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DC Charging Station for Electric and Plug-In Vehicles

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Abstract

This paper is focused on the evaluation of theoretical and experimental aspects related to the different operation modes of a laboratory power architecture, which realizes a micro grid for the charging of road electric and plug-in hybrid vehicles. The analyzed power configuration is based on a DC bus architecture, which presents the main advantage of an easy integration of renewable energy sources and buffered storage systems. A first phase of simulations is aimed to evaluate the main energy fluxes within the studied architecture and to identify the energy management strategies, which optimize simultaneously the power requirements from the main grid and charging times of different electric vehicles. A second phase is based on the experimental characterization of the analyzed power architecture, implementing the control strategies evaluated in the simulation environment, through a laboratory acquisition and control system. Then the experimental results coming from the laboratory prototype are compared with the simulation results, in order to achieve a better parameter setting of the simulation model for the analyzed structure. This preliminary analysis makes possible other simulations to be carried out on more complex architecture of micro-grids, taking into account the integration of renewable energy sources and high power buffer storage systems. Particular attention is also given to the analysis of ultra-fast charging operations and the related performance in terms of total efficiency, charging times, total power factor and power requirements from the main grid. This study represents a further step toward the new concept of smart grid scenario for electric vehicles.

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Keywords: Recharging Stations, Energy Storage, Vehicle to Grid, Electric Vehicles, Micro Grid

1. Introduction

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Nowadays, the transportation sector depends on liquid fossil fuel derived from crude oil for 95%, which implies that 50% of the crude oil production is used only for transportation. In this contest, road vehicles based on full electric or hybrid drives attract great attention as a good solution to solve the problems of liquid fossil fuel dependence. Moreover, the storage systems of the electric and plug-in hybrid vehicles, when connected to recharging stations, may represent a great advantage for the main grid in terms of integration/interaction with the renewable energy sources. From this point of view the electric power systems industry is facing issues related to the massive integration in the electric grid of electric vehicles. [1, 2].

The following sections, starting from the description of a prototype laboratory DC charging station, reports simulations and preliminary experimental results on the proposed architecture, with reference to one of main different operative conditions.

2. Experimental

A prototype of micro-grid for fast recharging operations of electric vehicles has been designed and realized to run laboratory tests, with the aim of studying and evaluating the operative characteristics of a DC based recharging station with buffered storage system and battery packs for electric powered vehicles. The power electric scheme of the prototype recharging station is reported in Figure 1.

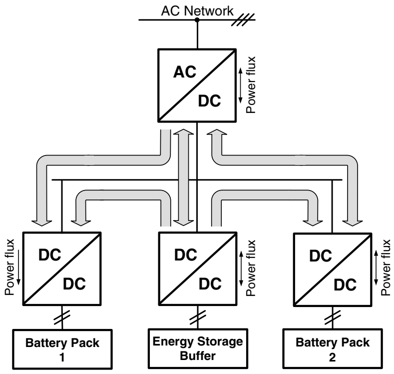

Fig. 1. Block scheme and main power fluxes of the recharging station laboratory prototype

The realized DC bus, obtained through a bidirectional AC/DC power converter of 20 kVA, allows the connection of different DC electric loads, such as the battery packs of the recharging electric vehicles and energy storage buffer, and renewable energy sources, through high efficiency DC/DC power converters. [3, 4].

The operation modes of the laboratory recharging station, in terms of main power fluxes, are also shown with arrows in the block scheme of figure 1. It is clear the function of the energy storage buffer, which is able to reduce the power requirements from the main grid, during the fast charging operations.

For the design of the laboratory recharging station two different battery packs are taken as reference, characterized by rated voltages of 48 V and 288 V DC. The 288 V battery pack is connected to the charging station through a 120A DC/DC bidirectional converter. The 48 V battery pack is connected to the recharging station through a unidirectional 60 A DC/DC power converter, characterized by the only operative mode of recharging the battery pack. Moreover a 288 V energy storage buffer is connected to the DC bus by means of a 20 A DC/DC bidirectional power converter. Figure 2 shows a picture of the realized DC fast recharging station laboratory prototype for road electric and plug-in hybrid vehicles.

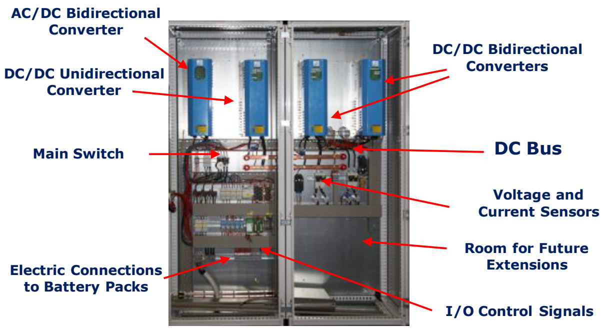

Fig. 2. Laboratory prototype of the DC fast charging station for full electric and plug-in hybrid vehicles.

The preliminary experimental laboratory tests, reported in the following section, involved two energy storage systems a 288 V - 40 Ah lead acid battery pack and a 51 V - 40 Ah $LiFePO_4$ battery pack.

3. Results and Discussion

The numerical results are evaluated by means of a simulation model based on Matlab-Simulink environment to evaluate in particular the DC power fluxes. The equivalent electric scheme of the DC bus and the DC/DC converters results as it is shown in Figure 6.

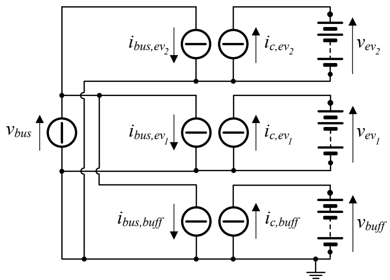

Fig. 3. Block Scheme of the Bidirectional DC/DC Converter.

The evaluation of the main power fluxes through the above model allows the identification of the energy management strategies for the innovative DC charging station, which is able to optimize simultaneously the power requirements from the main grid and charging times of different electric vehicles.

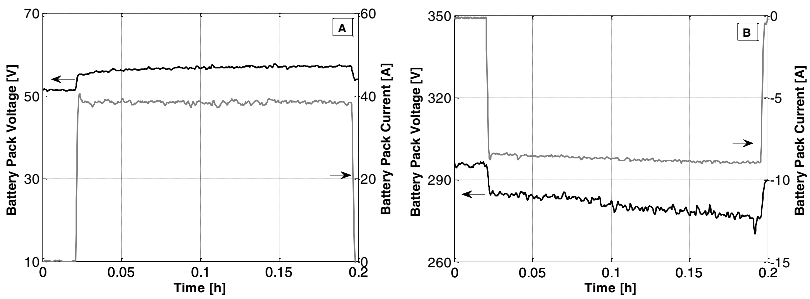

Fig. 4. Voltage and current for the charging LiFePO4 battery pack (A) and discharging Pb energy storage buffer (B), during islanding operations

Figure 4 shows preliminary experimental results related to islanding operative operations, when the $LiFePO_4$ battery pack is charged at 40 A with energy coming from the energy storage buffer.

4. Conclusions

In this paper the main design criteria, setting up and experimental tests of a DC micro-grid for fast recharging stations of road full electric and plug-in hybrid vehicles, are presented. The obtained preliminary laboratory and simulation results on the prototype of DC charging station showed the potential improvements in terms of charging times not far from the typical fuelling times taken by traditional vehicles. This could be supported by a further reduction in cost of high power converters and increasing in charging rate of the storage system technologies.

Finally this work represents a first study, which might be considered a useful breakthrough to improve the knowledge about the real behaviour of fast DC architectures working in dynamic and islanded operative conditions.

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Biography

Clemente Capasso graduated in Electrical Engineering from the University of Naples Federico II. Since 2010 works as a laboratory researcher for the Istituto Motori of the National Research Council of Italy. He is a PhD student in electrical engineering from November 2011. His main fields of interest are storage systems for the electric propulsion, recharging systems for plug-in vehicles and fuel cells hybrid propulsion systems.

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Ottorino Veneri graduated and awarded his PhD in Electrical Engineering by the University of Naples Federico II. Since 2002 he works as a researcher with the Istituto Motori of the Italian National Research Council. His main fields of interest are the electric drives for transportation systems, electric energy converters, electric energy storage systems and power sources with hydrogen fuel cells.