Abstract

The transportation sector is one of the major contributors to the global greenhouse gas generation and is thus subject to considerable political attention. In view of the increasing concerns on the long-term effects of CO_2 emissions in the atmosphere and the worsening air quality in most urban areas, a worldwide shift towards vehicle electrification is currently underway. Government policies are pushing for the phase-out of internal combustion engine vehicles (ICEVs), i.e. no longer able to satisfy the increasingly strict emission requirements, meanwhile supporting the adoption of electric vehicles (EVs).

Even though EVs provide several advantages with respect to ICEVs, such as better performance, no local pollution, reduced maintenance and cost of ownership, limited noise emissions and the option of charging at home and/or at work, there are still significant challenges that impair their widespread adoption. In particular, potential EV customers are typically discouraged by the higher price with respect to comparable ICEVs and fear "range anxiety", due to the limited range (i.e., typically 200 – 500 km), the long charging times (i.e., usually exceeding 30 min for a full charge) and the general lack of charging stations. To ensure a broader EV adoption, the key technical challenges to be overcome are related to improving current battery technology (i.e., in terms of cost, energy density, charge rate, lifetime degradation, etc.), enhancing the performance of EV powertrain components (i.e., in terms of efficiency, size, weight, etc.) and scaling up dramatically the charging infrastructure (i.e., in terms of charging power, number of stations, number of stalls, etc.).

In this context, this thesis deals with the converter-level challenges related to the development of high-power EV battery chargers, which represent a key enabler to mainstream EV adoption as they address one of the major customer concerns, i.e. the charging time. In particular, the focus is on ultra-fast battery charging technology, which aims to achieve a stop-and-go EV refueling experience similar to the one of an ICEV, targeting $\approx$ 200 km of added range in 5 min. The main goal of this dissertation is to analyze, design, control and assess experimentally a modular converter concept for EV ultra-fast charging, addressing the challenging requirements set by the application. The performed research activity has resulted in several contributions, mainly related to the converter analysis and modeling, the converter design and the converter control.