electronics Engineering from Madurai Kamaraj University in 1989. He received his M.E(Power Systems) from Annamalai University, in 1991. He has 25 years of teaching experience. At present he is working as Professor in EEE Department, Bannari Amman Institute of Technology, Sathyamangalam. Currently his research includes power converters for renewable systems.