European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'11)
Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2011

Optimal Operation of Smart Grids Including Distributed Generation Units and Plug in Vehicles

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Abstract. The paper deals with the optimal operation of a Smart Grid (SG) including distributed resources based on dispersed generation (DG) units and plug-in vehicle fleets with the aim of furnishing some services both inside the SG and outside to the interconnected electrical system. The distributed resources are connected through power electronic interfaces and are coordinated by a centralized control system to provide the usual energy service as well as some ancillary services such as reactive power control and compensation for some continuous Power Quality (PQ) disturbances into the SG. In addition, plug-in vehicle fleets are coordinated to charge/discharge their storage systems with the aim to perform the Smart Charging service, so as to provide regulation service for the interconnected electrical system, as well as to compensate the variability of DG units powers based on uncertain primary sources. Computer time domain simulations were effected on a low voltage 30-bus SG including wind turbine, photovoltaic systems and plug-in vehicles.

Key words
Smart Grid, Energy Storage System, Renewable Energies, Plug-in vehicles.

1. Introduction

The level of penetration of plug-in (electric or hybrid) vehicles is significantly growing and it is supposed to increase still more in the near future due to their potential to reduce emission levels as well as costs of transportation. Their inclusion in smart grids and the integration with renewable distributed generators lead to a series of challenges in grid operation, especially in terms of several services that can improve the operation of distribution networks.
Plug-in vehicles, in fact, can have the multiple roles of loads and energy sources since they are intrinsically distributed energy storage systems. Most vehicles are typically driven only a few hours per day and are parked the rest of the time (during the night or work). This characteristic gives the opportunity to furnish several services to the grid while optimizing the charging and discharging operations [1]. It has to be noted that, rather than with individual vehicle batteries, effective impact on grid service provision can be obtained by grouping together a large number of vehicles through an *aggregator*.
A certain number of aggregated parked plug-in vehicles, could, theoretically, provide several important services to the grid such as regulation, peak power, spinning reserve and other ancillary services [1-3][1]. In practice, only some of them are an attractive market opportunity for plug-in vehicles.
The types of services that can be furnished to the grid can require both two-way or one-way energy flows to the distribution network.
In literature, the services that can be supplied from the plug-in vehicles requiring a two-way energy flow from and to the network are usually referred to as *Vehicle-to-grid* (V2G) [2].
On the other hand, a particular service that requires a one-way energy flow from the distribution network to the vehicle, is referred to as *Smart Charging* [1]. This last service can be considered a part of the abovementioned regulation service. In fact, in general an aggregation of controllable loads can be used to mach, at all times during the operation of the grid, the power generated and the power consumed by loads (*Demand Dispatch*); plug-in vehicles, when parked, can be considered an aggregation of controllable loads.
In addition, when included in a SG, the plug-in vehicle fleet, connected to the grid through a bidirectional battery charger [4-6], can also be integrated with other energy resources and all can provide in an optimal way some or all of the above services to the distribution grid to whom the SG is linked.
In this paper, the optimal operation of a SG including distributed resources based on renewable sources and plug-in vehicle fleets with the aim of furnishing some energy and ancillary services has been considered. DG

[1] Regulation service is based on the use of controllable generation units or aggregated loads to regulate frequency and voltage by matching generation to load demand; the ability to increase power generation (or decrease loads) from a baseline level is refferred to as 'regulation up' and the other to decrease power generation (or increase loads) from a baseline is referred to as 'regulation down'. Peak power is the use of generation units during peak load periods. Spinning reserve is an additional power capacity that can be requested in case of outage [1-3].