PERFORMANCE ANALYSIS OF VARIOUS ULTRACAPACITOR AND ITS HYBRID WITH BATTERIES

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ABSTRACT:

This work focuses on the testing and application of Ultracapacitors and its combination with batteries for electric energy storage. Batteries, used as power sources in many applications cannot meet the power requirement during the surge. Batteries can easily provide constant power whereas Ultracapacitors are more suitable in pulse power applications. Also the combination of Ultracapacitor and battery not only provides sufficient power in various applications but improves life of the battery as well. In this work, charging of individual Ultracapacitor and their bank is done and its characteristics are obtained using different loads. Hybrid combination of Ultracapacitors and battery is tested and its performance is also studied.

Keywords: Battery, Electro-chemical double layer capacitor, Hybrid energy storage, Ultracapacitors.

I. INTRODUCTION

Energy is one of the most significant factor for the development of a nation in present world. People are shifting more and more towards renewable sources, but its applications are restricted to certain uses because of its variable nature. So energy storage becomes an equally important part. Most commonly available energy storage technology is battery. But batteries cannot meet the power requirement during the surge. Ultracapacitor is exactly the secondary power source which can provide peak power attributing to its fast charging and discharging ability. Hybridizing it with a battery will increase the energy storage system efficiency by 10% [1]. It fills the gap between a conventional capacitor and a battery. The lifespan of a battery will be enhanced by shifting the surge current to the ultra capacitor. The difference between a conventional capacitor and ultra capacitor is that the latter has increased energy density and higher capacitance. Unlike a battery, it has high power density and reduces the size of battery pack due to peak power demand. Also in recent years, fuel cells have replaced internal combustion engines for future generation vehicles. Therefore hybridizing them with ultra capacitors will make up for both and provide a high efficiency at the same time an environment friendly, zero emission vehicle drive engine.

II.WORKING PRINCIPLE OF ULTRA CAPACITOR

Ultra capacitor is also known as super capacitor or electro-chemical double layer capacitor (EDLC). It is defined as an energy storage device to store electrostatic energy by electrolytic polarization.

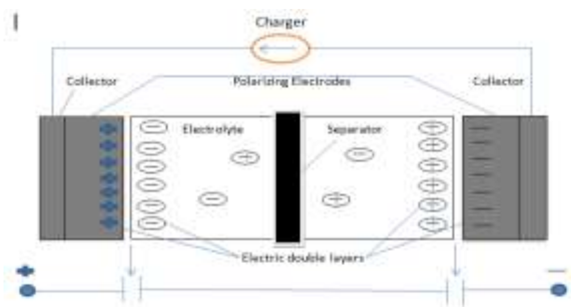

Fig.1 Typical configuration of an EDLC cell

Fig.1 shows the configuration of ultra capacitor or EDLC cell. Two solid active porous carbon electrodes are used and electrolyte is filled in the remaining space. EDLCs do not use separate dielectric material. A separator is used between the two sections. It also consists of current collector at the two ends. When the electrodes are charged to a voltage, an array of charged particles and induced charges is formed at both sides of the plate. This is a double layer formation and therefore Ultracapacitors are also called electric double layer capacitors. The whole phenomenon is physical with no chemical reactions involved like in batteries and reversible too, giving them high charging cycles with no degradation. A highly porous carbon electrode is used so that the electrolyte interface area is very high and thus results in very high capacitance value.

$C = \frac{\varepsilon_0 A}{d}$ ------------------- eq. (i)

Where C is the capacitance in farads,

A is the overlapping surface area in square meters,

D is the dielectric thickness in nm,

ε_0 is the electric constant of value 8.854×10^{-12} F m^{-1}

The ratio of surface area to charge separation distance (dielectric thickness) in ultra capacitor is of the order of 10^{12}. The high content of energy stored by ultra capacitor in comparison to conventional electrolytic capacitor is by activated carbon electrode material having the extremely high surface area and the short distance of charge separation created by the opposite charges in the interface between electrode and electrolyte [3].The comparison of batteries and ultra capacitors is tabulated in Table 1.Ultra capacitors and batteries possess the advantages of high power density and high energy density, respectively [3].

Table .1

Attributes	**Ultra capacitor**	**Batteries**
Power density	>1000W/kg	< 500 W/kg
Energy density	< 5 Wh/kg	10-100 Wh/kg
Hot temperature	+65 ^{o}C	+40 ^{o}C
Cold temperature	< -40 ^{o}C	20 ^{o}C
Efficiency	98%	95%
Charging time	Fraction of seconds to several minutes	Several hours
Charging/Discharging efficiency	88%-98%	70%-85%
Self discharge	Hours to days	Weeks to several months
Cycle life	$10^{6} – 10^{8}$	200 - 1000
Lifetime	8-14 years	1-5 years
Toxicity	Non-toxic	Lead, strong acid
Monitoring	Not required, simple current, voltage measurement	Sophisticated
Handling	Human handling	Requires equipment

III. ULTRACAPACITOR TESTING

Ultracapacitor Charging- Charging of ultracapacitors is simple while at the same time may present some unique challenges. Ultracapacitor of different capacities are charged. Method used is constant current charging. In this method a constant current is set and voltage is fixed equal to the Ultracapacitor voltage. Initially charging starts with the set current and voltage builds up. Once the voltage reaches to capacitor voltage, current starts to decrease and reaches to minimum value. Charging characters tics of Ultracapacitors is shown below.

1. Charging of 100F, 2.7V Ultracapacitor - Charging of 100F ultracapacitor is performed keeping constant current 4A and fixed voltage at 2.6V.

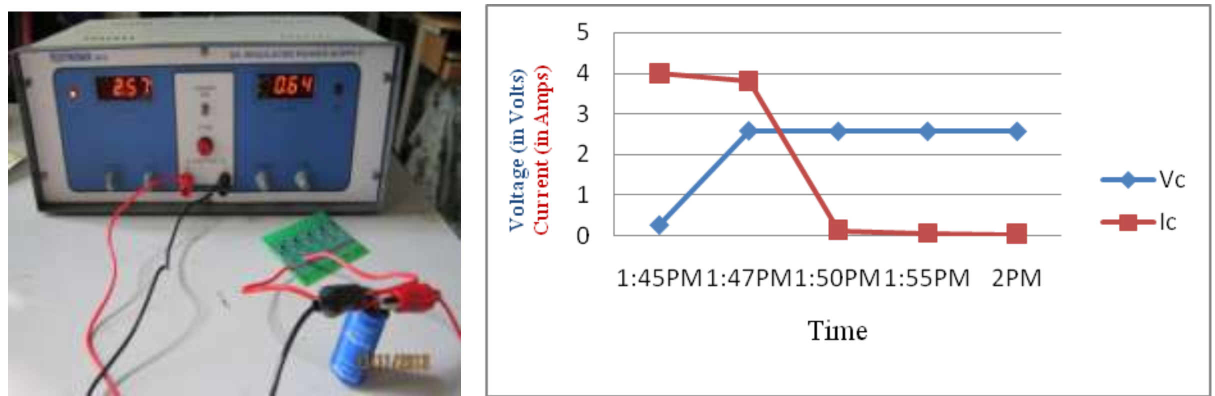

Figure 1. Setup for charging of 100F, 2.7V Ultracapacitor and its characterstics

2. Charging of 360F, 2.7V Ultracapacitor - Charging of 360F ultracapacitor is performed keeping constant current 4A and fixed voltage at 2.6V.

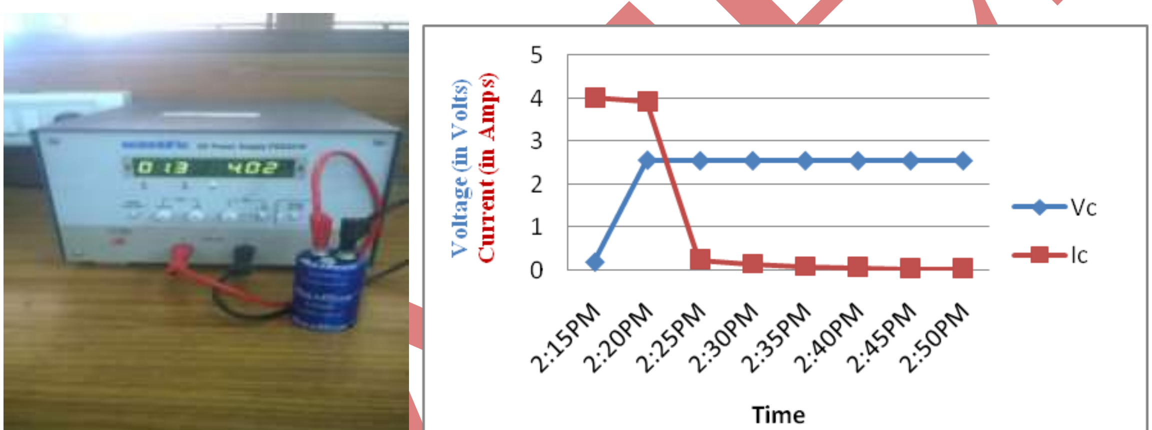

Figure 2. Setup for Charging of 100F, 2.7V and its Characteristics

3. Charging of 100F, 13.5V Ultracapacitor Bank- Ultracapacitors are connected in series for powering 12V dc motor. Five 100F Ultracapacitors are connected in series through balancing circuit for uniform charging in each individual cell. Charging of 100F ultracapacitor bank is performed keeping constant current 4A and fixed voltage at 13.5V.

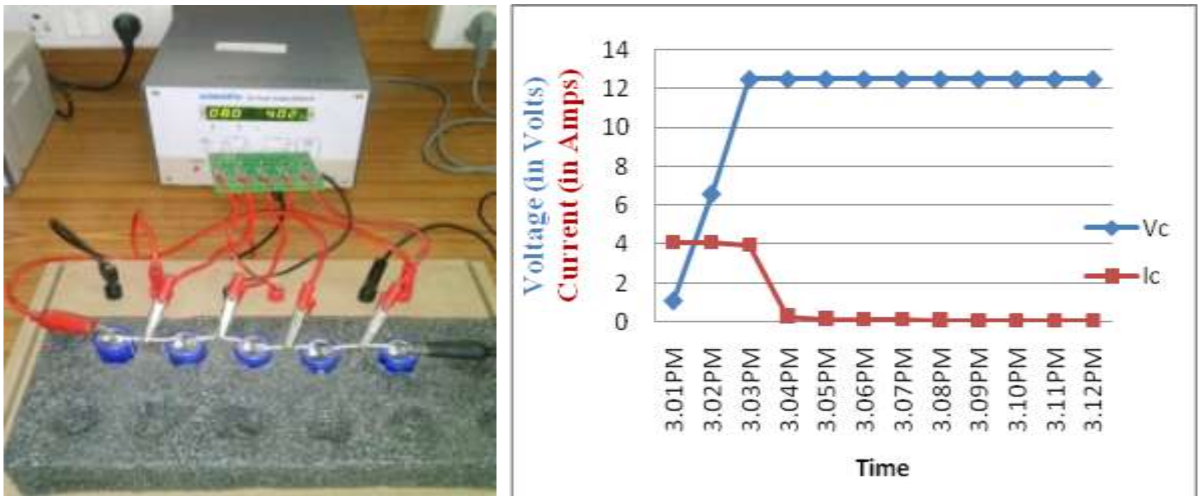

Figure 3. Setup for Charging of 100F, 13.5V Ultracapacitor Bank and its characteristics.

Ultracapacitor Discharging - Ultracapacitors are charged to rated voltage and then discharged through different static or dynamic loads. In the experiment various loads are taken like LED, Lamp Load, Motor etc. and their performances are analyzed using their discharging time and surge current requirement for application. Variations in load characteristics are observed when powered from ultracapacitors alone and when Ultracapacitors are used in hybrid with batteries to supply the load.

1. Lamp Load–100F ultracapacitors bank are tested on lamp load where each LED light is rated at 4W, 12V. Five tube light are used which makes total 20W load. Variation in current drawn is measured which reflects the lumens available from lamp.

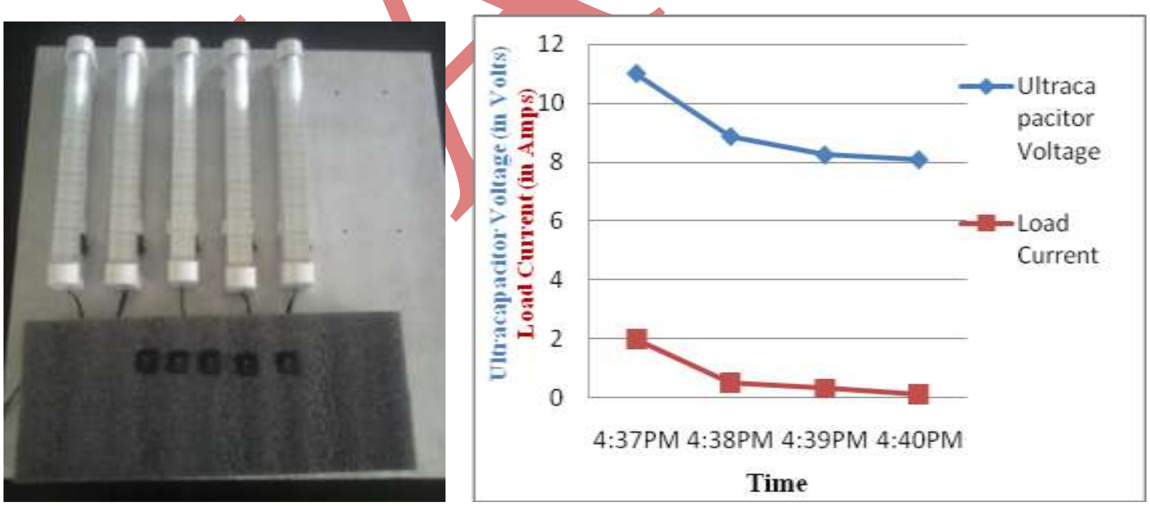

Figure 4. Setup of Lamp Load and Discharging Characteristics of Lamp Load

2. Motor Load–In this test motor is taken as a load and its shaft is connected to wheel for loading the motor and power is supplied from ultracapacitor and battery in parallel. Battery is charged to 12V and ultracapacitor upto 13V and connected to supply the motor. Load chararcteristics of this test shows that motor initially draws the surge current of 7A from ultracapacitor and then runs on battery drawing average current of 0.7A. Ultracapacitor discharges to certain level upto 8.03V and then start charging from battery, in this way ultracapacitor charges and discharges to meet the load requirement. This shows that the ultracapacitor can be used as a power souce for pulse power applications in EV.

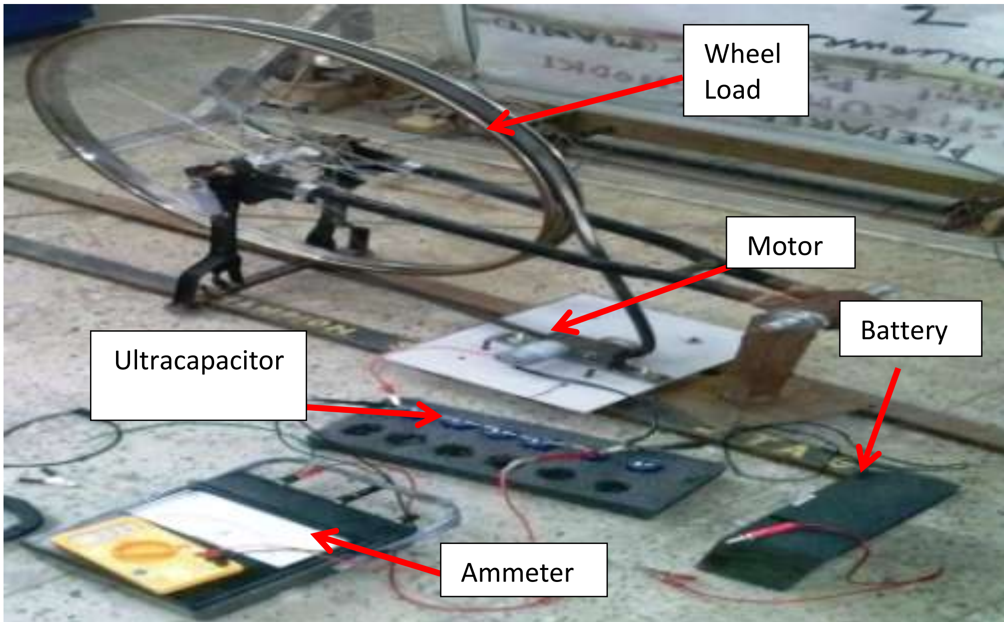

Figure 5. Setup for Discharging of Ultracapacitor and Battery through Motor

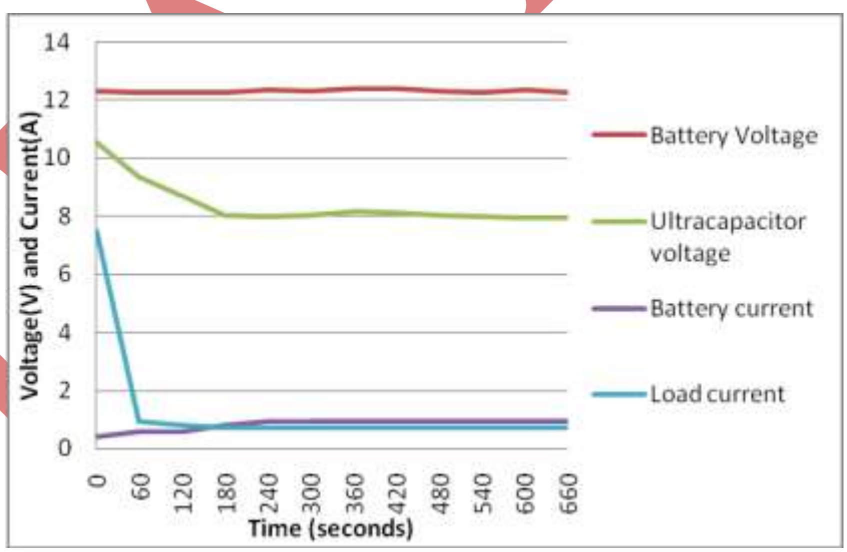

Figure 6. Variation of battery and Ultracapacitor parameters with time for the hybrid system

IV. CONCLUSION

From the experiment conducted it has been found that Ultracapacitor can be charged and discharged faster than batteries. Ultracapacitors are very robust as they can be charged with high current and maximum current can be drawn within short durations. More the current faster the charging of the Ultracapacitor but the charging current must be within the rated value. From the hybrid combination, it is seen that the peak power required is easily supplied by the Ultracapacitor which will help in increasing the life of the battery. Unlike batteries, Ultracapacitors may be charged and discharged at similar rates. This is very useful in energy recovery systems such as dynamic braking of transport systems and systems where high pulse power is required.

V. REFERENCES

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