CONTROLLED CHARGING OF ULTRA CAPACITOR BY PWM TECHNIQUE

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Abstract

Ultrcapacitor (UC) or Supercapacitor(SC) is gaining popularity owing to large values of capacitance, high power density, high energy density and fast charging. UC has found applications in many industries as a reliable energy storage device. This paper is aimed at presenting the charging characteristics of UC when charged using PWM technique. Other methods of charging UC, like constant voltage and constant charging method, pose certain limitations and increase the charging time. A comparison is drawn when UC is charged using constant current charging method and PWM technique. The proposed method facilitates relatively faster charging of UC in a controlled manner.

Key Words: *Ultracapacitor, charging and discharging rate, energy density, PWM technique.*

1. Introduction

The conventional sources of generating energy are soon going to get depleted. Industrialists person and engineers are hunting for new domains of electricity generation. In the hindsight, sources like solar, hydro and wind have contributed fairly in reducing the burden on conventional fossil fuels. However, all of these sources face a common and an entrancing problem of a reliable energy storage device. Popular energy storage devices like battery and flywheel encounter problems of reliable operation. However, with the advancement in technology, UC is gaining acceptability as a reliable energy storage device.

Inherently, UC has larger capacitance values when compared to other storage devices. This, undoubtedly, substantially increases its energy handling capacity.

Ultracapacitors are governed by the same basic principles as conventional capacitors. The supercapacitor, also known as ultracapacitor or double-layer capacitor, differs from a regular capacitor in that it has very high capacitance. Ultracapacitors utilize high surface area electrode materials and thin electrolytic dielectrics to achieve capacitances several orders of magnitude larger than conventional capacitors. In doing so, Ultracapacitors are able to attain greater energy densities while still maintaining the characteristic high power density of conventional capacitors. A capacitor stores energy by means of a static charge as opposed to an electrochemical reaction. Applying a voltage differential on the positive and negative plates charges the capacitor. This is similar to the build-up of electrical charge when walking on a carpet. They typically store 10 to 100 times more energy per unit volume or mass than electrolytic capacitors, can accept and deliver charge much faster than batteries, and tolerate many more charge and discharge cycles than rechargeable batteries.

2.1 Experimental setup for charging of UC

Fig. 1 shows the block diagram for charging UC using a DC source. The set-up consists of a source, UC and resistance in series with the UC to limit the high value of inrush current. The digital storage oscilloscope is connected across the UC to record the charging waveforms.

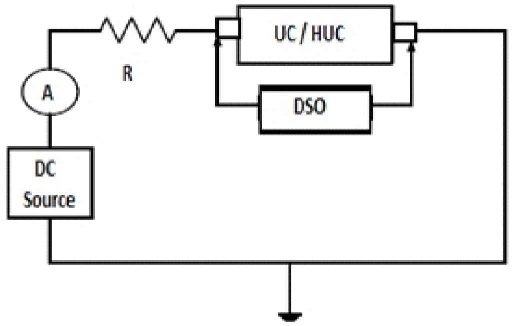

Fig.1. Block diagram for charging of UC

The UC used in this experiment is a Maxwell Technologies ultracapacitor with rated voltage of 16 Volts and rated capacitance of 58 Farads.

2.2 Charging of UC Using Constant Current Method

The UC in this experiment is charged by a constant current charging method. IC 731 is used to generate a constant current of 1 Ampere. The fig.2 below shows the experimental set-up for charging of UC by IC 731.

Fig.2. Charging of UC by constant current method

The experimental result shows that the UC takes 14 minutes to get charged to a value of 14 V at the constant current input of 1 A.

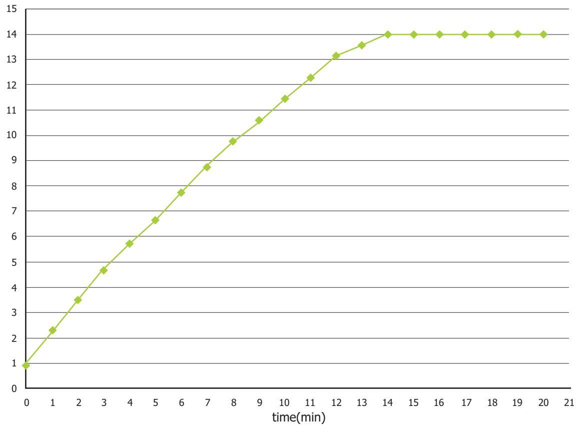

Fig.3. Charging characteristic of UC using constant current charging method

The UC was charged using IC 731 and the charging voltage profile is shown in Fig. 3 as a graph plotted Voltage versus Time. From the graph, it is observed that the UC starts charging from an uncharged condition and takes 14 minutes to charge completely up-to its rated value. After 14 minutes, the voltage remains constant implying that the device has been completely charged.

2.4 Charging of UC Using PWM Technique

Pulse width modulation (PWM) techniqueis employed to charge the UC, as it poses advantages over other techniques in terms of offering control of the charging pulses. Pulse Width Modulation, is a method of controlling the amount of power to a load without having to dissipate any power in the load driver. Comparing a ramping waveform with a DC level produces the PWM waveform. In PWM technique, the time period and hence the frequency remains fixed. Only the ON time and OFF time of the pulse(duty cycle) varies. The square wave signal has same ON and OFF time (50% duty cycle) whereas a PWM signal has a variable duty cycle.

In this technique, the pulses can be controlled by varying the duty ratio and hence, the charging rate can thereby be readily controlled. In order to facilitate a faster charging, a boost converter is used to boost the voltage from battery.

Fig 4 shows the set-up for charging UC using PWM technique using 555 timer IC.

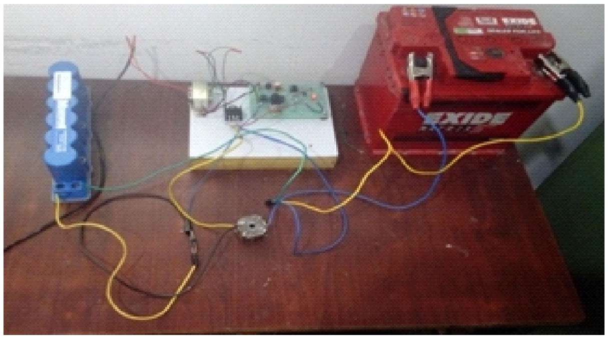

Fig.4. UC Charging by PWM technique using 555 timer IC

The figure 5 below shows the charging characteristics of UC when charged using PWM technique.

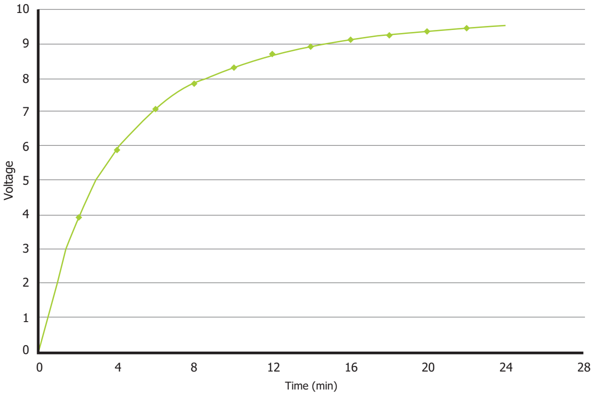

Fig.5. Charging characteristics of UC using PWM technique

It takes 24 minutes for UC to charge up to a value of 9.5 V at a duty ratio of 50%.

The figure 6 below shows the circuit diagram for charging of UC using PWM signals generated by Arduino.

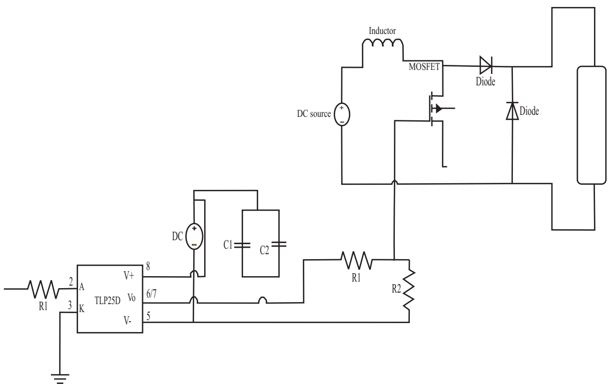

Fig.6. Block diagram for Charging of UC using PWM technique generated by Arduino

In figure 6, arduino is used to generate pulse-width modulated wave pulses using a program. Arduino is a developer. This arduino uses ATmega 328 IC for generating controlled pulse signal. A program is fed to microcontroller to generate 500Hz pulse. AT Mega IC requires 5V supply. In order to amplify and isolate the pulse gate driver IC TLP250 is used. These output pulses from arduino are given to the input of driver circuit. To complement PWM technique, dc to dc boost converter is required. To trigger the dc to dc converter MOSFET driver circuit is used.

Fig. 7 below shows the hardware implementation of charging of UC using PWM pulses generated by Arduino developer.

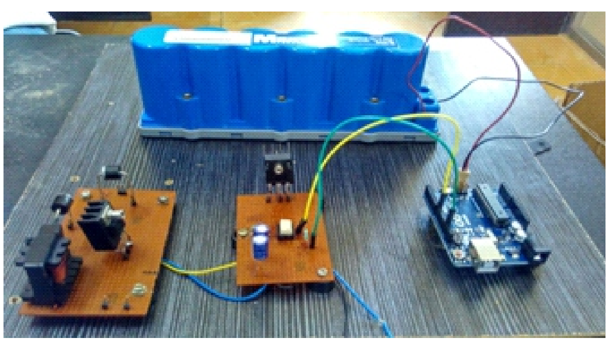

Fig.7. UC Charging by PWM technique using Arduino

The driver circuit comprises of an IC TLP205 connected across a source of 12V. The two pins of input and output are separated by air gap. The signal is transferred by infrared radiations. The MOSFET is turned ON and OFF due to these signals. When MOSFET is ON, inductor is charged and when MOSFET turns OFF, inductor releases energy. This boosted voltage is used to charge the ultracapacitor rated 16.2V.

Fig. 8 and 9 below shows the waveforms obtained from Arduino. Fig 8 is the output voltage with magnitude of 1.5 Volts. This voltage is further boosted upto 12.4 Volts using boost circuit and the corresponding boosted voltage waveform is shown in fig. 9.

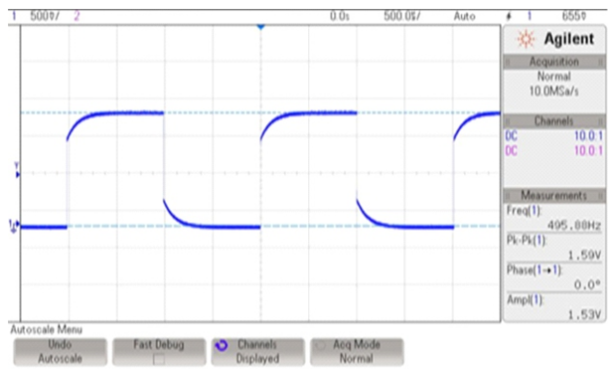

Fig.8. PWM output waveform using Arduino

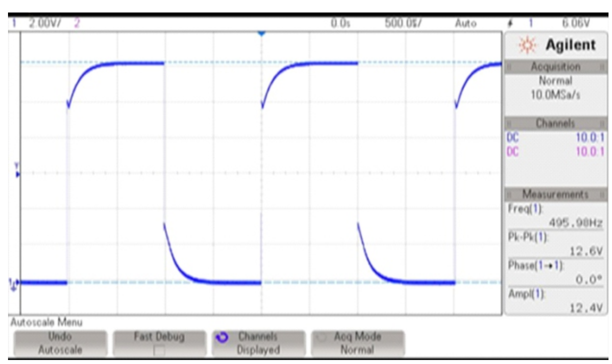

Fig.9. PWM output waveform using Arduino after boosting

Fig. 8 shows the output using using microcontroller IC gives the modulated pulses with duty ratio of 50% where the frequency obtained is 495.88Hz practically.

Fig. 9 shows the boosted output pulses with duty ratio of 50% is then supplied to the ultracapacitor for its charging. The output voltage is 12.6V with frequency of 495.98Hz.

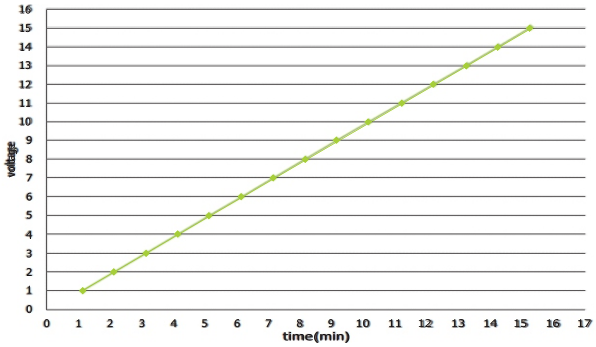

Fig. 10 Charging characteristics of UC using PWM pulses from Arduino

2.5 Charging of UC Using flash charging Technique

Flash charging is gaining wider popularity owing to increased shift of vehicle manufacturers towards the electric vehicles. Considering the nearing threat of extinction of conventional fuels, charging of storage devices, particularly UC, has come to the limelight. Flash charging serves the purpose of electric vehicle manufacturers by facilitating faster charging of storage devices. Fig. 11 below shows the block diagram for charging of UC using Flash charging method.

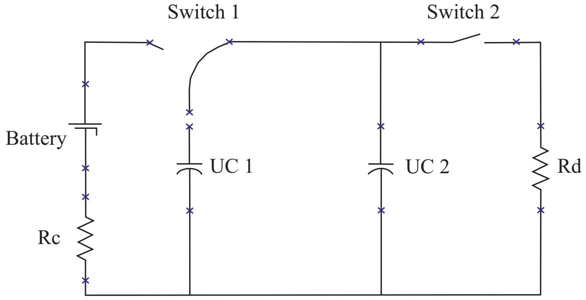

Fig 11.Block diagram for flash charging

Fig. 12 below shows the charging characteristic of an UC when charged using flash charging technique. It can be seen that the UC is charged up-to 15 volts in 180 seconds (3 minutes).

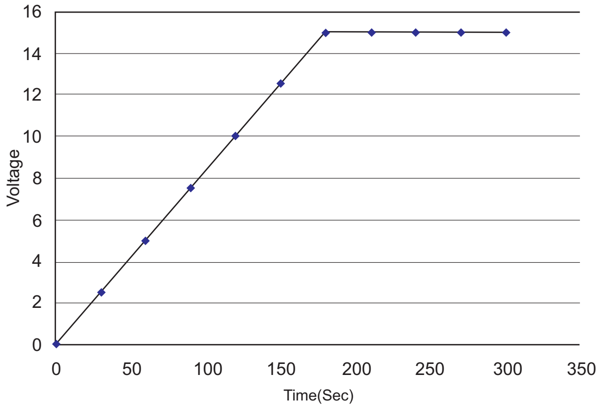

Fig 12. Flash charging characteristics of UC

3. RESULTS AND DISCUSSION

From the experimental studies, we have observed that flash charging poses many advantages over other methods of charging UC. The flash charging method charges the UC very quickly. Fig 13.below shows the comparative analysis of the charging methods of UC.

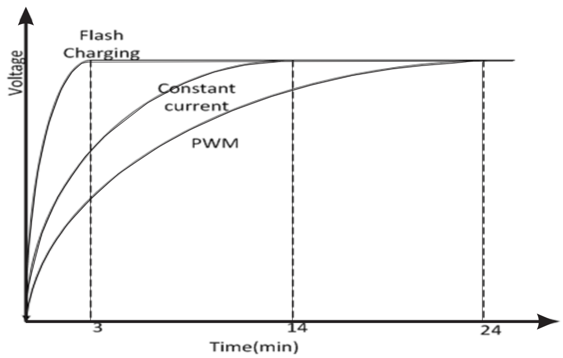

Fig. 13. Comparison of charging characteristics of UC

It is seen from the above graph that the UC is charged very quickly by employing the flash charging method.

4. CONCLUSIONS

The paper presents the experimental results of the charging characteristics of UC using constant current, PWM and flash charging method. It is quite apparent from the results that the flash charging method poses an advantage over other methods in terms of charging time required to charge the UC. This peculiarity of flash charging method can be made use of to charge the ultracapacitor driven short distance city buses. It can also find a valuable application in pulse power applications where a quick outburst of power is desirable. However, charging of UC using PWM technique offers wide control over the charging rate.

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