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Performance Evaluation of Hybrid Super Capacitor Module for Energy Storage Applications

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Abstract: **This paper presents and evaluates performance of hybrid super-capacitor under different load conditions and its charge/discharge characteristics. The paper also gives the brief introduction of equivalent circuit for hybrid super-capacitor. In the search of energy storage device with better performance scientist have recently launched a new type of device named as hybrid super-capacitor. It has an advantage of high energy density and high power density. Its working voltage is much greater than the existing super-capacitor(<3.5V), which makes it unique and helps to meet the requirements of high pulsed power system and high energy density like electric vehicle Finally the equivalent circuit model was simulated with the help of Matlab/Simulink. The result proves the high precision and validity of the new model. Also various tests are carried out on hybrid super-capacitor experimentally and their results are discussed.**

Index Terms-- **energy storage device; hybrid super-capacitor; pulse power system; electric vehicle**

I. INTRODUCTION

Now days the electricity generation by using renewable and clean energy resources such as solar energy and wind energy have made great progress. But all such energy sources have common problem that is how to store and release the energy, for better performance including efficiency. For this purpose, various alternatives are available, ex.-battery, fuel cell, flywheel battery and super-capacitor etc. Among all these equipment, super-capacitor which has advantage of high power density, high charging and discharging current levels, broad working temperature range and high durability for large no. of switching OFF/ON cycles. Hence these are preferred for many applications.

Super-capacitor can be classified according to its working principle as Double layer Super-capacitor, Electrochemical super-capacitor and Hybrid super-capacitor. The hybrid super-capacitor means has two different types of electrodes. One of them is double layer super-capacitor material such as active carbon; the other is electrochemical-super-capacitor material such as ruthenium dioxide. This kind of super capacitor includes the advantages of double layer super-capacitor and electrochemical-super-capacitor, so it can be employed in high energy and power density demand systems [3]. The general needs of super-capacitors are high working voltage, big capacitance and low resistance for pulse power supply applications, especially for the pulsed power supply of electromagnetic launch system applications. However the working voltage of existing super-capacitors is very low (<3.5V), which has restricted its further applications. To meet the requirements of high voltage, conventionally an engineer connects number of super-capacitors in series. But the total capacitance of energy storage device decreases, and the inner resistance increases. Based on the high working voltage of electrolytic capacitor the concept of hybrid super-capacitor was proposed.[2]

II. EQUIVALENT CICUIT OF HYBRID SUPER-CAPACITOR

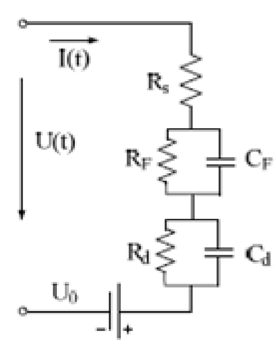

Figure3. Equivalent circuit model of hybrid super-capacitor

In fig.3 Rs is the serial resistor. The components like current collector, electrolyte and separator provide the conducting loop for the electric charges. So these components can be modeled as a serial resistor. The parallel combination of R_F and C_F represents the positive electrode of hybrid super-capacitor. As chemical reaction takes place during the phrase of charging/discharging it can be modeled as parallel combination of resistor and capacitor. The parallel combination of Cd and Rd gives the negative electrode of hybrid super-capacitor. As there is no chemical reaction takes place it can be simply regarded as an ideal polarized electrode. But taking the real situation under consideration the more proper equivalent circuit of negative electrode is also a parallel combination of resistor and capacitor. Equivalent circuit model of hybrid super-capacitor can be model by connecting the positive and negative electrodes in series. Uo is the internal voltage source whose value is equal to the lower limit of the voltage range of device [3, 4].

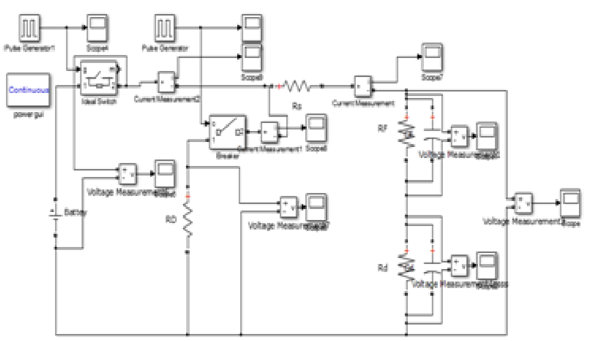

Figure.2 Simulation circuit model of hybrid super-capacitor in Matlab/Simulink

Fig.2 shows the simulation model of Hybrid Super-capacitor which was built in Matlab/Simulink. In first stage hybrid super-capacitor is charged with the help of battery up to 10V. Once the hybrid super-capacitor is fully charged, it allows discharging through the resistance RD of 5Ω. In simulation model instead of Uo initial voltage of 0.8V is given to the capacitors.

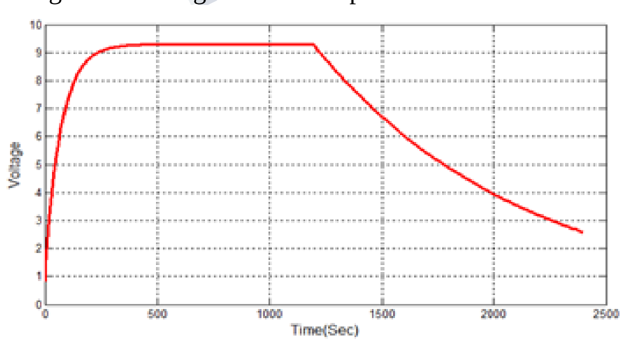

Figure3. Simulation results of voltage

In fig.3 the charging profile of hybrid super-capacitor is up to 1200 seconds and after that it starts to discharge. We can see from the figure hybrid super-capacitor takes around 200 seconds to charge completely and takes 1200 seconds to discharge. Figure demonstrates a very good charging performance of hybrid super-capacitor to meet the requirement of pulsed power application.

III. THE VCAP8000 HYBRID SUPER-CAPACITOR

The super-capacitor used in this experiment is Lanzar VCAP8000 80Farad, 16Volts hybrid super-capacitor. Its working voltage is 19V DC and its surge voltage limit is 24V DC. Its equivalent series resistance is 0.0015Ω at 25^oC. Its outer case is made up of chrome plastic and has the blue flashing LED lights. It has the 4 digits blue light display DV voltage meter that can measure 0.1dcv range. Also it has reverse pole connection buzz warning function. If the capacitor is connected wrongly by reversing the positive and negative wires during the installation process the pcb will issue a noise to give warning.

Figure 4. The 16v vcap8000 hybrid super-capacitor

IV. HYBRID SUPER-CAPACITOR EVALUATION STATION

The author designed and fabricated an evaluation station for the charging of hybrid super-capacitor as shown in fig.5 and fig.6. The hybrid super-capacitor is charge with the help of variable DC source. Charging resistance is connected in series with hybrid super-capacitor to protect the device from the inrush current. Digital storage oscilloscope (DSO) is connected across the device to see the charging voltage characteristics [6].

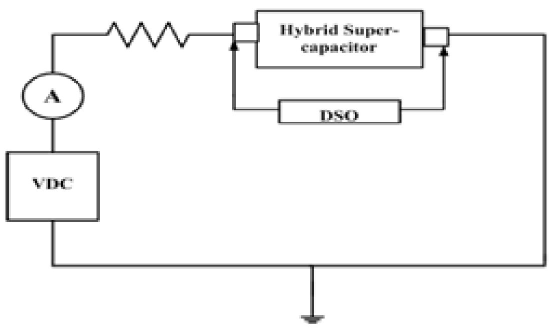

Figure5. Hybrid super-capacitor charging block diagram

Figure6. Hybrid super-capacitor evaluation station

V. CONSTANT CURRENT CHARGER

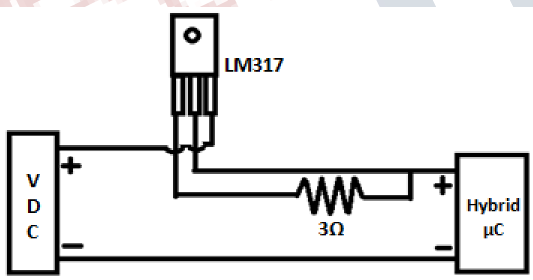

Figure.7 Block Diagram Of Constant Current Charger

After studying and experimenting all the possible methods of charging it is found that by constant current charging we can charge hybrid super-capacitor in faster rate. So author has designed and fabricated constant current charger for charging the hybrid super capacitor module. Ic lm317 is been used which will not allow to exceed current above 0.4ampere. Fig. 7 shows the block diagram of constant current charger in which its input points are connected to the variable dc source and output is connected to the input of hybrid super-capacitor module.

VI. EXPERIMENTAL RESULTS

A. Charge profile

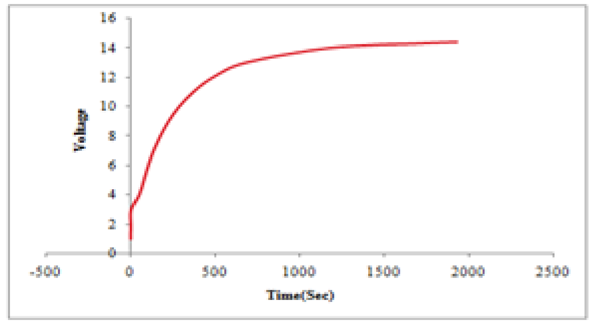

Figure8. Charge profile of hybrid super-capacitor

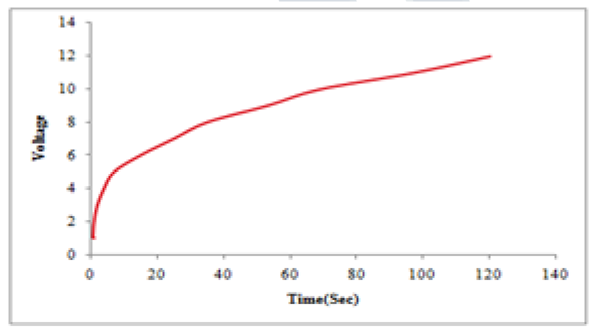

Figure9. Charge profile of hybrid super-capacitor using constant

B. Current Charger

Fig.8 shows the charge profile of hybrid super-capacitor connecting 50Ω resistance in series to protect the module from the starting inrush current. It takes around 2000 seconds to completely charge the device. Fig.9 shows the charging profile of hybrid super-capacitor with the help of proposed constant current charger. And we can see from the waveform that capacitor is charges very fast within just 2minuts it get charged completely.

(b) ***Discharge Profile***

Firstly hybrid super-capacitor is charged at 12v and then allowed it to discharge through different types of load which have the same power rating.

- ❖ Discharging with dynamic load- dc motor(fan load),12v,0.15a
- ❖ Discharging with static load-80Ω rheostat

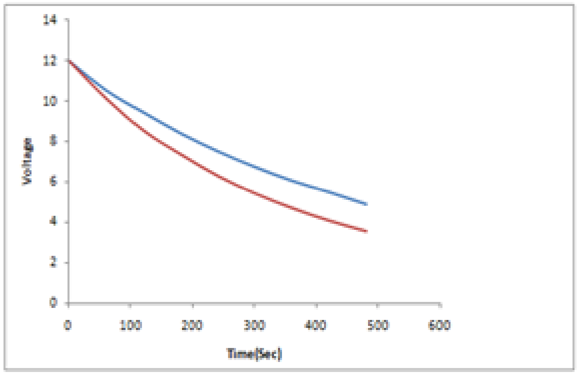

Figure10. Discharge voltage profile

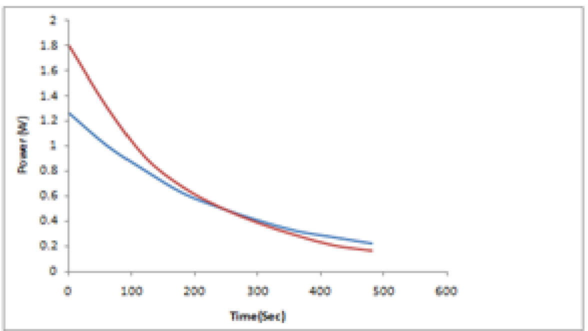

Figure11. Discharge power profile

In fig.10 and fig.11 red curve shows the discharge profile of static load and blue curve indicates the discharge profile of dynamic load. In case of static load as the power is varies directly with the square of voltage so small decrease in voltage will result in large dissipation of power. In case of dynamic load as voltage decreases speed of motor decreases therefore air circulated decreases also power decreases therefore current decreases. From the curve we can see that dynamic load is extracting less power because it has more balanced voltage discharge.

VII. CONCLUSION

(A) The hybrid super-capacitor has higher energy density as well as power density. It can be fast charge and discharge so can be use for the pulsed power applications.

(B) The new equivalent circuit model of hybrid super-capacitor is presented in this paper and its results gives the performance characteristics of hybrid super-capacitor.

(C) It can be charge at very fast rate using constant current charger.

(D) It is more suitable for dynamic load than static load as it has less power consumption in case of dynamic load.

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