Plug-in electric vehicles as a harmonic compensator into microgrids

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ABSTRACT

Plug-in Electric Vehicles (PEVs) can be used as harmonic compensator by injecting/absorbing harmonic current to/from the grid. Considering harmonic power compensation as an ancillary service, similar to reactive power ancillary service market (RPASM) or reserve market, PEVs can participate in harmonic power ancillary service market and thereby PEVs should offer their prices in the harmonic power market. For this approach, Harmonic Expected Payment Function (HEPF) of PEV is constructed based on the capability curve of PEVs. The HEPF includes the cost of losses as well as lost opportunity cost (LOC) incurred by reduction of active power for harmonic power compensation. The harmonic power market (HPM) is cleared by minimizing Harmonic Total Payment Function (HTPF), which in fact, is the amount of dollars paid to the accepted PEVs in the market. The effectiveness of the proposed HPM is studied on a 14-node microgrid. The results indicate that, with the proposed framework, PEVs can incorporate in the harmonic market with enough economic incentives. The distribution system operator (DSO) concern about the harmonic disturbance can be remarkably relieved as well.

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1. Introduction

Besides the remarkable emission decrease, plug-in electric vehicles (PEVs) have many capabilities which is helpful for power system by using vehicle to grid (V2G) technology (Tan et al., 2016). This matter is mainly for the reason that PEVs are parked about 95 percent of day (Mitra et al., 2011). The increasing penetration of such PEVs in the power system can be either beneficial with proper management or detrimental in the case of uncontrolled operation. PEVs can be used in ancillary services and spinning reserve (Mirmoradi and Hashemi, 2016), voltage and frequency regulation (Wu et al., 2012), load balancing and peak load meeting (Mets et al., 2010), improving the usage of renewable energy resources (Fazelpour et al., 2014), preventing frequency drop (Zhong et al., 2014), improving voltage unbalance (Farahani, 2017), minimizing the distribution system energy loss (Nafisi et al., 2016) and risk control (Lefeng et al., 2013).

PEVs are also useful in reactive power ancillary service. Farahani et al. (2012) have presented the modeling and participating of such vehicles in RPASM that they submit their offer price components to the market and they would be paid if accepted in the RPASM. A multi-objective framework for RPASM is presented in by Farahani et al. (2013) with the incorporation of PEVs with the objective functions of system losses and the total payment, both to be minimized. Farahani et al. (2014b) have proposed a framework to consider the stochastic and intermittent nature of PEVs in the RPASM.

Some other research works are devoted to study the effect of PEVs charging stations on the power quality of system. The effect of five types of PEVs on the system current and voltage harmonics distortion in charging mode are considered by Orr et al. (1984). In 1998, a statistical method was used to forecast the impact of PEVs charging on the grid harmonic voltage indicating that the injected current harmonic by chargers to the grid leads to violate the total harmonic distortion (THD) of system above the boundary level (Staats et al., 1998). Similarly, the effect of charging of bus transportation system in Taiwan on the voltage flicker, harmonic distortion and voltage unbalance are studied by Su et al. (2016).

Farhoodnea et al. (2013) have studied the influence of PEVs penetration on the power system in the presence of wind turbine, photovoltaic (PVs) and fuel cells. Also, Tovilović and Rajaković (2015) have assessed the simultaneous operation of PEVs and PVs
which concludes that the joint operation of PEVs and PVs can decrease both the transformer peak load and grid harmonic voltages. The power quality characteristics of a battery charger are investigated by Trovão et al. (2011) for two vehicles in which voltage, current, active and reactive power of charger are measured during charging and THD of voltage and current are calculated. A probabilistic method based on Monte Carlo simulation is used to evaluate how effective can PEVs be on the power system while few works have paid attention to PEVs ability in harmonic power control and management. The scheduling of PEVs with the goal of minimizing system harmonic losses and system THD are presented by Farahani et al. (2014a).

The main contributions and novelties of this paper are:

- Proposing a framework for PEVs to participate in the HPM for compensating network harmonic
- Proposing HEPF of PEVs based on their capability curves
- Definition of HTPF to clear HPM with enough economic motivation.
- Considering LOC region in the harmonic market clearing process.

The rest of the paper is organized as follows. In section 2, the capability of PEVs as an active power filter is presented. Proposed framework for HPM is presented in section 3. Simulation results of the proposed method on a residential distribution feeder are evaluated in section 4. Finally, some conclusions are discussed in section 5.
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