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Identification of control and management strategies for LV unbalanced microgrids with plugged-in electric vehicles

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ABSTRACT

This paper addresses issues concerning the integration of single-phase charging devices for electric vehicles (EV) in low-voltage microgrids. Fast release energy storage is a key issue for microgrid islanding operation. EV batteries provide an additional storage capacity, which can now be exploited in order to improve MG islanding. Aiming to do so, different control strategies were developed and tested: (1) a local control approach where no communication link is required and (2) a centralized charging control solution. The local control approach is based on the measuring of EV terminal voltage and frequency in order to define the charging or discharging rates of the batteries. The centralized control strategy allows balancing single-phase loads connected to the microgrid by adapting the charging rates of the EV storage devices. Simulation results show that EV batteries can actively contribute for voltage balancing and frequency control during islanding operating conditions.

1. Introduction

The electric power systems industry is about to face a major new challenge: future massive integration in the electric grid of plug-in electric vehicles (EV). The stimulus for this change is that electricity is likely to become the preferred energy vector for a new generation of road vehicles. This new trend will be established in a scenario characterized by large penetration of renewable power sources (RES), some of them with an intermittent nature like wind generation. The integration of these RES will involve also microgeneration solutions, being these small generation units connected to the LV grid.

There are two ways of accommodating the connection of EV in distribution grids. The first is to plan for new networks in such way that they can fully handle the new loads, regardless of the control scheme, requiring heavy investments in network reinforcements to do so. The second is to create a smart management system that fully integrates EV in the power system, exploiting also the potential of EV as energy storage devices and creating a large distributed storage infrastructure that can be used to help the system in several situations. The latter is, of course, the way that needs to be pursued.

EV will be charged with electricity from the grid and they can also provide power to the grid when parked, as discussed in the papers from Kempton and Tomić [1] and Brooks [2]. Assuming large penetration of EV in the transportation sector, a considerable volume of storage capacity will then be connected to the grid during most of the time [1], such that it can be used to help managing the electric power system, delivering namely ancillary compensation services, leading to the vehicle-to-grid (V2G) concept. Three elements are required in order to develop further this concept: a smart interface with the grid, communication with the grid operator to receive control signals and metering solutions to account for EV energy exchanges with the grid.

Progressive replacement of conventional vehicles by EV will require two types of interfacing structures: (a) charging stations used to charge fleets of EV or to charge EV that require fast charging or (b) domestic or public individual charging/grid interface points for slow charging. In this paper only EV connected to LV grids are addressed, considering the adoption of solution (b) in LV grids.

Implementing a smart EV management involves dealing with the concepts of SmartGrid and Microgrid (MG) [3], namely if EV are to be connected to LV networks. EV will interact with the electrical systems of the future, where distributed intelligence will be present, and are likely to reduce the need for conventional large energy storage devices that are required to deal with large scale intermittent renewable generation.

Storage capability has been identified as a key issue to allow for successful MG islanding operation. Different technologies, such as batteries, flywheels, or supercapacitors, can be used for this implementation. In the previous developments of the MG concept, storage units were considered to be interfaced with the grid through Voltage Source Inverters, responding proportionally to

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