ELECTRIC MOBILITY AND SMART GRIDS: COST-EFFECTIVE INTEGRATION OF ELECTRIC VEHICLES WITH THE POWER GRID

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Abstract

Introduction

In the future, combustion engine based vehicles will be replaced by plug-in hybrid electric vehicles (PHEVs) and pure electric vehicles (EVs). The major objectives of this transition are reductions of emissions (e.g. CO_2 gases) and noise as well as a significant improvement of the vehicles' energy efficiency. In addition, rising fuel costs and stricter emissions standards will accelerate this process of change. Hence, auto manufacturer and power supply companies will be faced with a lot of new technological as well as economic challenges over the next few years. This paper is focused on cost-effective integration of EVs with the power grid by means of smart charging strategies and integrated on-board chargers [1].

Charging strategies

EVs are a new type of additional load on the power grid. The changes in the load profile depend on the number of EVs as well as on the used charging strategies. State-of-the-art charging strategies such as simple charging and dual tariff charging based on simple time-of-use (TOU) pricing are not appropriate solutions for charging a large number of EVs. In the case of simple charging, electricity costs are the same during the whole day. Hence, EVs start charging immediately when they arrive somewhere, trying to fully recharge their batteries [2]. Dual tariff charging is a well-known approach for shifting loads of households from day to night. Therefore, the electricity costs are low during the night and high throughout the rest of the day. Several research groups [2] [3] [4] have shown that both strategies causes peak demands such as morning and evening peaks. Peak demands could lead to violations of power grid constrains. In these studies and simulations, profiles of other loads, different areas (e.g. residential, commercial, industry) and different seasons of the year have also been considered [3] [4]. Hence, smart charging is necessary to reduce peak demands and to realize the so-called valley-filling. In the majority of cases a novel smart power grid infrastructure is also mandatory. Further major objectives of smart charging based on a smart power grid are the reduction of electricity costs of consumers and the efficient integration of renewable energy sources. Furthermore, it enables a sophisticated update of the already existing power grid infrastructure.

On-board chargers

In addition, all EVs must be equipped with a bidirectional on-board charger (Fig. 1.b.). A bidirectional charger is a combined AC/DC rectifier and DC/AC inverter. This type of charger enables vehicle-to-grid (V2G) operation. Hence, EVs can also be used as a distributed energy storage capacity. However, EVs already contain inverters for driving their motors. Therefore the most effective solution is to integrate the charger in the already existing motor inverter (Fig. 1.c.). Such a module is called integrated on-board charger [5] [6]. The major objectives of an integrated on-board charger are reductions of manufacturing costs, maintenance costs, size and weight of the EV. Furthermore, novel silicon carbide (SiC) MOSFETs and parallel interleaved inverter topologies are essential for the reduction of power losses and the size of passive components (mains filter).

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The paper is organized as follows. Several smart charging strategies are presented and assessed in Section 2. In Section 3 we introduce different approaches for the implementation of chargers in EVs. The concept of our bidirectional integrated on-board charger is briefly presented in Section 4. Finally, Section 5 concludes the paper.

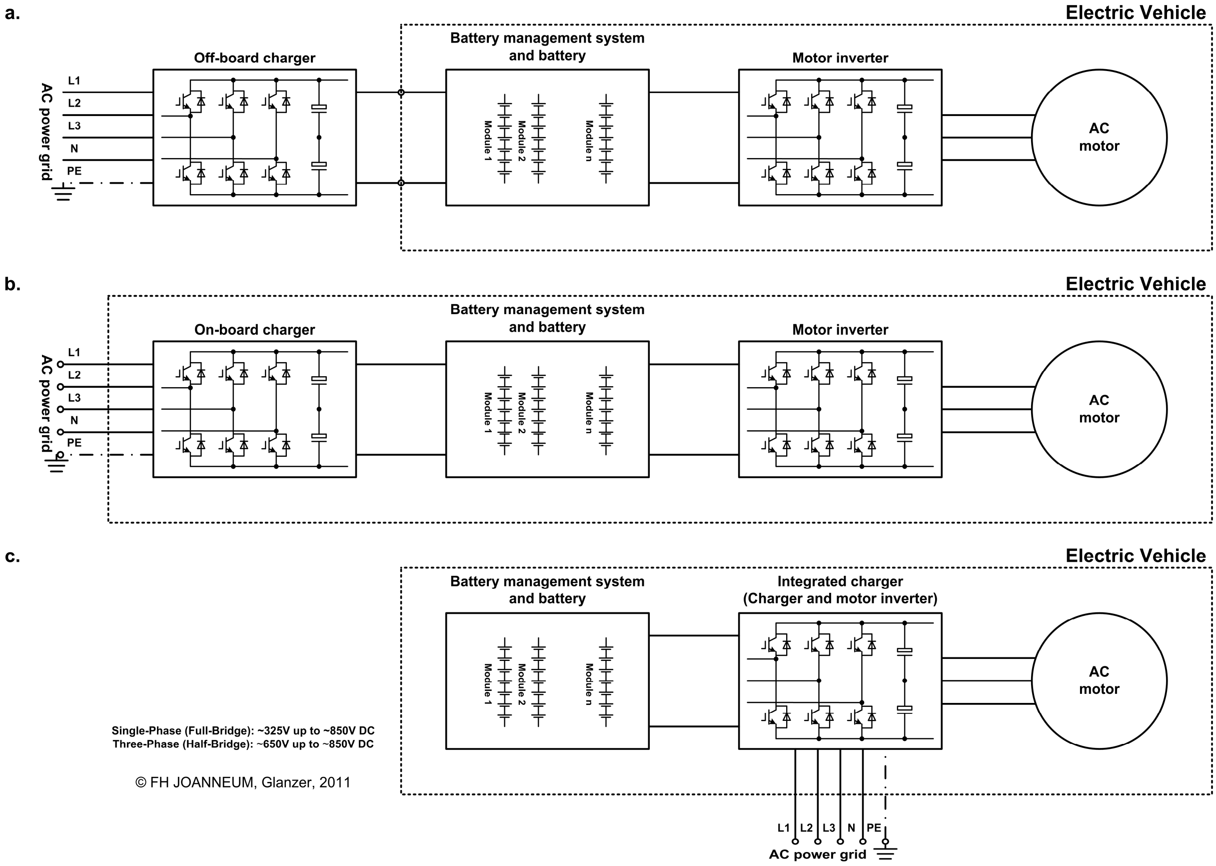

Figure 1. Block diagrams of (a.) an off-board charger topology, (b.) an on-board charger topology and (c.) an integrated on-board charger topology [1].

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