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Using battery & Supercapacitor for electric cars start up

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***Abstract*— This paper treats the start-up of hybrid electrical vehicle in cold condition. The storage elements remains the critical point in the development of the vehicles. The study considers the supercapacitors (high power density) that store energy in the form of electrical charge complementary to the batteries (high energy density). The concept of this hybrid system is to introduce, in addition to the energy source (battery), a power source (supercapacitor). This hybridization technology has better performance, especially in terms of cost, design and life span of the batteries than a system composed solely of batteries, as is the case in most electric vehicles and hybrid electric vehicles the nowadays in the market. The goal of this work is to increase the effectiveness of the electric car start-up, which is directly depending on the battery performance. The proposed solution uses a hybridization of the battery with supercapacitors (SC). In addition, these SCs will be in charge of a rapid heating of the batteries, which will in turn recharge the SCs during the trip. Consequently, the lifespan of the battery is improved and thus the autonomy of the electric car.**

***Keywords*— electric car, battery, supercapacitor, heat pad hybridization**

I. Introduction

Electric cars are one of the amazing technological inventions. The German Flocken Elektrowagen, built in 1888, was the world's first electric car.

The main challenges to the development of Electric Vehicles (EV) is the performance of energy storage. However, several requirements must be imposed on energy sources, such as the energy density and high power, long cycle life, reliability, wide temperature range of operation and no polluting emission. Among of these sources are fuel cell, battery and super/ultracapacitor [1]. Indeed, using only one source is often insufficient and can drive to destruction of the source. For example, the EV using only the battery is often exposed to the damage caused by high peak power and rapid charging/discharging cycles such as in the acceleration/deceleration phases. For this, most applications use a hybrid system consisting of more than one type of power source in order to overcome the disadvantage of every single type [2]. From [3], the use of the SC in the storage system with battery can allow the absorption of the rapid fluctuations in power because it act such a buffer. In [4] this work falls within the framework of improving the performance of the storage system in EVs. In this study, it is shown that the introduction of the SC could significantly reduce the electrical stress of the battery. Moreover, by different parallel-series connection of battery and SC module, the improvement of the storage system can be achieved. In [5], this work deals with the control of energy management of a hybrid system comprising a battery and a SC to meet the load power demand in the traffic condition (i.e. frequent acceleration sequences and deceleration). Indeed, the strategy of the management of energy used is based on the algorithm of wavelet transform. And that, by introducing trip information to optimize the efficiency of the hybrid system and the life of batteries. [6] In this work, a hybrid energy storage system is used for photovoltaic generation systems that are associated with rapid power fluctuations. The hybrid system is an energy storage system of battery and SC. A method is used that optimize energy density characteristics of the battery system and the super power density. Obtained Results show that the SCs contribute to the attenuation of high frequency fluctuations, increasing the lifespan of batteries and help to address the peaks in solar power fluctuations without the severe penalty of round trip losses associated with a battery system. In [7] the study, the used of hybrid storage system is composed of lead-acid batteries and SCs that have the complementary performance. This storage system is used to increase the power grid stability of intermittent renewable energy sources. The batteries and SCs are associated to provide a pulsed current. In this paper, the batteries are used under its nominal conditions, i.e. the battery current has been limited in order to increase to lifetime. In order to control the power management between buck and boost converters connected to the same DC bus, an innovative cascade control with anti-windup is used and the performance of the hybrid energy storage system in real time is evaluated. In [8], the authors article study the efficiency of the combination of battery-SC in EV. They mentioned that a direct parallel connection can reduce the battery stress during acceleration and deceleration phases because the SC plays the role of the power buffer to smooth rapid power fluctuations. The results

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show that the design of this storage system provide the substantial conditions to the well-being of the battery system.

In addition to these works, several other studies have focused on the hybrid storage system used in EV at subzero temperatures. Because, in these environmental conditions, the EV suffers from degradation due to the energy and power limitation of the storage elements. For example, the study of [9] treats the hybrid energy storage system composed of semi-active battery/SC embedded in EV at subzero temperature. The dynamic programming approach is used to an optimal energy management strategy of the hybrid energy storage system for online use. The connective heating method is integrated into the dynamic programming process. A degradation model of $LiFePO_4$ battery is used in order to estimate the battery fade in wide temperature range. Indeed, in this work, the authors are focalized mainly on the battery element because its suffers from severe degradation.

Despite the number of studies that were performed on storage system embedded in EVs, are still facing problems, especially related to the autonomy, which is directly linked to the stored energy [10]. The principal issue treated in this work is the startup up of the EV at low (or negative) temperature [11], especially in cold countries like Canada, north of Europe, Russia...where it is snowing almost all the winter season and the temperature gets lower which makes the electric car startup harder and complicated.

The proposed solution in this work is based on the idea of using a heating system ("heat pad") which will heat the battery using SC power. The heating process can consume a relatively high part of the SC energy. Consequently, the recharging of the SC from batteries when low load demand or during the breaking of the car should be done [12]. Hence, the SC recharge is important and should incorporate the battery "pre-heating" consumption by using adequate controllers [13].

II. BATTERY/SUPERCAPACITOR PERFORMANCE AT WINTER CONDITIONS

There are big differences between rechargeable batteries and SCs. The figure 1 shows a difference in term of voltage and charge/discharge time.

In the context of this work, it is interesting to know the performances of batteries and SCs used in EV at subzero temperatures ($T < 0$ ° C). For this, it is necessary to carefully select the battery/SCs, which can work at severe climates especially at cold temperatures.

A. Batteries

The temperature is one of important parameters that reduce the lifetime and therefore the degradation of the batteries. This storage element used in hybrid EV should operate in a wide temperature range from -40 to 80 °C [14]. So, at low temperature, battery performance is limited mainly by two parameters, which are the internal resistance and minimum voltage. Where, at subzero temperatures, the internal resistance increases and the power capacity decreases [15].

B. Supercapacitors:

The studies for space applications, non-aqueous SCs are available operating at temperatures -40 °C. The SC is ideal for energy storage that undergoes frequent charge and discharge cycles at high current and short duration [13]. The operating temperature presents an important factor that influences on SC performance. The performance of most SCs using electrolytes either aqueous or non-aqueous nature deteriorates at cold temperatures, where these conditions reduce the power density of the SC due of freezing of the aqueous electrolyte and the viscosity of the non-aqueous electrolyte 16]

III. THE PROPOSED SOLUTION

To date, several techniques have been developed to achieve a high performance of the hybrid storage system at low temperature. The proposed solution for this problematic is to increase the EV battery voltage to start up the car easily without problems, to do that one need to heat this battery. Authors propose the use of a heating pad. The pads called also Silicone Rubber Heaters are pasted on the battery surface in order to heat it, with these heaters; heat can be placed where it is needed. In the application process, these heaters improve heat transfer; speed warm ups and decrease wattage requirements. Because very little material separates the element from the part, heat transfer is rapid and efficient. The "Silicone Rubber Heaters" delivers low mass and easily repeatable distributed watt densities, provides longer heater life, provides the desired flexibility for many dynamic applications and can operate in high temperature, up to 260 °C (550 °F), and watt densities up to 12.5 W/cm^2 (80 W/in^2). In addition, cost is not expensive.

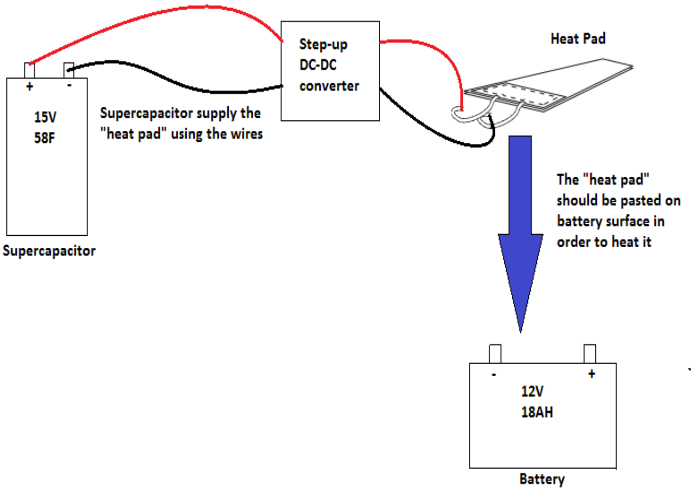

Fig.3. Synoptic of the solution using heat pad and SC

IV. CONCLUSION

The combination between SC and batteries helps to reduce the energy consumption in a vehicle. SCs can play an important role in the development of hybrid vehicles through the energy recovery during braking, and its large life time (huge number of cycle). In the suggested solution, "heat pads"

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were used to heat the battery and to enhance the startup at hard environmental conditions. Here the battery is preheated in less than one minute when outside temperature is around -20°C. The heat energy is supplied using SC allowing fast heat and can easily be recharged during the regenerative braking

The proposed solution is very simple and can be easily implemented since the battery heating control can be performed using a simple thermostatic switch between SC and heat pad (no action needs from the driver). In order to increase the voltage, and consequently increase to temperature of heat pad, one can use several SC packs in series. To recharge the SC, the solution is to use the braking energy, and convert it into electrical energy, which can be enough to charge SCs.

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