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Experimental Analysis of a Zebra Battery Based Propulsion System for Urban Bus under Dynamic Conditions

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Abstract

In this paper preliminary results on a Zebra battery based propulsion system for urban bus applications are presented. The analysis is carried out with the support of a laboratory 1:1 scale test bench, focusing the attention on a 65 kW electric drive, specifically designed for urban bus applications, supplied by two 20 kWh Zebra batteries working in parallel. The electric power train is connected, through a fixed ratio gear box, to a 100 kW regenerative electric brake provided with speed and torque controls, in order to evaluate the propulsion system performance in steady state and dynamic operative conditions. On the base of the architecture of a urban bus, powered by the same electric propulsion system studied in laboratory, a Matlab-Simulink model has been carried out to assess the dynamic behavior of the full electric urban bus and also other possible hybrid configurations, working on standard and real driving cycles, taking into account the resistant forces represented by proper vehicle/road/aerodynamic parameters. For the above configurations an evaluation of the expected real vehicle performance, in different operative road conditions, can be validated through the laboratory dynamic test bench.

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Keywords: Batteries, Electric Vheicles, Electric Drives, Dynamic Test Bench

1. Introduction

Battery powered electric busses represent an interesting alternative to conventional urban vehicles toward the long awaited achievement of sustainable public transportation means. In fact, this new technology of road vehicles is expected to reduce the fossil fuel dependency, improving the energy

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efficiency and the impact on global warming. Anyway, the wide spread of this kind of technology is deeply dependent by the real performance of electric energy storage systems.

The base architecture of the propulsion system for electric urban busses is reported in Fig. 1 with a block diagram, which shows the main components, such as the battery pack, the electric drive, the transmission system and the battery charger.

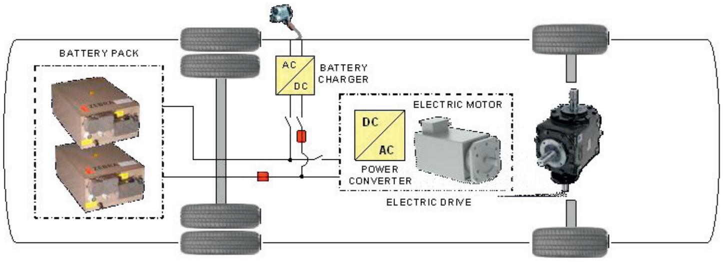

Fig. 1. Block diagram of the architecture for an electric urban bus.

The analysis of these kinds of architecture, using specific road vehicle prototypes, implies great issues, particularly in terms of measurement and control of the main parameters, related to the real working conditions of a vehicle on the road, mechanical solicitations and safety in general. These issues can be easily simplified, either at the beginning of a study of new configurations or in case of retrofit applications, when the real performance of the whole propulsion system is evaluated on laboratory test benches [1,2].

The aim of this paper is to conduct a preliminary analysis of real performance of an electric power train for urban bus application based on Zebra battery packs as energy storage systems, due to the lack of knowledge on this kind of experimental applications. This evaluation is carried out by means of the acquisition of experimental data related to the whole propulsion system running on a laboratory test bench, and the utilization of these results as an experimental knowledge base for the development of a Matlab-Simulink model of an urban electric bus [3-5].

2. Experimental

A dynamic test bench is used to run laboratory tests with the aim of evaluating the performance of a Zebra battery based propulsion system for urban busses on standard driving cycles. The block scheme of the above propulsion system laboratory test bench is reported in Figure 2, where a 65 kW electric drive is mechanically connected to a dynamic brake through a gear ratio between motor and wheels, obtained with a transmission gear box. This means that the vehicle resistant forces, i.e. the rolling and aerodynamic resistances, are applied to the wheel shaft through the electric brake. The electric drive is powered by two Zebra batteries connected in parallel, which are recharged from the main grid by means of two low power battery chargers.

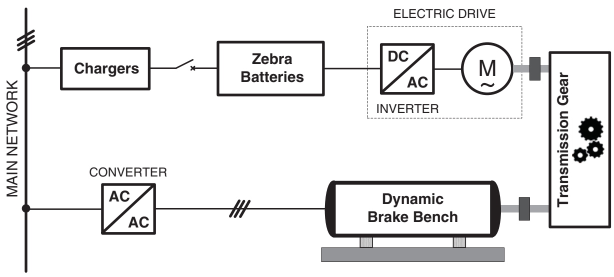

Fig.2. Block scheme of the Zebra battery based propulsion system test bench.

Also the 100 kW dynamic electric brake is electrically connected to the main grid through a bidirectional converter, with the possibility for the electric energy to be taken-from and fed-back to the main grid depending on the operative conditions. The dynamic electric brake is based on an asynchronous machine and equipped with an encoder and a torque flange sensor characterized by an accuracy of 0.05%. The brake is controlled by a proper software, which allows the operator to set either a limit value of the motor speed/torque or an imposed profile of motor speed/torque. Other details of the components realizing the electric power train and the test bench are reported in [5], together with the characteristics of the laboratory measurement and control systems, which allow to obtain the experimental results reported in the following sections.

3. Results and Discussions

The laboratory results are evaluated taking into account the parameters of an urban bus to be used in the Italian historical centres. In particular in this paper the experimental results make reference to an example of the driving cycle composed by the first two steps of the standard ECE driving cycle [6]. For this driving cycle, in the following Figure 3 the comparison between the actual and reference speed is reported with the measured battery and mechanical power for a reduced vehicle weight.

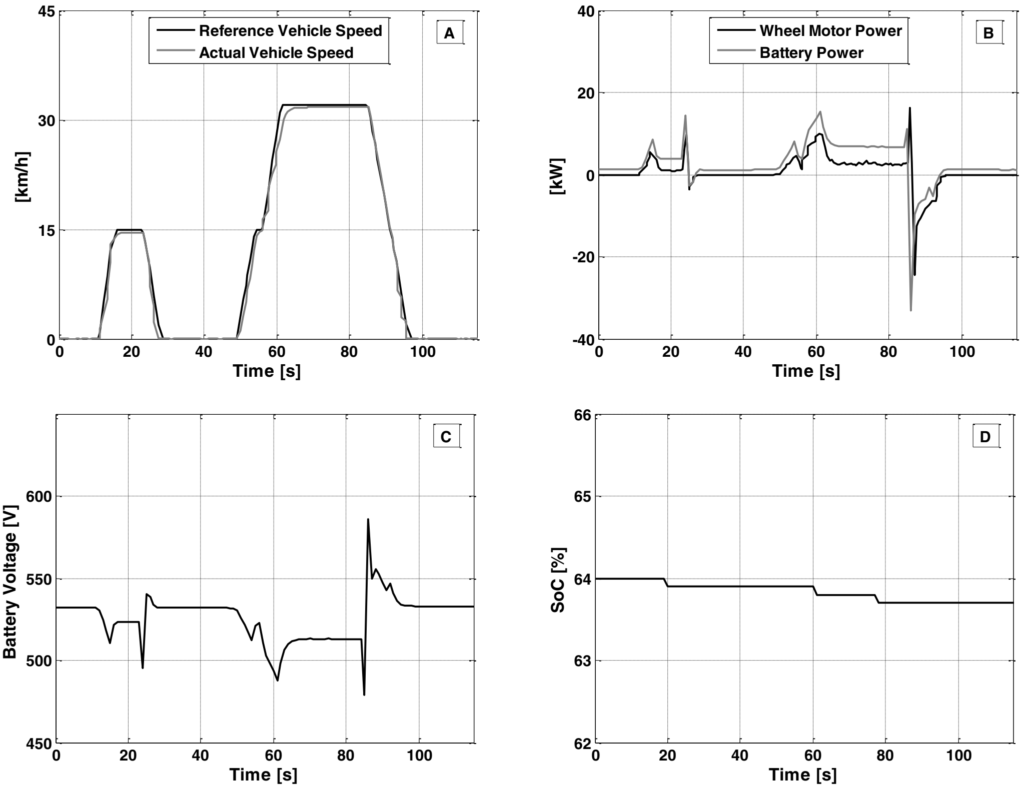

Fig. 3 Speed, electric and mechanical power, SOC and voltage vs time for the urban bus power train

A Matlab Simulink numerical model has been built on the base of the electromechanical characteristic of the electric machine working as motor and generator, efficiency of the power converter and transmission gear and real data evaluated in steady state charging/discharging operation for the real Zebra batteries obtained through the above test bench with specific tests. This model represents a starting point to evaluate the performance of other hybrid configuration for the same urban vehicle considered especially in terms of dynamic operations and driving range. For example, the driving range evaluated for the proposed urban bus configuration supplied by two 38 Ah and 550 V Zebra batteries connected in parallel results of about 65 km.

4. Conclusions

In this paper a Zebra battery based propulsion system for urban bus applications is presented, supporting the lack of knowledge on the experimental evaluations in the field of the transportation systems. The experimental study is carried out by means of a laboratory 1:1 scale test bench, which is able to operate the electric power train on real and standard driving cycles. In this way, different aspects related to the real behaviors of the power train can be experimentally evaluated, such as regenerative braking, motor and transmission gear losses. Preliminary experimental results reported in this paper allows the evaluation of a Matlab-Simulink numerical model of the full electric urban bus, useful to evaluate the performance of different hybrid architectures on similar driving cycles and including the integration of different energy storage systems, which allows the improvement of the vehicle performance and in particular of the driving range.

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Biography

Clemente Capasso graduated in Electrical Engineering from the University of Naples Federico II. Since 2010 he 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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