Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 1914–1919

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Optimal control strategy of ultra-capacitors in hybrid energy storage system for electric vehicles

Clemente Capasso[a], Davide Lauria[b], Ottorino Veneri[a]*

[a]*Istituto Motori – National Research Council of Italy, Via Marconi 4, Naples 80125, Italy*
[b]*Department of Industrial Engineering – University of Naples Federico II, Via Claudio 21, Naples 80125, Italy*

Abstract

This paper describes a novel Energy Management Strategy (EMS) for hybrid energy storage systems, when used to supply urban electric vehicles. A preliminary off-line procedure, based on nonlinear programming, is performed in order to optimize the battery current profile for fixed working cycles. Hence, a suitable control strategy, which is based on a constrained minimization problem, is tailored for real-time applications. This control strategy exploits the off-line solution of a proper isoperimetric problem and aims to dynamically optimize the battery durability by reducing peak charging/discharging current values. The main advantage of the analysed EMS consists in the easy on-board implementation through the use of one single parameter, which can be quickly identified through a simple off-line numerical procedure. The proposed strategy is evaluated in simulation environment, through the use of a Matlab-Simulink model, for the case study of an urban electric vehicle running on a ECE 15 driving cycles. Simulation results have confirmed the good performance of the above strategy in reducing the battery peak charging/discharging current through the proper management of the hybrid energy storage system.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: Hybrid Energy Storge Systems; Electric Vehicles; Isoperimetric Optimization; Electric Double Layer Capacitors; Zebra Batteries

* Corresponding author. Tel.: +39-081-7177143; fax: +39- 081-2396097.
E-mail address: o.veneri@im.cnr.it

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.390

1. Introduction

Nowadays, increasing environmental concerns and the expected depletion of oil resources are drawing the interest of researchers and manufacturers of the automotive sector towards new technical challenges, supporting clean and sustainable transportation systems [1]. In this regard, the use of electric propulsion systems appears to be a promising solution for near-term future, especially for the urban mobility context. In fact, vehicles equipped with these kinds of propulsion systems can benefit of various advantages, such as the possibility to operate in urban areas without tailpipe emissions and high values of well-to-wheel conversion efficiency [2]. In addition, recent development in battery technologies allows reaching high values of energy density, with consequent positive effects on the expected vehicle autonomy. Unfortunately, the mission of road electric vehicles is generally characterized by variable load demand and high power peaks, which are due to frequent acceleration and braking phases. These power peaks, as widely recognized in the scientific literature [3] [4], involve adverse effects for the on board battery packs, in terms of charging/discharging efficiency and durability.

A feasible solution for the above issues is represented by the use of hybrid energy storage systems (HESSs), which are based on a combination of batteries with high power density storage devices, such as supercapacitors. In this case, it is clear that the vehicle steady state operations can be performed by using the energy coming from the battery pack, whereas the peak charging/discharging power demands can be managed through the proper use of supercapacitors. With this aim, various papers reported in the scientific literatures have focused the attention on hybrid energy storage systems, mainly in terms of component sizing and optimal energy management strategies on the basis of the expected vehicle mission [5][6]. In this context, for the specific case study of an urban vehicle, this paper firstly introduces an optimal off-line energy management strategy (EMS), which is aimed to minimize the battery current variance through nonlinear programming. Then an on-line strategy, based on the calculus of variations theory, is proposed and compared with the off-line EMS through the use of simulation environment. This comparison is performed in terms of effectiveness in reducing the effect of high charging/discharging current peaks on battery durability.

2. Case Study and Optimization Problem

An electric version of the Renault Master is considered in this paper as case study of electric vehicle supplied by a hybrid energy storage system. The same version of this vehicle, supplied only by the battery pack, has been already considered by the authors in a previous paper, which reports the main vehicle characteristics and operative conditions [7]. The architecture chosen for this kind of vehicle is based on the well known SC/battery configuration, which is described and proposed in [8]. This configuration allows the management of power fluxes between the battery pack and supercapacitors by means of the proper control of a bidirectional DC/DC converter. The block scheme and electric parameters of the considered power-train, supplied by the hybrid energy storage system, is reported in Fig. 1.

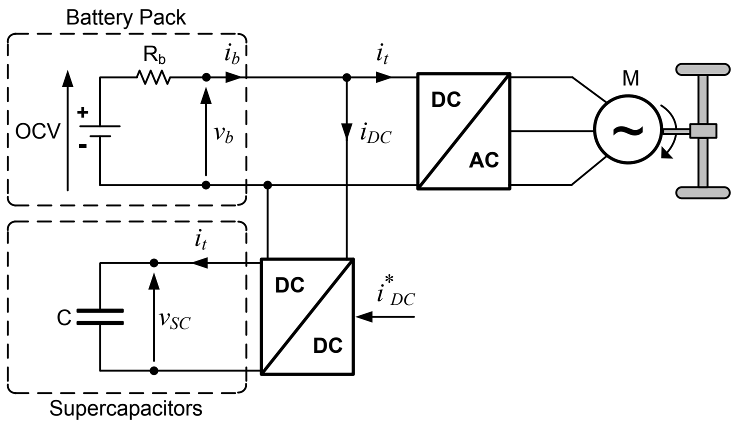

Fig. 1. Block scheme and electric parameters of the propulsion system under study.

The above described hybrid energy storage systems is based on 2 x 38 Ah - 550 V ZEBRA batteries, which are connected in electrical parallel, and a 63 F – 125 V module of supercapacitors. The DC/DC bidirectional power