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The electric vehicles as a mean to reduce CO_2 emissions and energy costs in isolated regions. The São Miguel (Azores) case study

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ABSTRACT

Most of small islands around the world today, are dependent on imported fossil fuels for the majority of their energy needs especially for transport activities and electricity production. The use of locally renewable energy resources and the implementation of energy efficiency measures could make a significant contribution to their economic development by reducing fossil fuel imports. An electrification of vehicles has been suggested as a way to both reduce pollutant emissions and increase security of supply of the transportation sector by reducing the dependence on oil products imports and facilitate the accommodation of renewable electricity generation, such as wind and, in the case of volcanic islands like São Miguel (Azores) of the geothermal energy whose penetration has been limited by the valley electricity consumption level. In this research, three scenarios of EV penetration were studied and it was verified that, for a 15% LD fleet replacement by EVs with 90% of all energy needs occurring during the night, the accommodation of 10 MW of new geothermal capacity becomes viable. Under this scenario, reductions of 8% in electricity costs, 14% in energy, 23% in fossil fuels use and CO_2 emissions for the transportation and electricity production sectors could be expected.

1. Introduction

Today, nearly all small islands in the world are totally dependent on expensive and environmentally problematic fossil fuels for their energy needs (FED, 2000). The conventional thermal power plants are used as the main source for electricity generation and the transportation sector is highly dependent on oil products. The rising price of fossil fuels has been increasing the costs of conventional thermal power production and has created a competitive advantage for the renewable energy technologies in islands. Furthermore, islands are usually endowed with good renewable resources such as sun, wind, geothermal and waves.

The Azores is an archipelago in the Atlantic Ocean, located about 1,300 km west of Portugal that includes nine major islands in three scattered groups. Electricity of Azores (EDA) is responsible for the production and distribution of electricity on the Azores islands and is very much aware of the importance of renewable energy, not only for environmental reasons, but also to reduce the islands' diesel/fuel oil dependency for electricity production (EDA, 2010).

São Miguel is the largest, most populous and developed of the Azores Islands and consequently has a high level of energy dependency that results from its scarcity of natural resources. It must therefore import oil products, which represents a negative factor relative to its economic and social development. In São Miguel, the oil products' consumption in 2009 was around 180,000 t (DGEG, 2007) distributed among the final products as depicted in Fig. 1. The main slice was for fuel oil that was used 77% for electricity production, 21% for industry and 2% in other sectors. Diesel and gasoline were basically used in transportation (93% for Diesel and 100% for gasoline).

More than 70% of all oil products' consumption in São Miguel was used for both transportation (40%) and electricity production (31%). As oil products are the only fossil fuels used in the island it is easy to understand that the transportation and electricity production sectors are responsible for more than 70% of fossil fuels use and CO_2 emissions in São Miguel.

São Miguel has about 65 km length and 16 km width, a total area of 760 km^2. This is suited for an electric vehicle (EV) use because the majority of daily trips are expected to be less than 100 km, so the range limitation problem almost does not exists in this island. EVs could provide a good opportunity to reduce CO_2 emissions from transport activities if the emissions that might be saved from reducing the consumption of oil would not be off-set by the additional CO_2 generated by the power sector in providing for the load the EVs represent.

Electricity production in São Miguel is almost 50% renewable with only three types of technology involved (Fig. 2).

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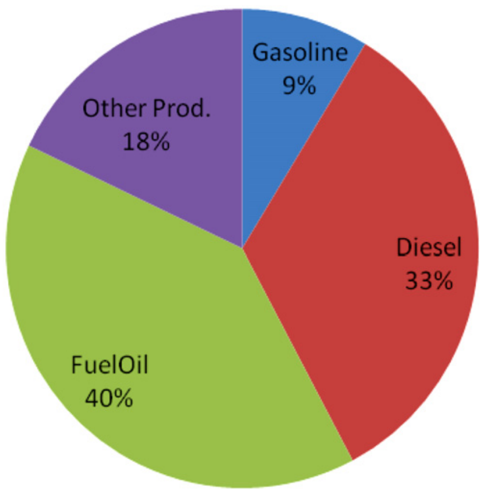

Fig. 1. Distribution of oil products' consumption in São Miguel at 2009.

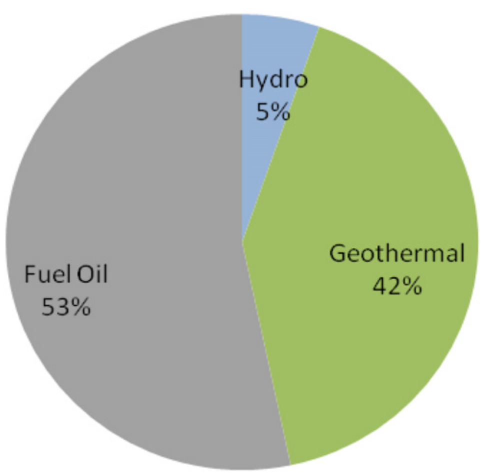

Fig. 2. Electricity production mix in S. Miguel at 2007.

One of the main features of power consumption is the difference in demand along the day and São Miguel is no exception, with a valley during the night representing 50–60% of the peak consumption. There is here an opportunity for a mass penetration of EVs that could be charged during off-peak hours and increase power demand during the night so that more renewable energy sources could be accommodated in the power system.

In this research, scenarios of EV penetration (energy needs) and scenarios of EV recharge profile (power needs) were created to obtain the hourly additional energy demand EVs would impose on the island's power system. Would this additional power demand be enough to accommodate an increase of 10 MW in geothermal capacity? What would be the EVs' penetration level (number of vehicles) that could justify the geothermal capacity increase in the next years (till 2020)? What is the expected EV's penetration level?

2. Literature review

Electric drive technology exists for more than a century but it was not a viable transport option due to limited range and production costs when compared with the internal combustion engine (ICE) technology. Only recently with battery technology development, radical innovation in electric vehicles caused profound changes in the way automakers develop their products and electric cars came into scene again.

Many studies have been done to evaluate the potential social, environmental and economic impacts of electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV) in many OECD (Organization for Economic Co-operation and Development) countries.

The capacity of the electric power infrastructure in different regions of the US was studied for the supply of the additional load due to PHEV penetration (Kintner-Meyer et al., 2007) and the economic assessment of the impacts of PHEV adoption on vehicles owners and on electric utilities (Scott et al., 2007).

Other studies (Hadley, 2006) considered the scenario of one million PHEVs added to a US sub-region and analyzed the potential changes in demand, impacts on generation adequacy, transmission and distribution and later the same analysis was extended to 13 US regions with the inclusion of GHG (Green House Gas) estimation for each of the seven scenarios performed for each region (Hadley, 2008).

A study made by NREL (National Renewable Energy Laboratory) focused only one specific region and four scenarios for charging were evaluated in terms of grid impact and also in terms of GHG emissions (Parks et al., 2007). The results showed that off-peak charging would be more efficient in terms of grid stress and energy costs and a significant reduction on CO_2 emissions was expected thought an increase in SO_2 emissions was also expected due to the off peak charging being composed of a large amount of coal generation.

The Samsoe Island (Denmark) case study is very interesting as it has a 100% renewable electricity production and so the EV could be considered a well-to-wheels zero emissions vehicle reducing fossil fuel use and imports in the island (Blyth, 2011). The Prince Eduard Island case study, where there was assumed that a total of 18,726 EVs could be on the island by 2030 (no further vehicles growth only ICEVs replacement by EVs) expect annual CO_2 emissions reduction around 115,000 t were expected (McCarville, 2009).

In recent years an interest in V2G (Vehicle-to-Grid) technology has increased, several researchers have studied that by adding vehicle to grid capability (V2G) where the vehicle can discharge as well as charge, a potential storage capacity can be provided to the grid offering regulation, peak power and spinning reserve's services with possible high revenues to vehicle's owners. This first article (Kempton and Letendre, 1996) presents an analysis based primarily on peak power, further work (Kempton and Letendre, 2002) show the value of ancillary services to be far higher than that of peak power and then follows a very complete exposition of the fundamentals of both the vehicle fleet and electric markets (Kempton and Tomic, 2005).

Other studies regarding battery electric vehicles and plug in hybrids are being performed almost every month in different countries. The results obtained in one place in earth cannot be used in other regions, only the methodologies. Apart from reasons that are related to car use habits and roads' topology, there is the electricity production source mix that is different from place to place, more expensive in some places and with more use of renewable sources in others.

3. Research methodology

This research is concerned with studying the potential impacts of the EVs in the São Miguel electricity system, focusing on the additional power demand, on emissions associated with EVs' recharge and on electricity costs. The impacts that the additional electric load would impose in the island, would be simulated for several EVs penetration scenarios. A dedicated tool, EEEIS – Economic Energy and Environment Impacts Simulator (Camus et al., 2011),