Chapter 12
Swarm Intelligence-Based Optimization for PHEV Charging Stations

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ABSTRACT

In this chapter, Gravitational Search Algorithm (GSA) and Particle Swarm Optimization (PSO) technique were applied for intelligent allocation of energy to the Plug-in Hybrid Electric Vehicles (PHEVs). Considering constraints such as energy price, remaining battery capacity, and remaining charging time, they optimized the State-of-Charge (SoC), a key performance indicator in hybrid electric vehicle for the betterment of charging infrastructure. Simulation results obtained for maximizing the highly non-linear objective function evaluates the performance of both techniques in terms of global best fitness and computation time.

INTRODUCTION

Recent researches on green technologies for transportation sector are gaining popularity among the research communities from different areas. In this wake, Plug-in hybrid electric vehicles (PHEVs) have great future because of their charge storage system and charging facilities from traditional grid system. Several researchers have proved that a great amount of reductions in greenhouse gas emissions and the increasing dependence on oil could be accomplished by electrification of transport sector (Caramanis & Foster, 2009). Future transportation sector will depend much on the advancement of this emerging field of vehicle optimization. Indeed, the adoption of hybrid electric vehicles (HEVs) has brought significant market success over the past decade. Vehicles can be classified into three groups: internal combustion engine vehicles (ICEV), hybrid electric vehicles (HEV) and all- electric vehicles (AEV) (Tie & Tan, 2013). Plug-in hybrid electric vehicles (PHEVs) which is very recently introduced promise to boost up the

overall fuel efficiency by holding a higher capacity battery system, which can be directly charged from conventional power grid system, that helps the vehicles to operate continuously in "all-electric-range" (AER). All-electric vehicles or AEVs is a kind of transport which use electric power as only sources to run the system. Plug-in hybrid electric vehicles with a connection to the smart grid can own all of these strategies. Hence, the widely extended adoption of PHEVs might play a significant role in the alternative energy integration into traditional grid systems (Lund & Kempton, 2008). There is a need of efficient mechanisms and algorithms for smart grid technologies in order to solve highly diverse problems like energy management, cost reduction, efficient charging station etc. with different objectives and system constraints (Hota, Juvvanapudi, & Bajpai, 2014).

According to a statistics of Electric Power Research Institute (EPRI), about 62% of the entire United States (US) vehicle will comprise of PHEVs within the year 2050 (Soares et al., 2013). Moreover, there is an increasing demand to implement this technology on the electric grid system. Large numbers of PHEVs have the capability to make threats to the stability of the power system. For example, in order to avoid disturbance when several thousand PHEVs are introduced into the system over a small period of time, the load on the power grid will need to be managed very carefully. One of the main targets is to facilitate the proper communication between the power grid and the PHEV. For the maximization of customer contentment and minimization of burdens on the grid, a complicated control appliance will need to be addressed in order to govern multiple battery loads from a numbers of PHEVs properly (Su & Chow, 2012a). The total demand pattern will also have an important impact on the electricity production due to differences in the needs of the PHEVs parked in the deck at certain time (Su & Chow, 2011). Proper management can ensure strain minimization of the grid and enhance the transmission and generation of electric power supply. The control of PHEV charging depending on the locations can be classified into two groups; household charging and public charging. The proposed optimization focuses on the public charging station for plug-in vehicles because most of PHEV charging is expected to take place in public charging location (Su & Chow, 2012). Wide penetration of PHEVs in the market depends on a well-organized charging infrastructure. The power demand from this new load will put extra stress on the traditional power grid (Morrow, Karner, & Francfort, 2008). As a result, a good number of PHEV charging stations with suitable facilities are essential to be built for recharging electric vehicles, for this some strategies have been proposed by the researchers (Mayfield, Jul. 2012). Charging stations are needed to be built at workplaces, markets/shopping malls and home. Boyle (2007) proposed the necessity of building new smart charging station with effective communication among utilities along with sub-station control infrastructure in view of grid stability and proper energy utilization. Furthermore, sizeable energy storage, cost minimization; Quality of Services (QoS) and intelligent charging station for optimal power are underway (Hess et al., 2012). In this wake, numerous techniques and methods were proposed for deployment of PHEV charging stations (Z. Li, Sahinoglu, Tao, & Teo, 2010).

One of the main targets is to facilitate the proper interaction between the power grid and the PHEV. For the maximization of customer satisfaction and minimization of burdens on the grid, a complicated control mechanism will need to be addressed in order to govern multiple battery loads from a numbers of PHEVs appropriately (Su & Chow, 2012b). Charging infrastructures are essential in order to facilitate the large-scale penetration of PHEVs. Different computational intelligence-based methods have been used by some researchers for charging station optimization of PHEV. Most of them applied traditional methods which are needed to be improved furthermore.

Swarm intelligence came from the mimic of the living colony such as ant, bird, and fish in nature, which shows unparalleled excellence in swarm than in single in food seeking or nest building. Drawing

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