Sliding Mode Control of a Hybrid Battery-Supercapacitor Energy Management System

Ezequiel Orozco, Héctor Chiacchiarini[1]

Dpto. de Ing. Eléctrica y de Computadoras, Universidad Nacional del Sur (UNS), Bahía Blanca, Argentina.
[1]Instituto de Inv. en Ing. Eléctrica "Alfredo Desages" (IIIE), Universidad Nacional del Sur (UNS) - CONICET, Bahía Blanca, Argentina.
E-mail: hgch@uns.edu.ar

Abstract: This work presents an Energy Management System (EMS) for a Hybryd energy Storage system (HESS) composed by battery and Supercapacitor (SC) which splits the power demand over the two storage devices, preventing the battery to be stressed by fast changing current demands. High frequency current components are mainly derived to the SC who has to respond to the fast changing power demand, while the battery is reserved to smoothly recharge the SC when necessary. Sliding mode control is used, and simulation results are included.

Keywords: Energy management, Energy storage, control

INTRODUCTION

The market share of electric vehicles (EVs) and hybrid electric vehicles (HEVs) is gradually increasing and the associated technologies are fast developing in response to the actual demands and challenges about sustainable economy. Lithium ion (Li-ion) batteries have many comparative advantages respect to other technologies and nowadays are mainly selected for electric transportation (Emadi, 2015, Opitza et al., 2017). Nowadays, battery technologies offer high performance devices with increasing energy density but still suffering from degradation problems due to normal usage (Wang et al., 2020), which have to be properly addressed following adequate usage rules (Waldman et al., 2014, Xie et al., 2014) to preserve their health (Kabir & Demirocak, 2017, Yang et al., 2018, Xu et al., 2018, Jafari et al., 2018).

Batteries can be combined with other storage devices (e.g Battery, Fuel Cell and SC, or battery and SC) creating HESS where the technological advantages of each device can be exploited in a proper way (Amaya et al., 2020). In such HESS, an EMS is needed to coordinate the proper usage of each device while preserving the health of the device (Yue et al., 2019, Biswas et al., 2019, Fu et al., 2020). The battery health depends on the current demand, cycling, temperatures, and other factors, which produce degradation of the internal components, with impact mainly on the output impedance and on the storage capacity. The electrical factors to consider for battery preservation are: state of charge, current demand, current variations and cycling. Thus, an adequate EMS should implement adequate preservation rules (Chiacchiarini et al., 2020) by splitting the current demand between the battery and the other storage devices, such that the stress on the battery could be reduced.

This work presents a EMS which splits the power demand over the two storage devices, preventing the battery to be stressed by fast changing current demands. High frequency current components are mainly derived to the supercapacitor who has to respond to the fast changing power demand, while the battery is reserved to smoothly recharge the supercapacitor when necessary. The strategy is based on sliding modes (Utkin, 1992). The sliding dynamics is designed such that the SC can react to fast current changes, and the battery can provide the average power demand, needed to restore the SC state of charge. The system architecture includes a dc-link node where the traction converter sinks or demands the traction power, and where the power transferred from the storage devices is injected through specific dc-dc converters. The sliding controllers are designed to command each dc-dc converter in order to implement the strategy. Simulation results are included to illustrate the basic idea and the system performance. Comparisons with other power-splitting strategies are also included.

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