Application of Ultra-capacitors in an Electric Toy Vehicle

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Abstract: *This paper presents an experimental investigation of the application of ultra-capacitors for a battery operated electric vehicle. The batteries can supply rated current for a longer duration, but the vehicle may require large current during starting. Therefore, the energy supplied by the battery may reduce if there are numbers of start-stops in the run. The ultra-capacitors are designed to provide large current for short durations. An electric toy vehicle has been used to test the advantages of both the sources. A passive balancing circuit has been tested to show that the voltage across the individual ultra-capacitors connected in series for charging be equal. The operation of the vehicle with the batteries alone, ultra-capacitors alone, and both batteries with ultra-capacitors have been investigated. It has been shown that ultra-capacitors can increase the range of the electric vehicle by minimizing the sharing current form the battery.*

Key words: *Battery, Passive balancing, Ultra-capacitors, Toy vehicle*

1. Introduction

An electrical vehicle operates using electrical motor to which the power is provided from stored source of energy, such as batteries. The vehicle has zero emissions except from the batteries. The electrical vehicle transport system is eco-friendly if the batteries are also charged from an eco-friendly source of energy, like wind, bio etc. In the existing system of transport mainly petrol/diesel operated engines are used. These vehicles have emissions but due to strict norms, they are getting reduced. A cooling system is required as these engines generate considerable heat during combustion. To obtain variable speed and speed –power balance, a gear box is used. All these factors contribute to overall poor efficiency of the petrol/diesel vehicles [16].

In spite of negligible emissions by the battery operated electric vehicles, they are not viable proposition in replacing the existing petrol/diesel vehicles at present due to many reasons. Some of them may be the distance covered by the vehicles after charging the batteries may not be adequate. The method of recharging the batteries or replacing by charged batteries may be time consuming and complex, respectively. There may be the other reasons, like less power, more cost, weight, etc. To cover a span of distance the vehicle may start from zero speed a number of times. The motor will draw a large current at the time of start to provide necessary torque to the wheels. The total energy provided by the recharge batteries decreases if more than the rated current is drawn, therefore, vehicle will cover less distance. To prolong the range of the distance travelled by the vehicle the additional energy required by the motor at the time of start may be supplied by the ultra-capacitors [16, 17].

In this paper, a passive balancing technique is presented to balance the ultra-capacitors voltage when they are connected in series. A prototype model was integrated with two ultra-capacitors in series and testing of the model was conducted with battery, battery plus ultra-capacitors, and only with ultra-capacitors.

2. Structure of the multi-energy system

The batteries can supply more energy if the power is drawn at their rated current. The energy delivered by the recharged battery decreases if the power is drawn at a higher current than the rated. It is due to an increase in the energy dissipated in the internal resistance of the battery and it also shortens the life of the battery. The energy delivered with rated current Ir, for time hr/2 at rated voltage Vr. But the energy loss in the internal resistance of the battery is double in the second case, therefore, available energy decreases. On the other hand the ultra-capacitor can provide high current for short durations. Therefore, the problem can be dissolved by using both the components as shown in Fig.1. The motor controller decides that under different operating conditions which component will provide power to the motor.

3. Charging of the ultra-capacitors

The voltage across ultra-capacitors in a complete charged condition is low of the order of 2.5 volts to 2.7 volts. Therefore, they are connected in series to attain a voltage level required for a particular application. The stack of the ultra-capacitors connected in series gets discharged by the supplying its power to the load and may require recharging. A constant current source is used to supply the charging current to the ultra-capacitors. If the ultra-capacitors have variation in capacitance, there will be variation in voltage across the ultra-capacitors. The ultra-capacitor with more capacitance may be charged to lower voltages and the ultra-capacitors with less capacitance may be charged to higher voltages. The ultra-capacitor may have different capacitance which may be due to manufacturing tolerances or by aging also. It will result in overcharging or undercharging of some of the ultra-capacitors. The effect will also be reduction in life of some of the ultra-capacitors and energy storage may not be at its maximum level.

To avoid unequal charging of the ultra-capacitors, a passive balancing technique is used. This can be achieved by regulating the voltage of individual ultra-capacitors. A simple approach is to use bypass resistors in parallel with the ultra-capacitors for equalization as shown in Fig.2. The value of the resistances is chosen between 1/10 to 1/100 of the leakage resistance of the ultra-capacitors [24, 25].

4. Experimental Results-

To charge the two ultra-capacitors UC1 and UC2 with a constant current source, as shown in Fig.2, 10 ohms, 10 watts, resistances are connected in parallel. The specifications of the ultra-capacitors used is given in Appendix-I. The two ultra-capacitors were charged with constant current source without the balancing resistances and the individual voltages were measured at regular intervals. The increase in the voltage with the time is shown in Fig.3. Similarly the charging of the ultra-capacitors were carried with the passive balancing and the variation in voltage is shown in Fig.4. It has been observed that the charging of the ultra-capacitors with balancing resistances results in equal voltage across the ultra-capacitors.

4.1 Integrating the ultra-capacitors in a test vehicle-

An electric toy vehicle powered by a battery was taken for experimentation. The battery in the toy vehicle was rated as 6 volts, 4.5 Ah. The circuit diagram was modified to include the ultra-capacitors as shown in Fig.5. The diodes were used to reduce the voltage applied across the ultra-capacitors. The battery requires constant voltage of 7.5 volts to charge but the ultra-capacitors in series require only 5.4 volts, therefore, IN5408 diodes were introduced. The toy vehicle fitted with the ultra-capacitors and the battery is shown in Fig.6. To collect the test data, all the measuring points were taken outside on a terminal box as shown in Fig.7. The ultra-capacitors were given at a constant current of 3A the terminal blocks for the charging.

4.2 Testing of the vehicle-

The testing of the vehicle was carried by supplying power from the battery (6 volts, 4.5 Ah) to the motor with load of 1.3A, as shown in Fig.8. The ultra-capacitors were not in the circuit at that time. The discharging characteristic of the battery in the vehicle was obtained as shown in Fig.9. Similarly the power to the motor was supplied by connecting the ultra-capacitors and the discharging characteristic was obtained as shown in Fig.10, for constant load of 1.3A.

Finally the motor of the toy vehicle was operated by connecting both the battery and the ultra-capacitors in parallel. To measure the response at the starting time of the vehicle, the current signal was measured by C.R.O. as shown in Fig.11.

5. Problems encountered during experimentation

- Leakage of electrolyte in one ultracapacitor was observed during accidental short-circuit of terminals as shown in Fig.12.
- The electrolyte which is organic in nature contains acetonytrile,ecologically hazardous and inflammable substance.
- This supports the claims of aqueous electrolyte based ultracapacitor manufacturers such as M/s ELIT JSC, Russia that organic electrolyte based ultracapacitors should be used in general and specifically for automotive applications.

6. Conclusions

An experimental study has been conducted to increase the range of the electric vehicles by using ultra-capacitors. A passive balancing technique has been given for charging of ultra-capacitors to have equal voltage on all the ultra-capacitors after getting charged. Tests have been conducted on a toy vehicle by operating with battery, ultra-capacitors, and a combination of battery plus ultra-capacitors. It has been concluded that the range of the vehicle and the life of the battery increases by the use of ultra-capacitors.

APPENDIX -I

The specification of the used ultra-capacitors is shown below;

- Name of manufacturer- NESSCAP, South Korea
- Rated Capacitance- 5000F
- Capacitance Tolerance -10%/20%
- Rated Voltage -2.7 volts
- Surge Voltage- 2.85 volts
- Maximum Stored Energy -5.0625Wh
- Power Density-5.12 kW/Kg
- Weight -890gm
- Operating Temperature Range -40 to +60 degree centigrade
- Cycle Life (25 degree centigrade)-500000 cycles
- Electrical Series Resistance -0.35 milli ohms.
- Cost of one ultracapacitor cell- $200.

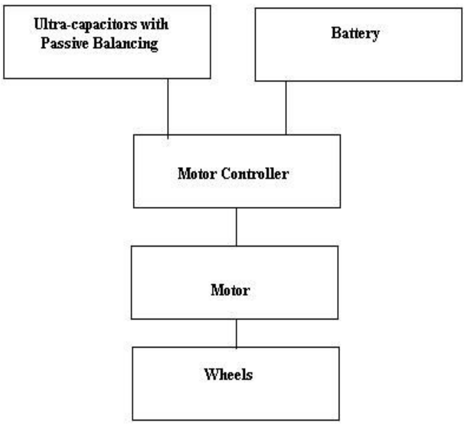


Fig.1. Multi –energy control system

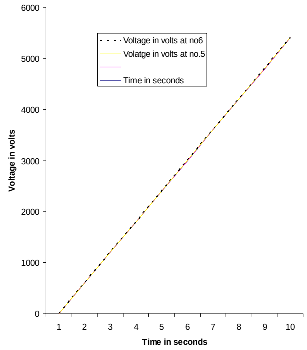


Fig.4.Charging of the ultracapacitors with passive balancing

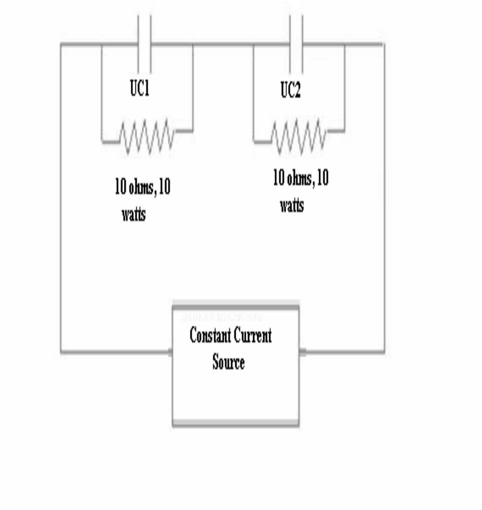
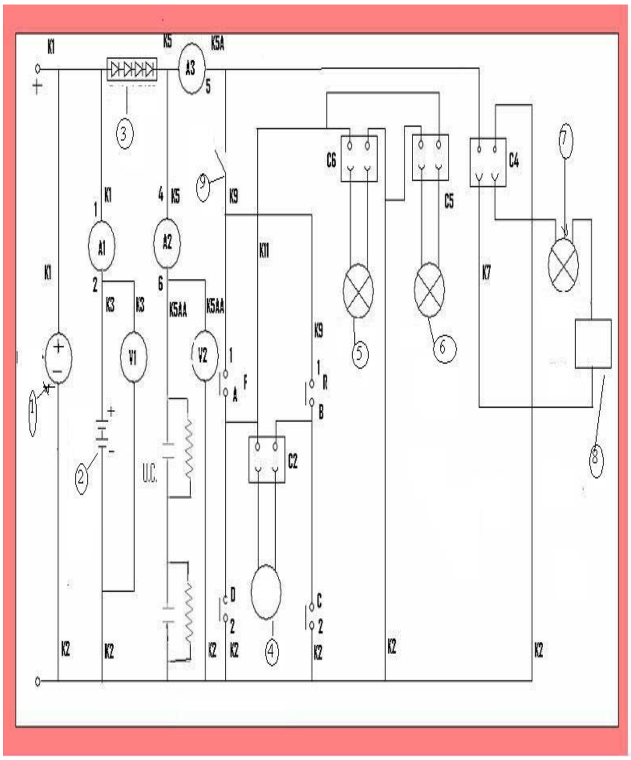


Fig.2. Charging of Ultra-capacitors



1-Charger, 2- Battery of 6 volts, 4.5Ah, 3- Diodes, 4-Motor 5-Tail lamp, 6- Front Lamp, 7-Loud speaker, and 8- Flash

Fig.5. Electrical circuit diagram of the electric toy vehicle

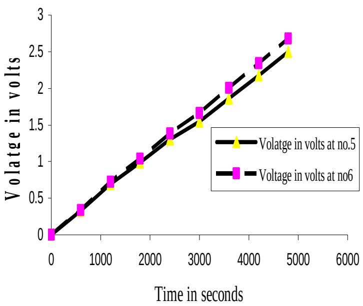


Fig.3. Charging of the ultracapacitors without balancing

Fig.6.Fitting of the ultracapacitors using resistive balancing

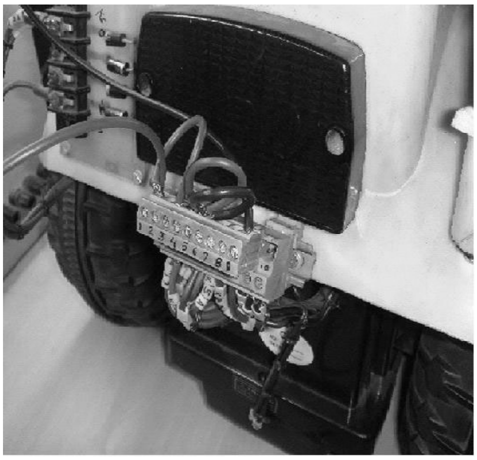


Fig.7.Showing all connections on a connector

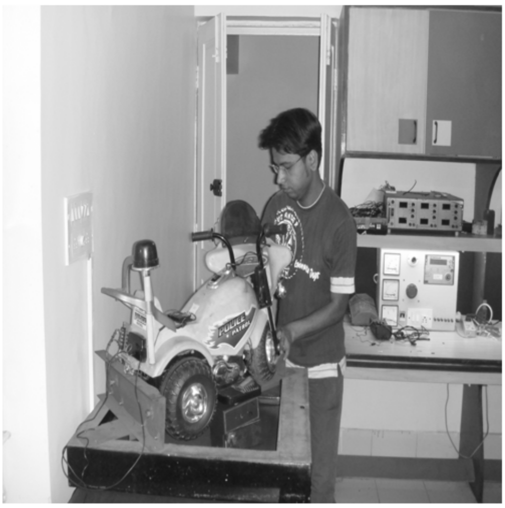


Fig.8. Showing the discharging test on the vehicle

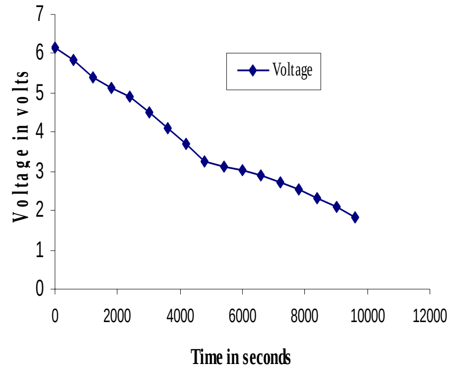


Fig.9.The discharging characteristic of the battery alone fitted in the vehicle model

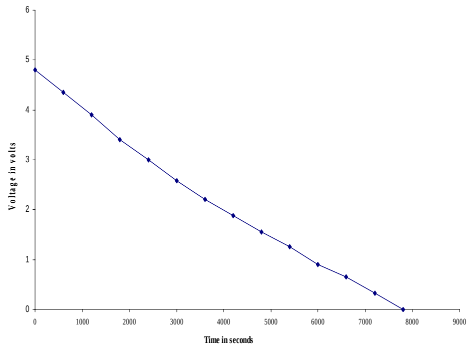


Fig.10 The discharging characteristic of the ultracapacitors alone fitted in the vehicle model

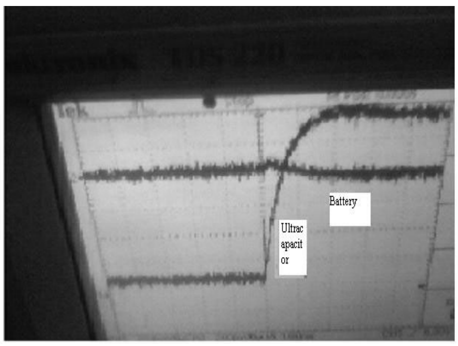


Fig. 11.Showing the discharging results with ultracapacitor and battery both in circuit

Fig.12.Showing the leakage of electrolyte during experimentation

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Biographies-

Pawan Sharma received the A.M.I.E. degree from Institution of Engineers, India, in 2005, the M. Tech degree from National Institute of Technology, India, in 2008 and at present pursuing PhD from Centre for Energy Studies, Indian Institute of Technology Delhi, India.His research interests include automatic generation control, reactive power control, hybrid power systems, wind, small hydro systems, and electric vehicles.