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Sustainable options for electric vehicle technologies

Andreas Poullikkas*

Department of Electrical Engineering, Cyprus University of Technology, PO Box 50329, 3603 Limassol, Cyprus

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ABSTRACT

In this work, an overview regarding electric vehicle technologies and associated charging mechanisms is carried out. The review covers a broad range of topics related to electric vehicles, such as the basic types of these vehicles and their technical characteristics, fuel economy and CO_2 emissions, the electric vehicle charging mechanisms and the notions of grid to vehicle and vehicle to grid architectures. In particular three main types of electric vehicles, namely, the hybrid electric vehicles (HEVs), the plug-in electric vehicles (PHEVs) and the full electric vehicles (FEVs) are discussed in detailed. The major difference between these types of vehicles is that for the last two types, the battery can be externally recharged. In addition, FEVs operate only on battery charge and therefore always employ the charge depleting mode of operation requiring high power, high energy battery packs. On the other hand, PHEVs offer the possibility of on-board battery charging and the option of charge depleting or charge sustaining modes of operation. Finally HEVs, which were the first type of electric vehicles to be manufactured, offer higher travelling range compared to PHEVs and FEVs due to the existence of the internal combustion engine. Although tank-to-wheel efficiencies of electric vehicles show that they have higher fuel economies than conventional gasoline vehicles, the well-to-wheel efficiency is a more appropriate measure to use for comparing fuel economy and CO_2 emissions in order to account for the effect of electricity consumption from these vehicles. From the perspective of a full cycle analysis, the electricity available to recharge the batteries must be generated from renewable or clean sources in order for such vehicles to have zero emissions. On the other hand, when electric vehicles are recharged from electricity produced from conventional technology power plants such as oil or coal-fired plants, they may produce equal or sometimes more greenhouse gas emissions than conventional gasoline vehicles.

Contents

1. Introduction . . . 1278
2. Types of electric vehicles . . . 1278
   2.1. Hybrid electric vehicles . . . 1278
      2.1.1. Mode of operation . . . 1279
      2.1.2. Battery considerations . . . 1279
   2.2. Plug-in hybrid electric vehicles . . . 1280
      2.2.1. Modes of operation . . . 1280
      2.2.2. Battery considerations . . . 1280
   2.3. Full electric vehicles . . . 1281
      2.3.1. Mode of operation . . . 1281
      2.3.2. Battery considerations . . . 1282
3. Comparative assessment . . . 1282
4. Grid to vehicle charging . . . 1283
   4.1. Household outlets . . . 1283
   4.2. Electric vehicle network . . . 1283

* Fax: +357 25 002635.
E-mail address: andreas.poullikkas@cut.ac.cy

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4.3. Benefits and problems associated with G2V charging . . . 1284
5. Vehicle to grid electricity . . . 1285
6. Conclusions . . . 1285
References . . . 1285

1. Introduction

Growing concerns over climate change and security of energy supply are driving a shift in the transport sector from fossil to alternative fuels and new electric vehicle propulsion systems capable of delivering long-term sustainability. Globally three quarters of transport greenhouse emissions come from road transport. The transport sector is especially vulnerable to oil supply disruption and price volatility and despite huge reductions in emissions of harmful emissions, concerns over air quality and noise, especially in urban areas are also under consideration [1].

Electric vehicles are a promising technology for the drastic reduction of road transport emissions. This is an important element in reducing carbon dioxide (CO_2) emissions, air pollutants and noise from passenger cars and light commercial vehicles. At the same time, the electric passenger cars that are under development are not yet competitive with conventional vehicle technology [2]. Costs are still high and battery technology is still under developed leading to many uncertainties with respect to crucial issues, such as battery technology, impacts on emissions, interaction with electricity generation and costs and business case of large-scale introduction.

In this work, an overview regarding electric vehicle technologies and associated charging mechanisms is carried out. The review covers a broad range of topics related to electric vehicles, such as the basic types of these vehicles and their technical characteristics, fuel economy and CO_2 emissions, the electric vehicle charging mechanisms and the notions of grid to vehicle and vehicle to grid architectures.

In Section 2, the types of electric vehicles and their operation are discussed in detail and in Section 3 a comparative assessment is presented. In Section 4, the current and future grid to vehicle charging methods and infrastructures are presented and in Section 5 the vehicle to grid technology is discussed as a potential future option for electric vehicles. The conclusions are summarized in Section 6.

2. Types of electric vehicles

Currently there are three main types of electric vehicles that have passed from the demonstration to the production stage of the manufacturing process [3]. These are shown in Table 1 and they are the hybrid electric vehicles (HEVs), the plug-in electric vehicles (PHEVs) and the full electric vehicles (FEVs). The major difference between these types of vehicles is that for the last two types, the battery can be externally recharged.

2.1. Hybrid electric vehicles

A HEV is a type of hybrid vehicle, which combines two distinct power sources in order to provide driving power. The two power sources are a conventional internal combustion engine (ICE) and a battery/electric motor system as shown in Fig. 1. The presence of the battery and the electric motor system is intended to achieve either better vehicle fuel economy or better performance than a conventional ICE vehicle. This is essentially achieved since the low efficiency ICE is now used in combination with a much higher efficiency power source, such as the battery. Currently, a variety of HEV types exist in the automotive market with varying degrees of independent ICE/electric motor operation. The size of the components, such as that of ICE and of the electric motor, can significantly influence the control strategy of HEV. The ratio between the maximum power of the electric motor and the maximum power of the power train is referred to as hybridization ratio. A high hybridization ratio results in a large electric path (electric motor and battery) and a small ICE. On the other hand, a low hybridization ratio results in a small electric path and a large ICE [4]. A simplified version of hybrid power trains is the so-called mild hybrid, which has an integrated starter generator (ISG) instead of an electric propulsion motor.

Typically, HEVs are equipped with a standard ICE and a battery pack connected to an electrical motor [5]. Full HEVs are able to perform in both the conventional vehicle transmission mode by utilizing the ICE with conventional fuel, typically gasoline, and/or in an electric power mode by using electrical power from the

Table 1
Types of electric vehicles.

Vehicle type	Internal combustion engine	Battery charging
Hybrid electric vehicle	Yes	On-board (internal)
Plug-in electric vehicle	Yes	On-board (internal) and/or external charging
Full electric vehicle	No	External charging

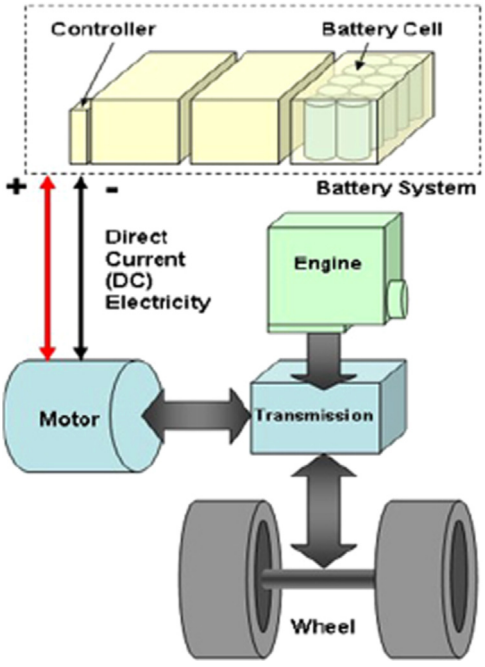

Fig. 1. Process diagram of a typical hybrid electric vehicle (HEV) [85].