A Discrete Event-Driven Model for Electric Vehicles Predictive Charging

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ABSTRACT

Very great research efforts have been made in the last decades to further develop and promote electric vehicles (EVs), their charging infrastructures, and operation techniques. However, little attention has been paid so far to the management of their charging planning, EVs assignment and mainly drivers’ assistance to get into adequate charging stations (CSs). The charging planning and EVs assignment need to be predicted taking into consideration all operating constraints of charging systems including EV characteristics, status of CSs, road traffic, etc. This paper presents a discrete event driven model for EVs predictive charging. The authors mainly focus on behavior modeling of the charging system using (max, +) algebra and Petri nets. The model is then used to anticipate maximum charging times and charging rates of EVs while respecting their various constraints.

Keywords: (Max, +) Algebra, Charging Process, Electric Vehicles, Modeling and Evaluation, Petri Nets, Prediction

1. INTRODUCTION

Many research efforts have been made in literature for developing and promoting EVs. However, little attention has been paid so far for their charging process and related infrastructures. This is due to the fact that charging process for EVs is more complex and completely different from refueling processes of vehicles that are powered by conventional power engines. Indeed, for charging management of EVs many parameters should be taken into account in order to adequately satisfy users and optimize the quality of provided services. In fact, the assignment
of EVs to CSs takes into account several dynamic parameters such as EVs’ characteristics, the dynamic state of CSs and traffic situation on the roads.

Certainly, the density of EVs in the road traffic becomes more and more important. However, using and promoting this type of vehicles remain limited because of their autonomy, long charging times, and fast discharging caused by excessive speed, roads profile and excessive use of electric accessories. This requires sophisticated charging methods and strategies, since the task is to suggest the adequate CS rather than just the nearest one (Ruzmetov et al., 2013) (Ruzmetov et al., 2014). In fact, one of the most major issues is related to the uncertainty of drivers to get a suitable CS with vacant charging points. In this paper, we continue these efforts and try to propose a formal approach aiming to anticipate, plan and propose adequate charging solutions for EVs. These solutions should take into account several parameters such as the location of EVs, the remaining energy in the battery, traffic conditions, and the length of queuing in each CS. The expression of the battery SoC of EV according to these parameters is further detailed in (Mkahl et al., 2015).

The charging management of EVs within a CS with performance metrics such as arriving rates of vehicles to charging points, the number of vehicles to serve, and required charging time can be seen as discrete events and entities. In this point of view, many appropriate tools have been developed in the literature to model and analyze such systems using discrete event systems theory (DES). In this work, we are interested in the use of this theory for specifying and modeling studied charging process. To do so, we focus mainly on the use of timed event graphs (TEG), as a subclass of Petri nets (PN), combined with (max, +) algebra. These formalisms have been considered as powerful tools for modeling and performance analysis of different types of discrete event systems (Nait-Sidi-Moh et al., 2009, De Schutter & Van Den Boom, 2008, Baccelli et al., 1992.). Using these modeling tools, we aim through this work to act appropriately on the service time of charging tasks in order to serve maximum charging requests while satisfying the constraints of each EV. The proposed model allows defining a predictive function of the charging process by providing useful information and suggesting adequate CSs and charging time for each EV when it is necessary.

The reminder of this paper is structured as follows. Section 2 presents a survey of related work. The problem statement and system description are given in Section 3. Section 4 is devoted to the modeling and evaluation of the system. Section 5 presents a predictive charging approach with suggested charging solutions for EVs together with obtained results. The last section concludes the paper and gives some directions of future work.

2. RELATED WORK

EVs charging process and its dynamic are one of the main problems for promoting this type of vehicles. To tackle this problem, several approaches were proposed in the literature to reduce charging times while ensuring high performances (e.g. more autonomy and performances). For example, in (Vandael et al., 2011) a multi-agent system has been used to model and control the charging and discharging of plug-in hybrid electric vehicles (PHEVs). Furthermore, authors compared the reducing imbalance costs by reactive scheduling and proactive scheduling. Simulations showed that reactive scheduling is able to reduce imbalance costs by 14%, while proactive scheduling yields to a highest imbalance cost reduction of 44%.

The authors examined in (Saeid et al., 2011) the problem of optimizing the charging pattern of a PHEV. The optimization goal is to simultaneously minimize the total cost of fuel and electricity, and the total battery health degradation over a 24h naturalistic driving cycle. The first objective was calculated using stochastic optimization for power management, whereas the
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