Chapter 4

Impacts of Plug-in Electric Vehicles Integration in Distribution Networks under Different Charging Strategies

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Abstract The uncertainties related to when and where Plug-in Electric Vehicles (PEVs) will charge in the future requires the development of stochastic based approaches to identify the corresponding load scenarios. Such tools can be used to enhance existing system operators planning techniques, allowing them to obtain additional knowledge on the impacts of a new type of load, so far unknown or negligible to the power systems, the PEVs battery charging. This chapter presents a tool developed to evaluate the steady state impacts of integrating PEVs in distribution networks. It incorporates several PEV models, allowing estimating their charging impacts in a given network, during a predefined period, when different charging strategies are adopted (non-controlled charging, multiple tariff policies and controlled charging). It uses a stochastic model to simulate PEVs movement in a geographic region and a Monte Carlo method to create different scenarios of PEVs charging. It allows calculating the maximum number of PEVs that can be safely integrated in a given network and the changes provoked by PEVs in the load diagrams, voltage profiles, lines loading and energy losses. Additionally, the tool can also be used to quantify the critical mass (percentage) of PEV owners that need to adhere to controlled charging schemes in order to enable the safe operation of distribution networks.

Keywords: Charging Strategies, Critical Mass, Distribution Grid, Markov Model, Monte Carlo Simulation, Plug-in Electric Vehicle Impacts, Steady-State Operation.

4.1 Introduction

The foreseen rollout of Plug-in Electric Vehicles (PEVs) will considerably affect distribution grids management and operation. The extra amount of power they will demand from the grid will oblige system operators to understand the impacts resulting from PEVs connection into distribution networks.

Several approaches to this problem have been pursued. In [1], for instance, authors follow a deterministic strategy to locate PEVs along the network buses and, consequently, determine PEVs load during an entire day. Conversely, in [2], authors introduced a probabilistic method for determining PEVs load. In [3], Heydt analyzed the changes in the load diagram of a community of about 150 to 300 thousand people, in the USA, for increasing penetration levels of PEVs in the vehicle fleet. The author concluded that a salient factor to be considered in PEVs deployment is their charging during peak hours and referred that a possible method to alleviate peak loading and temperature rise in distribution transformers is through the use of load management techniques. Lopes et al., in [1, 4], studied the impacts of PEVs in distribution grids. These authors evaluated the PEVs charging impact on the grid technical constraints and concluded that PEVs can lead to the violation of statutory voltage and ratings limits, as well as to a significant increase in the energy losses. The authors stressed the need to develop and implement efficient management procedures for coordinating PEVs charging, in order to minimize the need to reinforce the grid infrastructures. Papadopoulos et al., in [5], also addressed the technical challenges related with the PEVs integration. Steady state voltage profiles of a typical Low Voltage (LV) network from the UK, under different PEVs penetration scenarios, were investigated and the results obtained showed that the grid voltage profiles are highly dependent on the number of PEVs integrated in the grid. Clement et al., in [2, 6], analyzed the PEVs impacts in distribution grids power losses and voltage

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