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Experimental measurements about harmonic current mitigation of electric vehicle battery chargers

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Abstract. The expected high penetration of battery chargers for electric vehicles (EV) in electric networks is foreseen as a potential problem for power quality. Battery chargers are non-linear devices that inject harmonic currents and pollute network voltages. Thus, their harmonic emissions must be analyzed and reduced by harmonic mitigation techniques to avoid future problems. This paper analyzes and reports some real case measurements of harmonics injected by single- and three-phase battery chargers and their attenuation using line choke inductances.

Key words

Battery chargers, harmonics, power quality.

1. Introduction

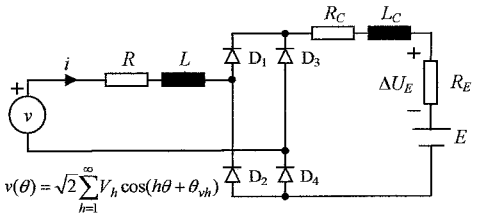
The growing presence of non-linear loads (NLLs) in commercial, industrial and residential installations has led to a rise in harmonic levels in power distribution systems. NLLs in such installations are generally small-power single-phase loads in the range of 300-3kW and high-power three-phase loads in the range of 15-75 kW. Small-power NLLs typically comprise switched-mode power supplies for office and entertainment equipment. The most relevant high-power NLLs consist of three-phase diode rectifiers used in adjustable-speed drives (ASDs), HVAC equipment and phase-controlled rectifiers for temperature regulation of residential households. In the future, a large increase of single and three-phase battery chargers is expected in electric installations, as EVs are becoming an ecologically attractive alternative to internal combustion (IC) cars. In particular, chargers will become widespread in residential networks. For this reason, several studies in the literature attempt to predict the harmonic impact of these non-linear loads on the network. Some investigate the harmonic emissions of battery chargers and clusters of these loads in the network [1]-[5]. Others focus on the effects of these devices on the supply system [6]-[9]. Thus, due to the increasing importance of the battery charger power quality problem, different techniques, such as improvements in chargers [10], [11] or active filters [12], have been proposed to mitigate the harmonic currents injected by these loads. Among of them, line choke inductances appear as the simplest yet effective method.

The paper analyzes the use of choke inductances to reduce the harmonic emission of single- and three-phase battery chargers. The study is supported by experimental measurements in actual installations.

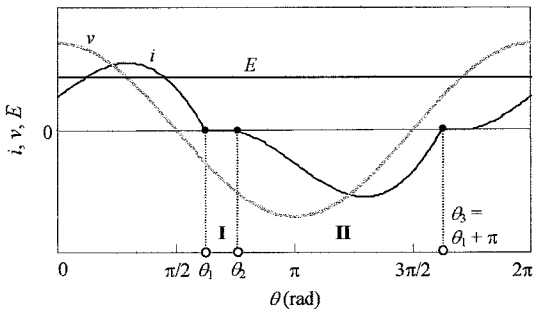
2. EV Battery Chargers

A. Single-phase Battery Chargers

Fig. 1(a) illustrates the typical equivalent circuit of single-phase battery chargers. It consists of a single-phase diode bridge with an AC inductor L (together with its associated resistance R), the resistance R_C and the inductance L_C of the charger circuit and the emf E of the battery under charge (together with its internal resistance R_E). The inductance L_C is commonly lower than the inductance L. As an example of charger behavior, Fig. 1(b) shows the AC current i drawn by the single-phase bridge considering that $L_C \ll L$. The supply voltage v and the battery voltage E are also plotted as



(a)



(b)

Fig. 1. Analysis of single-phase battery chargers: a) Equivalent circuit. b) Voltage and current waveforms.