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Comparative Study of Horizontal and Vertical Electrode Structure in Supercapacitors

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Abstract

Capacitance is an important parameter of electric energy storage device. It is the ability of electric energy storage device to store an electric charge. Capacitance value in farad indicates that it is supercapacitor and not conventional capacitor. Supercapacitor the new age energy storage device cannot store charge for a long time, hence they are presently used along with batteries as a hybrid storage device in which battery is the long term power source while supercapacitors provides peak power that the battery is unable to deliver. The capacitance is a function of geometry or design of electrode plates. The research paper demonstrates the effect of alignment of horizontal and vertical electrodes on quick charge and discharge cycle in supercapacitors and its subsequent effect on capacitance value. The study focuses on

effect of capacitance due to alignment of electrodes enabling researchers to design supercapacitors which can hold more charge so that supercapacitors can be used as primary energy storage device. Research was performed with preparation of electrodes using 5 types of activated carbons namely Vulcun XC-72, Pica, RP-20, C-60 and NORIT. The electrodes were prepared in specified dimension of rectangular shaped wire mesh plates and aqueous solution of potassium sulphate was used as electrolyte in research. The test was conducted on single electrode and it was initially charged at a voltage of 2.2V and its discharge current was recorded for a time period of 3 minutes, the same process was conducted for the stack type of electrodes. First series connection was established at the voltage of 6.6V for vertical and horizontal alignment of electrodes and discharge current was recorded. Similar process was carried for parallel connection at applied voltage of 2.2V. Value of capacitance of various supercapacitors made from these carbon materials is compared to select the best electrode material.

***Key Words*:**Supercapacitor, ultracapacitor, series, parallel, horizontal, vertical.

1 INTROUDCTION

Supercapacitors also known as electric double layer capacitors which increases energy storage ability due to a large increase in surface area through use of a porous electrolyte. Electrical energy is directly stored by using supercapacitors. There is no need to replace Supercapacitors because , they do not undergo life-limiting, irreversible, chemical reactions, and they do not experience dry-up problems. Supercapacitors are a new electric energy storage device with extremely high capacity density. They have a virtually unlimited service life, fast charge discharge capability and very low leakage current [1].

Basic design of supercapacitors consists of two electrodes separated by an ion-permeable membrane (separator), and an electrolyte ionically connecting both electrodes. The study aims at comparison of electrode performance on change from vertical alignment to horizontal alignment. The idea of horizontal alignment of electrode is derived from the study of horizontal plate structure of

electrodes in batteries which have significantly improved the cyclic stability and energy density of batteries [3]. The study will provide a comparative analysis of alignment of electrode and its effect on the performance of supercapacitors. This study will help in better electrode and supercapacitor design for overall improvement in specification of supercapacitor.

Faradays law is applicable in this experiment, the electrode used generate faradic current that is generated by reduction or oxidation of some chemical substance at an electrode. The voltage ratings in supercapacitors are generally 2.7V or less that is mainly obtained from the electrochemical stability of the electrolyte and electrode material. For high voltage application several cells has to connect in series. Placing of the cells in parallel manner is completely depends on the energy requirements. In case of series connection overall voltage increased by number of cells connected in series. Placing cells in parallel will not affect the voltage. When placing same value cell in series the system capacitance is reduced by the number of cells placed in series similarly placing same value cells in parallel will increase the overall system capacitance proportionately to the number of cells placed in parallel.[4].

2 EXPERIMENTATION

Laboratory trials were conducted for the preparation of electrodes using stainless steel wire mesh as current collector. Activated carbons such as Vulcun XC-72, Norit, Pica, RP-20 and C-60 were used as electrode material. To make faradic electrode slurry of composite material that is activated carbon and metal oxide is used as electrode material. In this experiment slurry of activated carbon and manganese dioxide loading density of 20mg per square centimeter. Acetone was used as mixing agent. No binder material is required as current collector, electrode material and separators are packed tightly over each other. A sandwich type fabrication process involved in the making of electrodes. The slurry prepared was pasted on the specific dimension of rectangular shaped wire mesh, with a help of adhesive and the separator was used to keep two electrode plates apart to prevent electrical short circuit and allows the transport ionic charge carriers. This was the fabrication process which

was involved in the experiment. For making of aqueous electrolyte K2SO4 is used. The prepared electrodes were tested in laboratory for single and stack type.

Trial 1: The single electrode was taken for the first trial. The electrode was placed in aqueous electrolyte in vertical and horizontal position. A voltage of 2.2Volts applied then discharge of current was noted for 3 minutes time period.

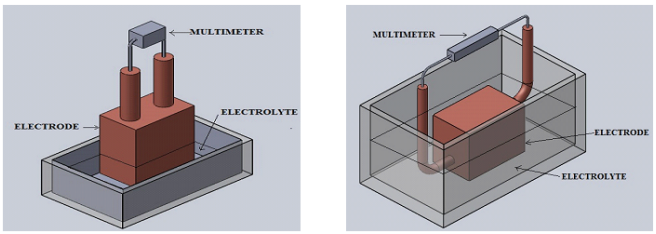

Fig 1. Schematic diagram of Front and Top view of single electrode structure in Vertical and horizontal form

Graphical comparison of results obtained is presented as below

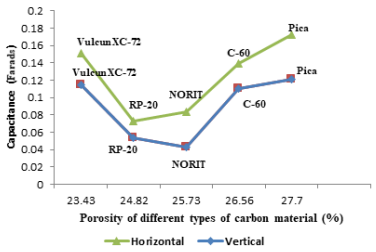

Fig 2. Value of Capacitance for single supercapacitor in vertical and horizontal form.

Trial 2-Comparison of 3 Electrodes Stacked in Series Connection: The series connected stack of three electrodes was placed in aqueous electrolyte solution in vertical and horizontal position. As it is a series connection the overall voltage will increase directly by the number of cells in series. One electrode represents one cell and each electrode is having a voltage rating of 2.2Volts. Hence in this trial maximum voltage was 6.6V and accordingly the discharge of current were noted for 3 minutes.

Principle involved: when placing cells in series the system capacitance is reduced by number of cells placed in series mathematically given by

$$C_{sys} = C_{cell} \div n \tag{1}$$

Where n is number of cell, Ccell is capacitance of single electrode and Csys is total capacitance of system.

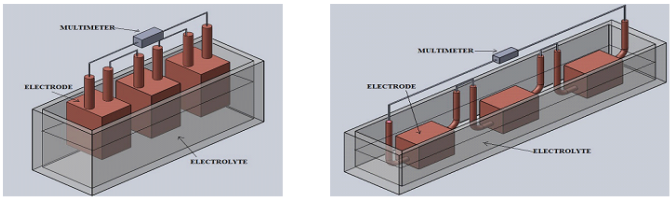

Fig 3. Schematic diagram of Front and Top view of series connected stack of three supercapacitor structure in Vertical and horizontal form

Graphical comparison of results obtained is presented as below

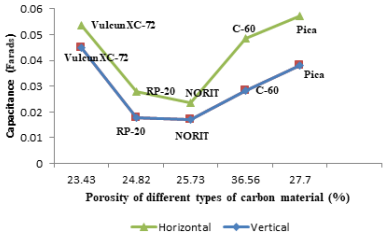

Fig 4. Value of Capacitance for series connected stack of three electrodes in vertical and horizontal form.

Trial 3: Comparison of 3 Electrodes Stacked in Parallel Connection: The parallel stacks of three electrodes were placed in electrolyte in vertical and horizontal position. The stacks of 3 electrodes were connected parallely and as it is a parallel connection the overall voltage will not be affected. Hence the voltage will be 2.2V and accordingly discharge of current was noted for 3 minutes

Principle involved: when placing cells in parallel the system capacitance is increased by number of cells placed in series mathematically given by

$$C_{sys} = C_{cell} \times n \tag{2}$$

Where n is number of cell, Ccell is capacitance of single electrode and Csys is the total system capacitance

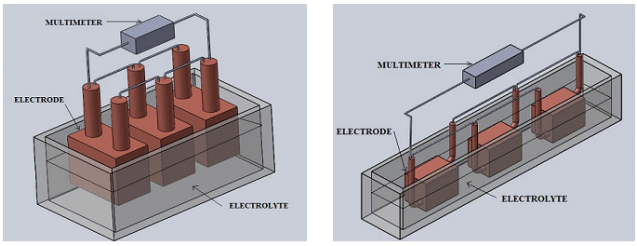

Fig 5. Schematic diagram of Front and Top view of series connected stack of three supercapacitors in Vertical and horizontal form

Graphical comparison of results obtained is presented as below

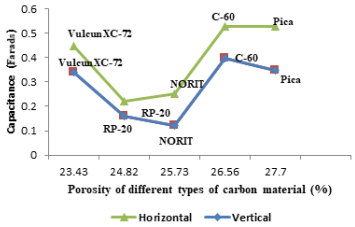

Fig 6. Value of Capacitance for parallel connected stack of three supercapacitors in vertical and horizontal form.

3 CONCLUSION

The lab experiments have shown the improvement in capacitance when electrodes are horizontally aligned. Vulcun XC-72 as electrode material has shown 30% increase in capacitance value in horizontal alignment of single electrode than vertical alignment. Vulcun XC-72 and RP-20 as electrode material has shown 33% and 24% increase in capacitance value in horizontal alignment of series as well as parallel connected stack of three electrodes than vertical

alignment. Hence it is clearly visible that out of 5 types of carbon material, Vulcun XC-72 and RP-20 has shown best value of capacitance for both types of alignment. It is clear from lab experiment that the series and parallel stack of supercapacitors follows the basic rule of capacitor that is in series connection the capacitance exactly one third the capacitance value of single capacitor and in parallel connection the capacitance is exactly thrice the capacitance value of single capacitor. In case of vertical alignment there exist the problem of leakage which affects the key parameters of supercapacitor particularly capacitance value and this problem is mitigated by horizontal alignment of supercapacitors where there is no provision for the leakage. Horizontal aligned electrodes are used mainly in coin shaped supercapacitors which finds the application in electric vehicle, electric wheelchair, fire alarm and security system, battle tank etc. These applications need quick burst of energy and stability. The horizontal alignment has shown promise because it can store more charge per unit of area as compared to vertical alignment.

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