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Design and Fabrication of a Hybrid Battery with Lead Acid Battery and Supercapacitor

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ABSTRACT

The electricity plays very important role in today's world and Day by day the need of energy is increasing due to which the energy storing is becoming the need of today's world. To solve this problem, we have to use the energy storing devices such as batteries, super capacitor etc. The batteries are the widely used device to store electrical energy but the costs of these batteries are increases as per its storing capacity.[1] To reduce this cost we are going to make the batteries which will be more affordable to the consumer and also we are going to increase the energy storing capacity of the batteries. Generally, the batteries consist of two electrodes one is positive and another one is negative and these electrodes are dipped in the electrolyte solution.[2]

In this project we have made a super capacitor which is used as a second electrode of lead acid battery. We have connected this super capacitor in series with the negative electrode. Super capacitors have high energy storing capacity, due to addition of this super capacitor, the energy storing capacity of battery increases and also the life of battery increases.[3]

Keywords-- Battery, Electrode, Capacitor, Super Capacitor

I. INTRODUCTION

Electrical energy is energy related to forces on electrically-charged particles and the movement of those particles (often electrons in wires, but not always).[4] This energy is supplied by the combination of current and electric potential (often referred to as voltage because electric potential is measured in volts) that is delivered by a circuit (e.g., provided by an electric power utility). Motion (current) is not required; for example, if there is a voltage difference in combination with charged particles, such as static electricity or a charged capacitor.[5]

Electrical energy is typically converted to another form of energy (e.g., thermal, motion, sound, light, radio waves, etc.). Electrical energy is usually sold by the kilowatt hour (1 kW·h = 3.6 MJ) which is the product of the power in kilowatts Multiplied by running time in hours. Electric utilities measure energy using an electricity meter, which keeps a running total of the electric energy delivered to a customer.[6]

As the need for energy Storage in the sector grows, so too does the range of solutions available as the demands become more specific and innovations drawing on state-of-the-art materials and technologies are developed. While the need is not new – people have been looking for ways to store energy that is produced at peak times for use at a later moment to reduce imbalances between energy demand and energy production – energy storage is now booming in the sector.[7] Applications are becoming more diverse and widespread geographically with the growth of variable wind and solar energies, decentralisation of the power system and the need for resilience in the network. A battery is a source of electric power consisting of one or more electrochemical cells with external connections for powering electrical devices.[8] When a battery is supplying power, its positive terminal is the cathode and its negative terminal is the anode. [28]The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal.[9] When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy.[10] Historically the term "battery" specifically referred to a device composed of multiple cells; however, the usage has evolved to include devices composed of a single cell.[11]

A. What is the Need of Energy Storage?

We know that energy neither be created nor be destroyed. The energy generated must be consumed at that time. Energy storage is the act of storing the energy at a time and can be consumed later on. Thus, it maintains the balance between energy production and energy demand.[12]

In today's world and for its never-ending energy demand is provided mainly by the use of non-renewable energy sources which are depleting in the course of time.[26] So, to avoid the future inconvenience in energy supply we can store the generated energy in various forms and in various devices.[13] There are various methods by which we can store the energy and prominent in them are battery, compressed air, and hydrogen and methane storage. A battery is an energy storage device that stores energy in the form of chemical energy and converted it into electrical energy and used for the various applications.[14]

B. Why Lead-Acid Battery is used in Energy Storage?

A Lead-Acid battery is a rechargeable type of battery that can be recharged once used and can be used multiple times. The prominent electrodes used in lead acid battery are Lead-di-oxide, Metallic Acid, carbon is used. In this battery we have used two electrodes in which the first electrode is made up of combination of Lead-Di-Oxide and Carbon whereas the second electrode is made up of combination of Lead-Di-Oxide and Lead + Carbon.[15]

We have chosen the Lead-Acid Battery from the various types of batteries because it has many advantages like high energy storage capacity, light weight, ability to deliver large surges of electricity, it is better than Lithium battery due to its less cost and most importantly it is cheaper and it is easier to install.[15]

C. Why Super Capacitor?

Super capacitors are widely used in today's world. They are also called as ultra-capacitors or electrochemical double layer capacitor, this are energy storage devices having high energy efficiency due to their good characteristics, they are used in energy storage system and the chances to be charged and discharged rapidly without loss of efficiency for a number of cycles.[18]

Super capacitors are ideal when a fast charge is needed to fulfill a short-term power need whereas batteries are chosen to provide long term energy combining the super capacitors with lead acid battery it is converted into the hybrid battery with satisfies both needs and reduces battery stress which reflects into longer service life.[19]

Super capacitors consist of two electrodes separated by ion permeable membrane which is called separator and an electrolyte ironically connecting both electrodes.[24]The electrolyte forms an ionic conductive connection between the two electrodes which differentiate them from traditional electrolytic capacitors where a dielectric layer always exist and the so called electrolyte.[20] When the voltage is applied the electrodes are polarized and ions in the electrolyte forms a electric double layer of opposite polarity corresponding to the electrodes polarity for example positive electrode will have a layer negative ions and the negative electrode will have layer of positive ions.[21]

Depending upon electrode material and the surface shape some ions may permit double layer becoming specifically absorbs ions and contribute with the total capacitance of the super capacitor.[22]

D. Construction of Super Capacitor

In the construction of super capacitor, we have used tow electrodes one is positive and other is negative electrodes. We tried different shapes and sizes of electrodes to find suitable capacitance of super capacitor. The different size and shapes diagram are as follows:

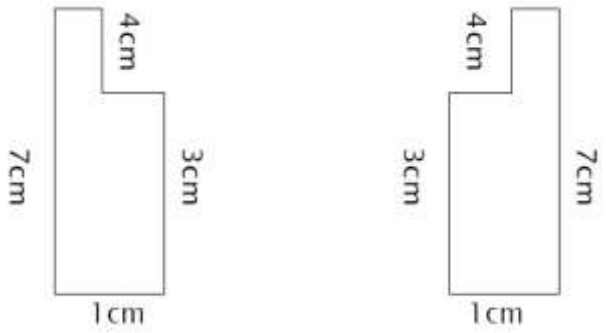


Figure 1: Dimension of supercapacitor Electrodes

As per above diagram the electrodes are constructed. On these electrodes a thin layer of different electrode materials is added. On the positive electrode the layer of MnO2+AC of 0.06mg is added and on the negative electrode the layer of activated carbon of 0.06mg is pasted. The ratio of the MnO2+AC is 1:1 i.e., the amount of MnO2 is 0.03 and AC is 0.03mg on positive electrode.

The electrodes are placed in the sandwiched manner i.e., one on the another by placing separator in between them.

Which is shown in the figure.

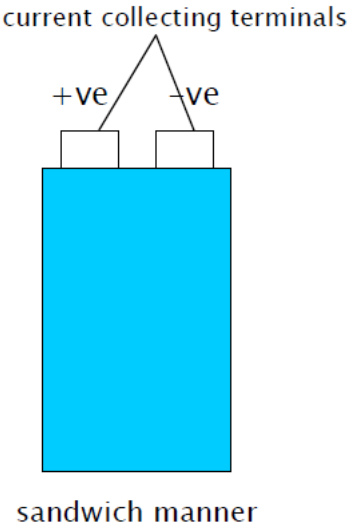


Figure 2: Super capacitor

I.e., The ratio of MnO2+AC for positive electrode is 1:1

MnO2 + AC
1 : 1
0.03 + 0.03
= 0.06 mg

F. Construction of Lead Acid Battery

In the construction of lead acid battery two electrodes are used. one is positive and another one is negative. The solution used to dip the electrodes is the Dilute H2SO4.

The H2SO4 has a specific gravity of 1.2 mole the beaker used to dip the electrodes is of 250 mL and made up of glass.

The H2SO4 is diluted by using the distilled water.

The amount of H2SO4 and Distilled water is given below:

Table I: Quantity of solution used in lead acid battery

Sr. No.	Solution	Quantity of solution
1	H2SO4	62.5 mL
2	Distilled Water	187.5 mL
	Total	250.0 mL

The total amount of diluted H2SO4 is 250mL.This solution is measured by using the measuring cylinder of 500mL and then it is poured into the 250mL beaker.

The electrodes used in battery are made up of lead dioxide and the lead + activated carbon.

The electrodes are packed into the polyethylene separators to avoid the direct contact of two electrodes with each other and with the solution. The electrodes are dipped in the electrolyte solution such that the terminals of two electrodes should not be dipped in the solution to make connection with the supply.

II. EXPERIMENTAL SETUP OF LEAD ACID BATTERY

In the experimental setup of Lead Acid battery, we have used the following equipment's:

Table II: Equipment used in lead acid battery

Sr. No.	Equipment	Quantity
1	Beaker	250 mL
2	Dilute H2SO4 solution	250 mL
3	Two Electrodes	1+ve ,1-ve
4	Dual power supply	0-30V,0-2A
5	Multimeter	

Firstly, the electrodes are dipped into the dilute H2SO4 solution. The electrodes are dipped such that the current collecting terminals are at such level that it should be available to make the connections. After that the dual power supply is connected to the terminals of the battery and the battery is charged to its full potential by constant current.

Due to constant current the battery is charged by faster rate. By which the time required to charge the battery reduces. After that when the battery is fully charged then remove the dual power supply and start discharging the battery.

A. Discharging of Lead Acid Battery

In the discharging process of lead acid battery, the following circuit diagram is useful for better understanding.

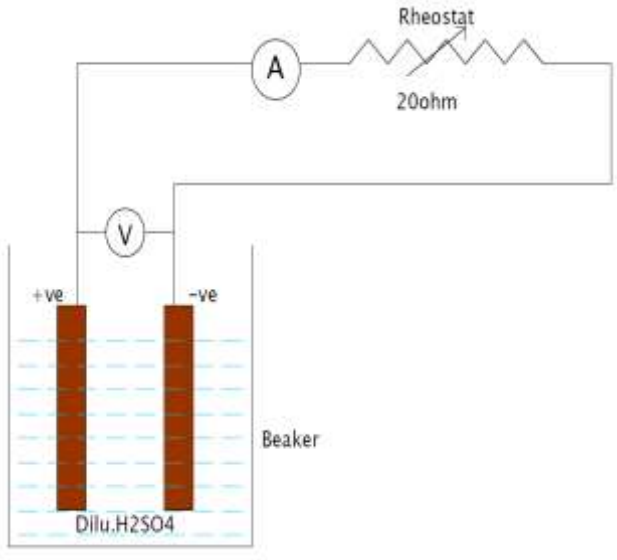


Figure 3: Circuit diagram of lead acid battery

For discharging process, the following circuit equipment's are used:

Table III

Sr. No.	Equipment	Rating
1	Voltmeter	0-5 V
2	Ammeter	0-1 A
3	Rheostat	50 ohm, 5A
4	Connecting wires	-

The connection is made as per the circuit diagram fig 3. The positive terminal of battery is connected to the ammeter's common terminal the second terminal of the ammeter is connected to the positive terminal of rheostat and negative terminal is connected to the negative terminal of the battery.

The rheostat is used as the load for the battery. The value of rheostat is set to the 20Ω. it is measured with the help of the multimeter. As the connections are done the battery start to discharge and the readings are taken with respect to the time. The readings are taken up to the battery voltage shows the constant readings. The battery is not fully discharged. it is discharged up to the 75% to 80% of its full voltage.

III. EXPERIMENTAL SETUP OF HYBRID BATTERY OR LEAD ACID BATTERY WITH SUPER CAPACITOR

The following equipment are used in the lead acid battery with super capacitor.

Table IV: Equipment's used in hybrid battery

Sr. No.	Equipment	Quantity
1	Beaker	250 mL
2	Dilute H2SO4	250 mL
3	Electrodes	Positive, Negative
4	Multimeter	
5	Super capacitor	Self-made
6	Dual Power Supply	0-30V,0-2A

In this setup the slight change is made into the battery terminals. Here the negative terminal is connected in the series with the super capacitor to increase the energy storing capacity of the battery as the capacitor is connected in series with the negative terminal of battery the voltage is increased and storing capacity also increases.

After these connections it is dipped into the dilute HSO4 solution and it is charged by Dual power supply. The battery is charged up to its full potential. After this switch off the power supply and start the procedure of discharging.

A. Discharging Process of Hybrid Battery or Lead Acid battery with Super Capacitor

In the discharging process the load is connected to the battery terminals to discharge the battery the load control lamp, rheostat, motor, etc. Here the rheostat is used to discharge the battery.

The circuit diagram for the discharging process is shown below:

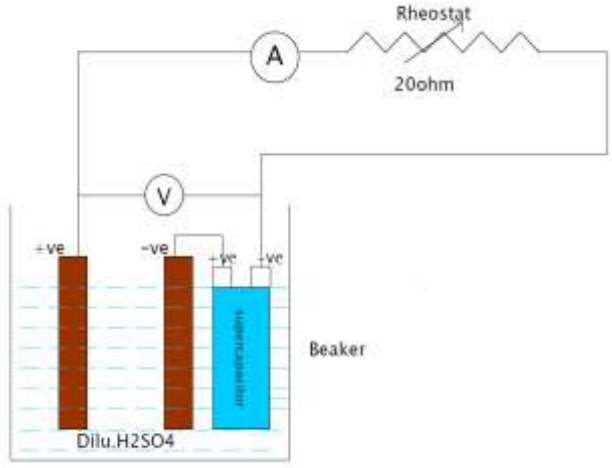


Figure 4: Circuit diagram of hybrid battery.

In the circuit diagram fig 6.1 the two electrodes are of the lead acid battery and the third terminal is of the super capacitor is connected in series with the negative terminal due to which the voltage is added which increases energy storing capacity of the battery.

The positive electrode is connected to the ammeter common terminal and the second terminal of the ammeter is connected to the rheostat which gives variable resistance value the secondary terminal of rheostat is connected to the negative terminal of super capacitor.

As the load is connected which is 20 Ω then the battery start discharging and the readings of the discharging is noted down. The readings are taken up to voltage reach at its constant value. The readings are taken with respect to the time.

IV. RESULT

Table V: Lead Acid battery readings

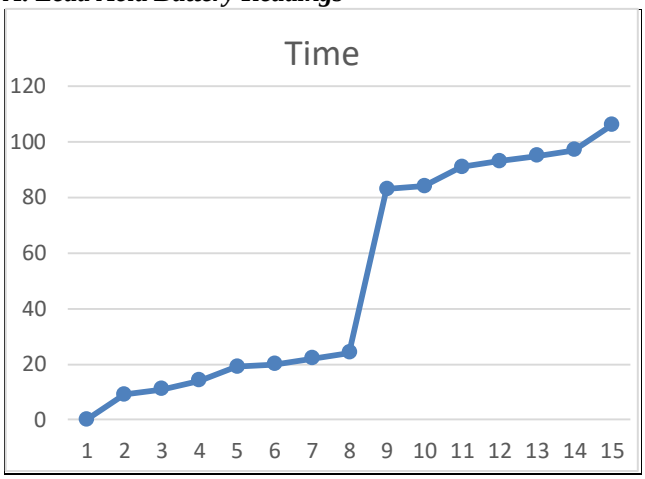
Sr. No	Voltage	Time
	Initial voltage =2.10	
1	2.09	9s
2	2.08	11s
3	2.01	14s
4	1.99	19s
5	1.97	20s
6	1.96	22s
7	1.95	24s
8	1.94	1m 23s
9	1.93	1m 24s
10	1.91	1m 31s
11	1.90	1m 33s
12	1.89	1m 35s
13	1.88	1m 37s
14	1.87	1m 46 s

Table VI: Lead Acid Battery with super capacitor readings

Sr. No.	Voltage	Time
	Initial voltage =2.20	0s
1	1.97	6s
2	1.96	9s
3	1.95	20s
4	1.91	28s
5	1.93	42s
6	1.92	1m 7s
7	1.91	3m 8s
8	1.90	4m 28s

V. GRAPHS

A. Lead Acid Battery Readings



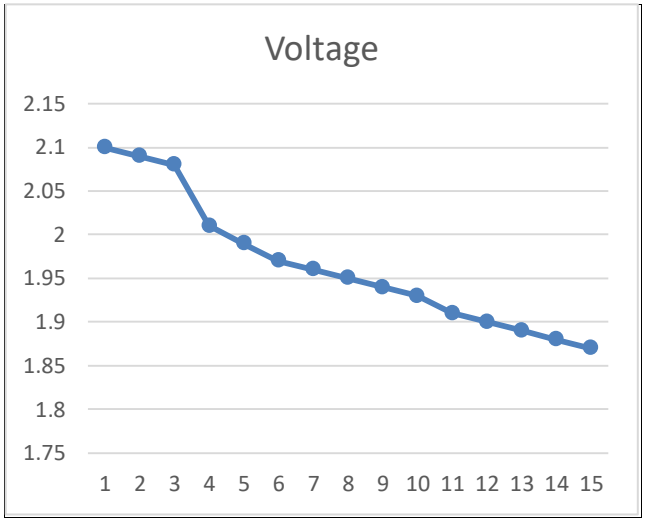
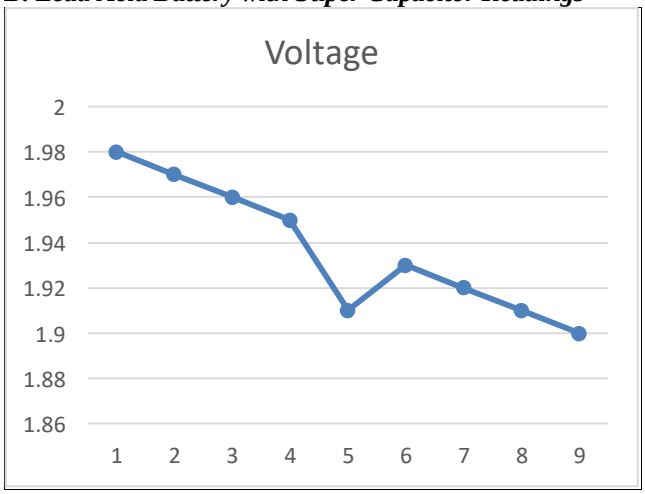


Figure A. Discharging graph of lead acid battery

B. Lead Acid Battery with Super Capacitor Readings



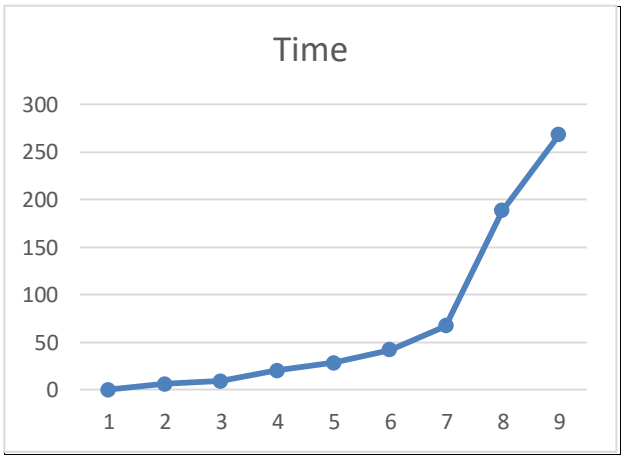


Figure B. Discharging Graph of Hybrid battery

VI. CONCLUSION

In this paper we have introduced two batteries the first one is lead acid battery and another one is lead acid battery with super capacitor and it is compared with each other. After comparing these two batteries we found that the energy storing capacity of lead acid battery with super capacitor is higher than the lead acid battery. In this project the brief construction and working of the lead acid battery and the hybrid battery is discussed also the comparison of these two batteries is performed on the points such as energy storing capacity, performance, discharging time, efficiency and it's cost after comparing these two batteries the result is that the energy storing capacity of the hybrid battery is higher than the lead acid battery due to use of capacitor the voltage is added.

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