Bulk Charger for Ultracapacitor

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Abstract— Requirement of fast charging of Ultracapacitor can be meet by bulk charging circuit. The desired aim is to obtain fast charging. Bulk charger can work at different current ratings to minimize the time required for charging. Different regulated integrated circuits are used to get sufficient voltage and current to match the requirement. Common chargers of Ultracapacitor require current and voltage sensors along with their control, which increases complications and its cost. Proposed hardware circuit is simple and does not require any special circuitry. Through testing, minimum time required to charge the Ultracapacitor is verified. This paper presents the hardware circuit including experimental results.

Key words: Ultracapacitor, Bulk Charger

I. INTRODUCTION

Recently automotive industries are moving towards developing electric vehicles which is directly responsible for the improvement of environment. Electric vehicles are significantly cleaner and more efficient. Electric vehicles use high energy density batteries, like lithium-ion (Li-ion) and nickel metal hydride (NiMH) battery, fuel cells successfully as an energy sources. But under certain operating conditions, such as quick acceleration, hill climbing and regenerative braking, their power densities are inadequate. The Ultracapacitor is higher power handling capacitive device [1]. Ultracapacitor can be used with batteries for performance improvement of electric vehicles. Periodic acceleration and deceleration cause power fluctuation which can be smoothened effectively by using Ultracapacitor- battery combination system. Concerning with the advances made on both materials and manufacturing process, Tecate Group Power Brust® product shows greater advantage in the market.

Before delivering the energy to the peak load, an Ultracapacitor should be fully charged. Large current will be acquired by an Ultracapacitor without initial charge, for a considerable duration. So that current limiting circuitry is combined with the charger. An Ultracapacitor- battery combination system doesn't require such circuitry [2]. Charging circuit with constant current- constant voltage control requires an expensive active current transducer for limiting the current. This makes the whole circuit complicated and costly. In this paper, an intelligent charger circuit named bulk charger is developed to tackle the problems. Absence of devices like current transducer, voltage and current sensor makes this circuit more effective.

II. ULTRACAPACITOR

An Ultracapacitor regularly named as a Supercapacitor or Electrochemical double layer capacitor having high volumetric and specific capacitance as it have high surface area along with the thinness of the double layer. Ultracapacitor provides large energy storage which is extensively used for firming the output of renewable installations with increase in grid stability. In cold weather, when batteries are drained due to repetitive starting, Ultracapacitor is used to start the electric vehicle. At starting, electric vehicle requires more power which is provided by Ultracapacitor. Regenerative braking system supplies continuous power to Ultracapacitor, thus it gives enough power to accelerate during ride through conditions. Primary energy sources like batteries, fuel cells, internal combustion engines are well sources as these supply continuous low power. However, they discharge and recharge gradually so they cannot competently handle peak power demands or summon up the energy in current applications. During peak power demands, Ultracapacitors provides quick bursts of power, then quickly accumulate the energy. Ultracapacitors can quickly discharge and recharge at very high rates, so that in today's application they efficiently accompaniment a primary energy source. If an Ultracapacitor is charged with combined constant voltage and constant current charging method, the rise in ultracapacitor voltage is same as that of ideal capacitor [3].

III. CHARGER MODEL

A typical Constant voltage charger is shown in figure 1. It consists of LM7815 IC which is a voltage regulator integrated circuit.

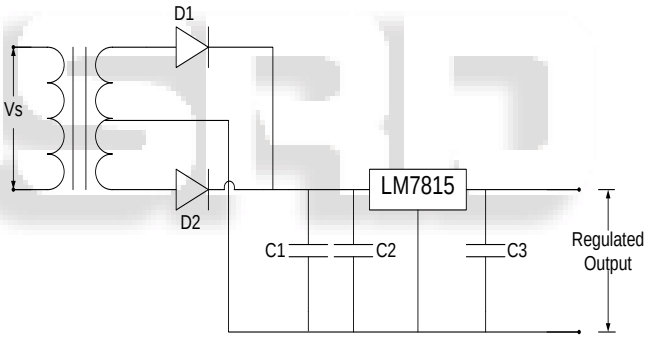

Fig. 1: Circuit diagram of constant voltage charger

Capacitor components are used to filter the output and make it stable. The use of LM7815 IC minimize the number of external components require for regulated output and improves transient response. It can give output current in excess of 1A.

An extensive series of charging current can be accepted by an Ultracapacitor. Figure 2 illustrates a 430F Ultracapacitor having operating voltage of 16.2V. The results obtained when 430F Ultracapacitor is charged with different series of current is shown in figure 3. This graph shows that the characteristic of Ultracapacitor with charging current of 1A, 2A and 3A is nearly same as that of an ideal capacitor.

Fig. 2: 430F, 16.2V Ultracapacitor Module

The results obtained from figure 3 reveals that the increase in charging current gives less charging time.

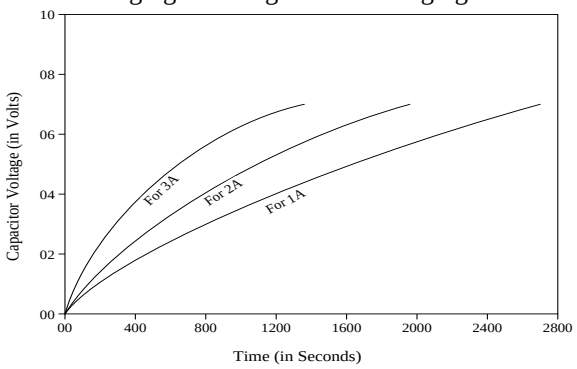

Fig. 3: Ultracapacitor charging graph for different charging currents

A. *Ultracapacitor Charger*

The important phenomenon is energy loss which must be taken into consideration while charging. Under zero initial charge condition, there is a great difference in Ultracapacitor and supply source voltages, this result into a large energy loss. As discussed earlier, minimum charging time is obtained due to large charging current. A charger circuit named Bulk Charger gives output voltage of 17V to charge the 430F Ultracapacitor.

B. *Bulk Charger Circuit*

Absence of control circuitry and current limiting devices make the circuit cheaper.

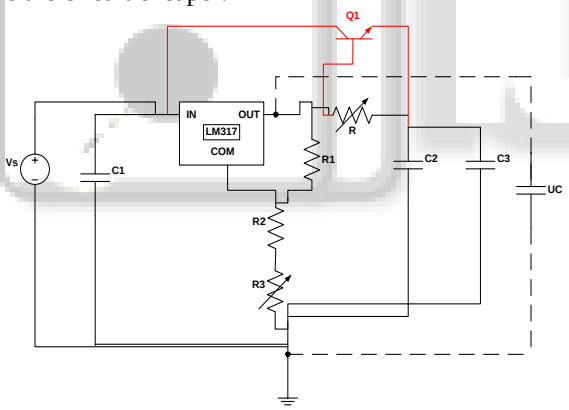

Fig. 4: Circuit for Bulk Charger

Also precise current control is not necessary as Ultracapacitor have a capability of receiving wide range of charging current. Figure 4 shows bulk charger mainly consists of LM317 IC and Transistor Q1. LM317 IC is known as 3-Terminal Adjustable Regulator having output voltage ranges from 1.25V to 37V. It is capable of supplying more than 1.5A current. The output voltage of LM317 IC is set by divider resistors R1, R2 and R3. R3 is a variable resistor which determines the IR drop with respect to ground, adjusted to get the accurate desired output voltage. Current restricting, thermal excess load protection are itself included in LM317 device. Whether the ADJUST terminal is detached, overload protection remains functional [LM317 pdf]. To supply more current, transistor Q1 is connected across the integrated circuit. Electrolytic capacitors C1, C2 and C3 filtered out the ripples and high switching frequency which flattens the supply current and thus prevented from fluctuations. The base terminal of transistor Q1 is connected with the variable resistor R to get the maximum output current. The circuits output is transferred to the Ultracapacitor represented as UC.

C. *Bulk Charger: Hardware Experiment Validation*

For charging of the Ultracapacitor, an experiment is accomplished. This Ultracapacitor is manufactured by Maxwell Technologies having 430F energy storage capacity [3]. The regulated output voltage (obtained from the integrated circuit) adjusted by the divider resistors is directly given to charge the Ultracapacitor. The charger circuit gives high current, thus named as Bulk Charger [4]. Transistor Q1 have a capacity of bypassing 10A current. As the charging time of Ultracapacitor is depend upon charging current, the current is increased by proper value transistor. A variable resistor R is adjusted to a minimum value, so that Ultracapacitor is charged by the maximum output current [5].

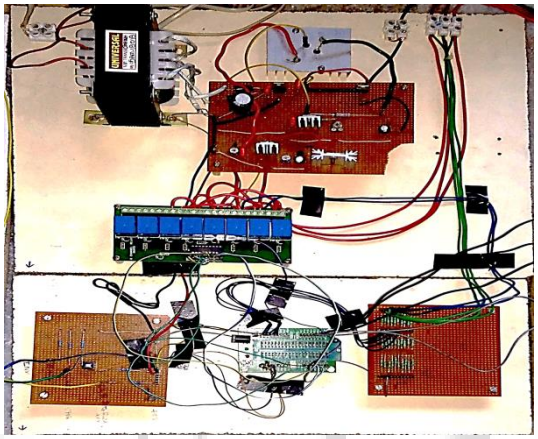

Fig. 5: Experimental setup

Figure 5 shows the experimental setup of Ultracapacitor charging.

Table 1 gives the charging time and according voltage values relates the graph shown in figure 6. The total time required to charge the Ultracapacitor to its rated value is 25 minutes.

Time (Minutes)	Voltage (Volts)
0 (Initial)	8.9
1	10.15
2	11.03
3	11.76
4	12.35
5	12.85
6	13.14

Table 1: Actual reading during charging the Ultracapacitor

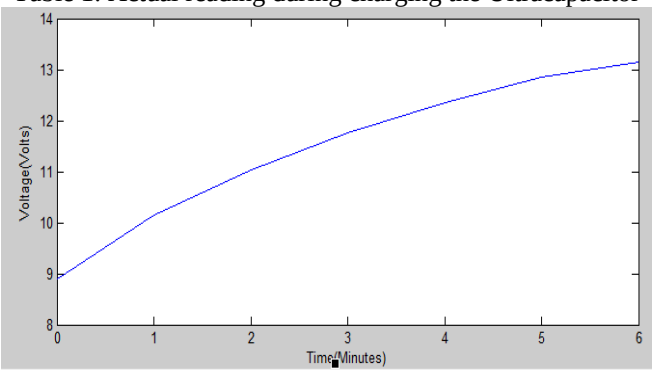

Fig. 6: Voltage graph of the Ultracapacitor during charging

The charger circuit is connected to the controller through relay switching circuit for charging termination. The set value in controller makes it to disconnect the Ultracapacitor when it is fully charged.

IV. CONCLUSIONS

An efficient charger for Ultracapacitor gives beneficial response in electric vehicle industry. By using less number of components, a new and cheaper charging circuit named Bulk Charger has been developed. Increase in current gives less charging time.

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