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Ultracapacitor Charging Methods

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Abstract - *Different charging methods are studied in the paper. The desired aim is to obtain fast charging. Each charging method has different procedure and has its own merits and demerits. Naturally, a given application will decide its suitable method. This paper presents the best charging method.*

Key Words: Ultracapacitor, charging methods, constant current charging and constant voltage charging.

1. INTRODUCTION

Ultracapacitor is an efficient energy storage device [1]. In 1957, General Electric engineers first noticed the electric double layer capacitor effect while experimenting with devices using porous carbon electrode. In 1966, the researchers at Ohio accidently discovered again the effect while working on experimental fuel cell designs. Regarding with the advances made on both materials and manufacturing process, Tecate Group Power Burst® product showed a superior advantage amongst all other ultracapacitors in the market. Today the high performance characteristics of Maxwell Technologies' ultracapacitors allow the system designer to develop hybrid power system solutions that cost less and perform better than non-hybrid solutions.
Ultracapacitors have very high capacitance, in the range of hundreds to thousands of farads. Compared to other capacitors, the ultracapacitors have higher energy density but when put against batteries or fuel cells, they cannot stack up well. Although ultracapacitor have very low energy density than batteries, they have special applications when large power peaks are to be supplied for a very short duration. Ultracapacitors first worked as 'support' to batteries. Attractive features of ultracapacitor are: higher power handling capacity and much longer shelf and cycle life than batteries. Long considered an enigma because of price, the advent surface area, excellent conductivity, high power density, and superior chemical and physical stability, herald a new era of practical usage. The advantages of using ultracapacitor technology are quite extensive. It is beneficial because of very high efficiency, high current capability, wide voltage range, wide temperature range, condition monitoring (state of charge and state of health), long cycle life, long operational life, life extension for other energy sources, ease of maintenance and straight forward integration. These ten reasons gives additional flexibility. Batteries cannot be charged and discharged at similar high rates like ultracapacitors.

2. METHODS OF CHARGING

1.1 Constant voltage charging

Constant voltage charging is also called as constant potential charging used to maintain the same voltage input to the ultracapacitor throughout the charging process, regardless of the ultracapacitor's state of charge [2]. Constant voltage charging provides a high inrush current to the ultracapacitor because of the higher potential difference between ultracapacitor and charger.

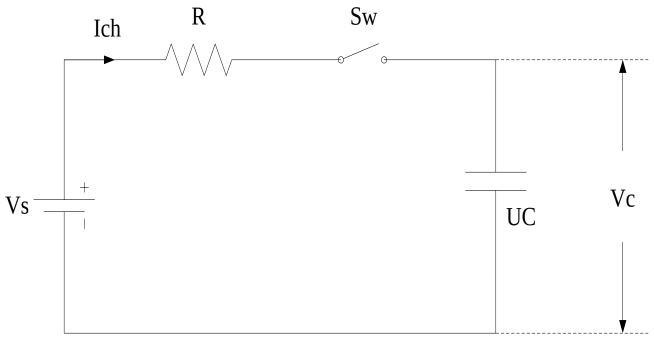

Fig -1: (a) Circuit for realizing constant voltage source where, Vs= Source Voltage, Ich= Charging Current, R= Resistance, Sw= Switch, UC= Ultracapacitor, Vc= Charging Voltage

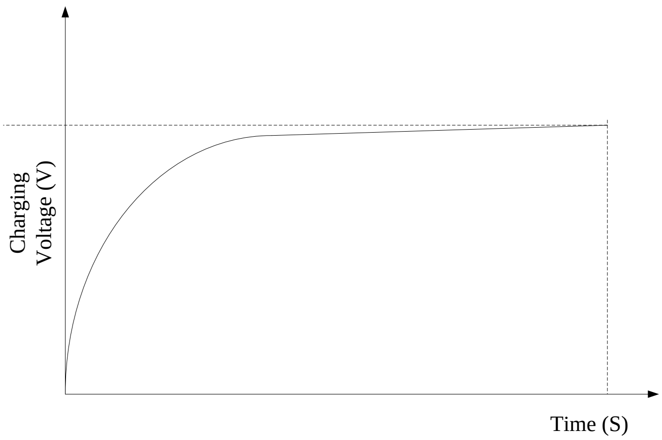

Fig -1: (b) Constant voltage charging

In figure 1 constant voltage charging along with the current waveform is shown which is basically a DC power supply consist of a step down transformer with a rectifier to provide the DC voltage to charge the ultracapacitor. The charging may return as much as 70% of the previous discharge in first 20 minutes. As the ultracapacitor charges its voltage increases quickly with a corresponding rapid decrease in charging current. As a result, even though the ultracapacitor reaches partial charge quickly, it requires prolonged charging to obtain a full charge.

1.2 Constant current charging

Constant current charging supplies a relatively constant current, regardless of the ultracapacitor's temperature and state of charge [3].

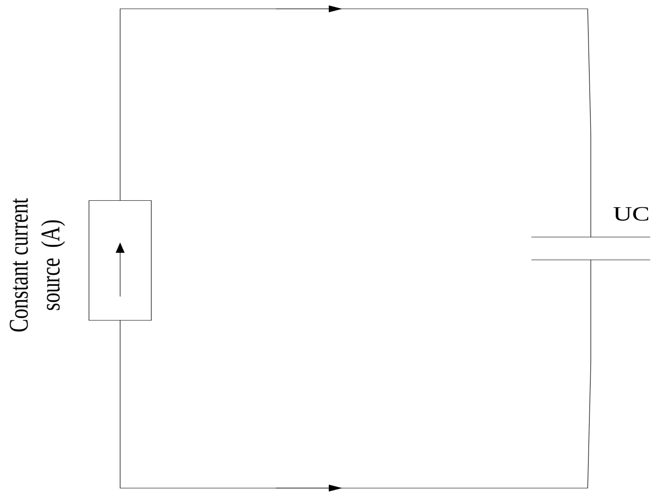

Fig 2: (a) circuit for realizing constant current source

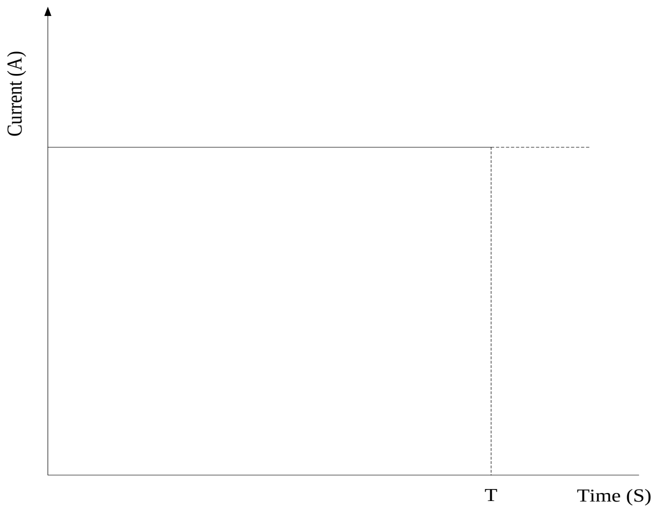

Fig. 2: (a) Constant current charging

The charging is most appropriate for cyclic operation where an ultracapacitor is often required to obtain a full charge overnight. Figure 2 shows constant current charger with waveform. It varies a voltage to maintain a constant current flow.

1.3 Flash charging

The charging time during flash charging is very less.

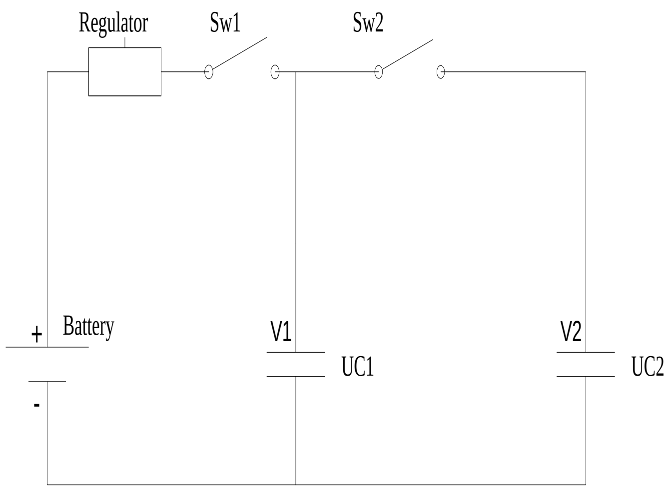

Fig 3: (a) Circuit to realize the flash charging

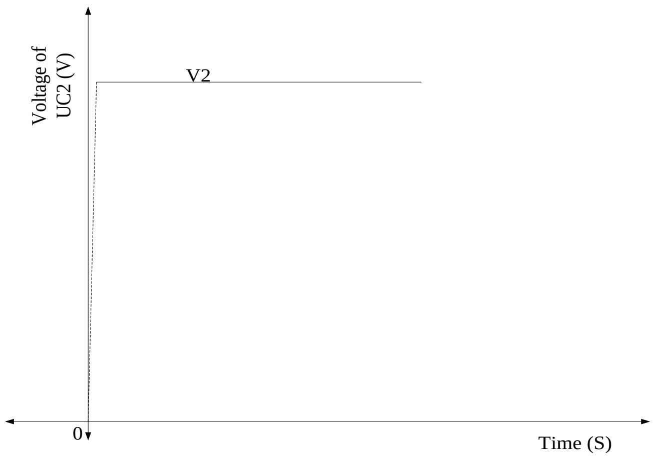

Fig 3: (b) flash charging

This is much advantageous for an electric bus to be recharged. In flash charging, electric bus powered via energy stored in on-board large ultracapacitors. When bus halts at its stops, a connector in the roof connects to the stationary electric system, which consists of a fully charged ultracapacitor. It uniformly delivers 400kW for 15 sec and flash charges the ultracapacitor on the bus. Figure 3 shows flash charging with its waveform.

1.4 Combined constant voltage and constant current charging

A constant DC supply uses variable resistances for getting constant current at the output. Figure 3 shows the charger circuit with waveform. Use of this method increases charging efficiency and life cycle of ultracapacitor.

2. MATHEMATICAL DESIGN OF COMBINED CONSTANT VOLTAGE AND CONSTANT CURRENT CHARGING METHOD

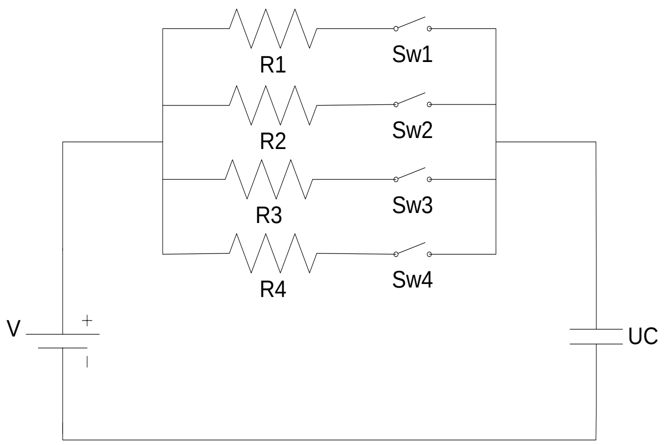

Fig 3: (a) Circuit to realize the combined source for charging

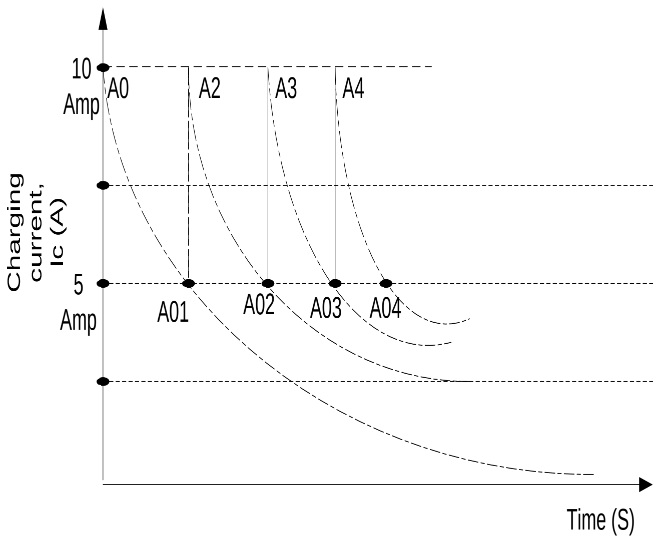

Fig 3: (b) Combination of current and voltage source

The following circuit of figure 4 shows $430F, 16V$ ultracapacitor supplied by 16V voltage source with 10A current. For $V = 16V$ and $I = 10\,A$, when switch $Sw1$ is closed,

$$R_1 = \frac{V}{I} = \frac{16}{10} = 1.6\Omega$$

This resistance decreases current to its half. Therefore at point $A01$, the current becomes $5A$. At that time voltage across capacitor is,

$$V_c = V - IR_1 = 16 - 5 \times 1.6 = 8V$$

$$time\ constant\ \tau_1 = R_1C = 1.6 \times 430 = 688\ Sec$$

$$\therefore For\ Time\ t_1,$$

$$I_c(t) = I \times e^{-t_1/\tau_1}$$

$$\therefore t_1 = 207.10\ Sec \approx 3.45 \text{ Mins.}$$

Thus ultracapacitor charged from $0\ to\ 8V$ in time 3.45 minutes approximately. Similarly for $A02\ to\ A04$, the time can be calculated. Therefore for total time required to fully charge the ultracapacitor,

$$\tau = 4 \times 688 = 2752\ Sec.$$

$$\therefore Total\ Time\ T,$$

$$5 = 10 \times e^{T/2752}$$

$$\therefore T = 828\ Sec. \approx 13.8\ Minutes$$

Thus, the total time required to fully charge the ultracapacitor is approximately 14 minutes. It can be found that, when charging current is 10A, the combined constant current and constant voltage charging efficiency is higher than other given methods.

3. CONCLUSIONS

The charging of ultracapacitor in less time is much necessary in electric vehicle industry. Combined constant voltage and constant current charging method has been studied in detail. To design a charger for ultracapacitor, the results obtained from the method can be used. More methods of charging such as float charging, bulk charging will be studied further.

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BIOGRAPHIES

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