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Impacts of plug-in electric vehicles in the portuguese electrical grid

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ABSTRACT

Powertrain electrification is currently the best alternative to ensure sustainable energy efficient personal mobility, increasing the integration of intermittent Renewable Energy Sources (RES), improving air quality in urban centres, and reducing greenhouse gas emissions from the transport sector and their dependence on fossil energy sources. With the increasing number of Electric Vehicles (EVs) available from automotive manufacturers, one key question that arises is the capability of the electrical grid to feed the increasing energy demand of the EV fleet without major investments. This paper shows that a progressive penetration of EVs, even at a rapid rate, is perfectly possible for vehicles that offer autonomy, energy consumption and charging characteristics that are currently available in the market. This analysis is based on data acquired during a year, using a Plug-in Hybrid Electric Vehicle (PEV) as the only vehicle for a typical, Southern European Portuguese family. The energy consumption of a gasoline and electric vehicle is presented, as well as its impact on the household load pattern. An analysis of the impact on the grid is also presented, considering several penetration rates (100 thousand, 500 thousand and 1 million vehicles). As well as the avoided use of fossil fuel per vehicle and consequent reduction in overall emissions when compared with a conventional vehicle.

1. Introduction

The increasing use of Renewable Energy Sources (RES) for electricity generation and the improvements achieved in energy storage technologies, as well as in power electronics have led to increasing interest in Electric Vehicles (EVs) (Lorf et al., 2013). Pure Electric Vehicles (PEVs), including Battery Electric Vehicles (BEVs), and Plug-in Hybrid Electric Vehicles (PHEVs) are increasingly seen as attractive solutions leading to the decarbonization of the energy economy and a shift to the use of renewable energy sources (World Energy Council, 2016). EVs can simultaneously address mobility needs and take advantage of the endogenous renewable energy captured with increasingly competitive technologies, with special emphasis on wind and solar power generation, thus contributing to greater energy independence (Gnann et al., 2015; Axsen and Kurani, 2010).

However, with the widespread adoption of EVs, an increase in electricity demand to charge these vehicles could pose significant challenges to the electrical grid in terms of additional load, if load management charging strategies are not implemented. Many authors indicate there is need for approaches to limit the maximum power to be extracted from the grid to recharge EVs (Ma et al., 2013; Callaway, 2009; De los Ríos Vergara and Nordstrom, 2011). Therefore, the impact of the large-scale integration of EVs needs to be evaluated.

The aim of this paper is to assess the potential impacts of EV fleets on the Portuguese electrical generation system. Therefore, the paper starts by assessing the impact of EVs on households, using real data to evaluate the consumption of EVs and to prove that,

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considering the typical profile of daily use, existing electrical installations and typical household power consumption, EVs can be easily integrated into any household, without the need for additional investment and/or significant concerns. The large-scale penetration with several fleet sizes, concentrating recharging during periods when there is renewable energy generation surplus in the system was then considered and assessed. The remainder of the paper is structured as follows. Section 2 presents the background data and related work relevant for the assessments discussed in the paper. Section 3 assesses the energy efficiency of PEVs using real data and Section 4 assesses the impact of charging on household electricity consumption. Then, Section 5 assesses the impact of EV fleets on the Portuguese electrical generation system. Finally, Section 6 summarizes the paper, emphasizing its main conclusions.

2. Background and related work

2.1. Background

Non-dispatchable renewable sources, based mainly on wind and run-of-river hydropower, along with dispatchable generation, based on combined cycle power plants have been developed in Portugal over the last decade to meet the decarbonization objectives of the electrical generation system. However, the combination of an excessive growth in intermittent generation and the reduction of demand have led to a power system with a surplus of installed capacity (18,533 MW of installed power with a peak power of 8,618 MW) (REN – Redes Energéticas Nacionais, 2016). One major consequence of such a surplus problem and high intermittence is that, in periods with a great deal of wind and water affluences, generation from intermittent renewable sources exceeds demand, forcing most thermal generation to be out of service. This has a high economic impact due to the operation costs of thermal power plants and the very low market value of the exported generation surplus. The Spanish market, the single potential importer, has a similar share of wind power, and therefore the same surplus, leading to market prices near zero in such periods, but simultaneously the energy is injected into the grid and paid for at a high feed-in-tariff.

Fig. 1 shows this occurrence on a typical day, where the renewable generation was greater than the demand during several periods of the day. Part of the surplus is used for pumping during the night, but a high share of the generation must be exported (all of the generation above the demand + pumping line). Therefore, the use of pumped storage has been growing from 638 GW h in 2008 to 1519 GW h in2016, representing approximately 3% of the energy consumption, but it is not enough to absorb the generation surplus (REN – Redes Energéticas Nacionais, 2016). Table 1 presents the evolution of the pumping requirements in the Portuguese electricity system between 2009 and 2016.

Easy access to credit and a massive investment to improve the road infrastructure has led Portugal from a car ratio of 258 cars per thousand inhabitants in 1990 to over 500 in 2013, with the distance per capita travelled also increasing to 10,000 km per year. In Portugal, the increase of mobility, combined with the increase of prices, has led to an increase in what is spent on fossil fuels from 1320 million Euros in 1998 to 6232 million in 2013 (Direcção Geral de Energia e Geologia, 2013). Tolls were also introduced in the

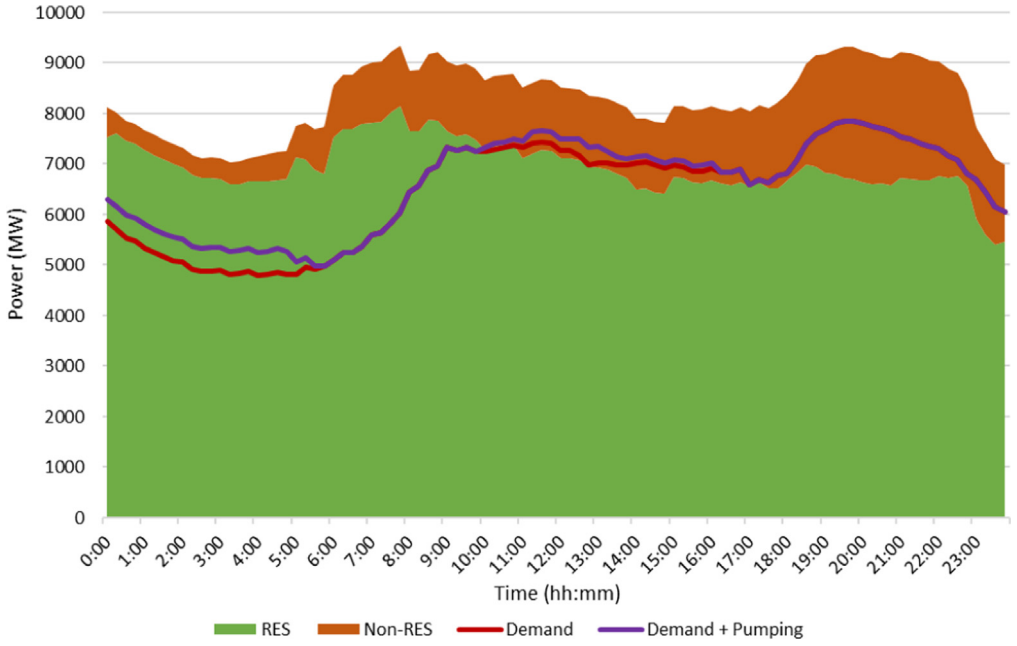

Fig. 1. Load pattern, for electricity generation and consumption, during February 16, 2016 in Portugal (REN – Redes Energéticas Nacionais, 2016). The diagram shows both RES (green) and Non-RES (orange) generation. Energy demand is shown in red, while demand plus pumping is shown in purple, to provide a perspective regarding pumping contribution to the overall demand. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)