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A Review Paper on Ultra Capacitor Technology and its Applications

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***Abstract*:- Ultra-capacitor technologies are reviewed with the emphasis on carbon-based devices using organic electrolytes. These devices have cell voltages of around 2.5-3V.The energy density of commercially available energy storing large devices have energy densities of 3-4 Wh/kg along with a pulse power capacity of 3-4 kW/kg. A small carbon-based laboratory prototype device has an energy density of 8.5 Wh/kg with a pulse power density greater than 10 kW/kg. The conceptual design of ultra-capacitor modules and energy storage units for vehicle applications indicated that the commercially available devices can be used effectively for starting the engine to assist batteries in passenger cars and large trucks and as the power assistant energy storing units for hybrid-electric vehicles for passenger cars and transport buses.**

INTRODUCTION:

Electrical energy storage is needed in both vehicles using conventional engines and those using electric and electric-hybrid powertrains. Presently in most of these applications, batteries are used as the energy storage device. The batteries must be sized to provide both the energy (kWh) and power (kW) required in the application. In some cases this results in the battery far exceeding one of the two requirements, as in the case where the power required is high and the energy storage required is relatively low. In such cases, the battery is said to be sized by power and the energy stored follows from the mass of the battery and the energy density (Wh/kg) of the battery chemistry. In these cases, an energy storage device having a very high power density (W/kg) and relatively low energy density (Wh/kg) could be a more effective solution to the energy storage problem in terms of weight, volume, and cost than a battery. The ultra capacitor is such an electrical energy storage device. The development of ultra capacitors for automotive applications has been in progress since about 1990. In this paper, the technology of ultra capacitors is reviewed, performance data presented for several advanced carbon- based devices, and illustrations of how advanced ultra capacitors can be used in several automotive applications discussed.

Ultra capacitors are being developed as an alternative to pulse batteries. Being an attractive alternative, ultra capacitors must have much higher power and much longer shelf and cycle life as compared to batteries. Ultra capacitors have much lower energy density than that of batteries and their low energy density is in most cases the factor that determines the feasibility of the use of ultra-capacitors particular high power application requirements.The characteristics of a number of ultra-capacitors and pulse batteries. The first approach to calculate the peak power of a battery is to determine the power at the so-called matched impedance condition at which half the energy of the discharge is used inthe form of electricity and other half is in heat. The maximum pulse power at this point is given by

$$P_{mi} = V_{oc}^2/4\ Rb$$

Where Voc is the open-circuit voltage of the battery and Rb is its resistance.

The discharge efficiency at this point is fifty percentages. For many applications where significant part of the energy is stored in the storage devices before getting used by the system, the efficiency of the charging/discharging cycle is very important to the system’s efficiency. The use of the energy storage device should be limited to conditions that result in high efficiency for both charging and discharging. The discharge/charge pulse power for a battery as function of efficiency is given by

$$P_{ef} = EF*(1-EF)*V_{oc}^2/R_b$$

here EF is the efficiency of high power pulse.

For EF=.95, P_{ef}/P_{mi} = .19. Hence in applications in which efficiency is a primary concern, the useable pulse power of the battery is much less than the peak power (P_{mi}) often quoted by the manufacturer for the battery. In the case of ultra capacitors, the peak pulse power during a discharge between V_o and $V_o/2$, where V_o is the rated voltage of the device, is given by

$$P_{uc} = 9/16*(1-EF)*V_o^2/R_{uc}$$

whereRuc is the resistance of the ultra capacitor.

The expression shown above deals with the reduction in voltage during the discharging of the device.Peak pulse power values for both matched impedance and high efficiency discharges of the batteries and ultra capacitors. It is apparent that in most cases the power of the ultra capacitors is much higher as compared to the batteries. Remember that it is not good approach to compare the high efficiency power density of the ultra capacitors with the matched impedance power density of the batteries as it is often done. The power storage capacityof both types of devices is dependent on their resistance and knowledge of the resistance is the key to determine the peak useable power capability.Thus measurement of the resistance of a battery in the pulsed mode is critical to an evaluation of its high power capability.

The ultra capacitors having a high power capability as well as a long life cycle makes it more preferable to battery. This is especially true of ultra capacitors using carbon electrodes. If, most rechargeable batteries, left unused for many months then performance will degrade markedly and be essentially useless after this time, due to self-discharge and corrosion effects. Ultra capacitors will be self-discharged over a period of time to low voltage, but will retain their capacitance and thus will be capable of recharge to their initial condition. The experiment has proved that ultra capacitors can be unused for many years and remain in nearly their original condition. Ultra capacitors can be deep cycled at high rates (discharge times of seconds) for 500,000 to 1,000,000 cycles with a relatively small change in characteristics (10-20% variation). But this is not possible with batteries even when the depth-of-discharge is small (10-20%). Hence the advantages of ultra capacitors are high power density, high efficiency, and long shelf and cycle life. The primary disadvantage of ultra capacitor is its low energy density (Wh/kg and Wh/l) than the batteries. Ultra capacitors can be recharged in very short time (seconds or fraction of seconds) compared to batteries when a source of energy is available at the high power levels required. The simplest capacitor stores the energy within a thin layer of dielectric which is supported by two metal plates that act as terminals of the device. The energy stored in a capacitor is given by $\frac{1}{2} CV^2$, here C is capacitance in Farads and V is the voltage between the terminal plates. The maximum potential of the capacitor depends on the breakdown characteristics of dielectric material. The charge Q stored in the capacitor is equal to CV. The capacitance of the dielectric capacitor is dependent on the dielectric constant (K) and the thickness of the dielectric material and its geometric area (A).

$$C = KA/ th$$

In a battery, energy is stored in chemical form as active material in its electrodes. Energy is emitted in electrical form by connecting a load between the terminals of the battery permitting the electrode materials to react chemically with the ions needed in the reactions to be transferred through the electrolyte. The usable energy stored in the battery is given as the product of voltage and charge i.e. VQ. The voltage depends on the active materials of the battery and is close to the open-circuit voltage (V_{oc}) for those materials. An ultra capacitor, sometimes referred to as an electrochemical capacitor, is an electrical energy storage device that is constructed much like a battery in that it has two electrodes immersed in an electrolyte with a separator between the electrodes. The surface area of the electrode materials in ultra capacitors is greater than that used in battery electrodes. Charge is stored in the micro pores near the interface of the solid electrode material and the electrolyte.It is convenient to discuss the mechanisms for energy storage in ultra capacitors in terms of double-layer and psuedo-capacitance separately. The physics and chemistry of these processes are explained in great detail in Reference 1.

CONCLUSION:

Electrical energy storage is needed in both vehicles using conventional engines and those using electric and electric-hybrid powertrains. Presently in most of these applications, batteries are used as the energy storage device. The batteries must be sized to provide both the energy (kWh) and power (kW) required in the application. In some cases this results in the battery far exceeding one of the two requirements, as in the case where the power required is high and the energy storage required is relatively low. In such cases, the battery is said to be sized by power and the energy stored follows from the mass of the battery and the energy density (Wh/kg) of the battery chemistry. In these cases, an energy storage device having a very high power density (W/kg) and relatively low energy density (Wh/kg) could be a more effective solution to the energy storage problem in terms of weight, volume, and cost than a battery. The ultra capacitor is such an electrical energy storage device. The development of ultra capacitors for automotive applications has been in progress since about 1990. In this paper, the technology of ultra capacitors is reviewed, performance data presented for several advanced carbon- based devices, and illustrations of how advanced ultra capacitors can be used in several automotive applications discussed.

Ultra capacitors are being developed as an alternative to pulse batteries. To be an attractive alternative, ultra capacitors must have much higher power and much longer shelf and cycle life than batteries. By "much" is meant at least one order of magnitude higher. Ultra capacitors have much lower energy density than batteries and their low energy density is in most cases the factor that determines the feasibility of their use in a particular high power application.The characteristics of a number of ultra capacitors and pulse batteries.The first and more standard approach to calculate the peak power is to determine the power at the so-called matched impedance condition at which one-half the energy of the discharge is in the form of electricity and one-half is in heat.

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