Multi-Objective Planning for Electric Vehicle Charging Stations Considering TOU Price

Qiao Sun[1] , Xingzhen Bai[2*], Lu Liu[3], Fasheng Liu[1], Xingquan Ji[2], James Hardy[3]
[1]College of Transportation, Shandong University of Science and Technology, Qingdao, China
[2]College of Electrical Engineering and Automation, Shandong University of Science and Technology, Qingdao, China
[3]Department of Engineering and Technology, University of Derby, Derby, United Kingdom
xzbai@sdust.edu.cn; l.liu@derby.ac.uk

***Abstract*— This paper proposes an Electric Vehicle charging station planning method which takes Time-of-Use price into consideration. First of all, the impact of Time-of-Use price on EV user charging behavior is described specifically. Secondly, a multi-objective model for the optimal planning of EV charging station is developed to maximize the charging demands captured by EV charging stations, minimize the total cost during charging, and minimize the electrical load variance. Thirdly, Particle Swarm Optimization algorithm with constriction factor is utilized to solve the planning problem. The Data Envelopment Analysis method is employed to select the optimal solution. Simulation results illustrate the effectiveness of the proposed method using case study consisting of an IEEE 33-node distribution system and a 33-node traffic network system as an example.**

Keywords –charging station; constriction factor; the Data Envelopment Analysis method (DEA); Time-of-Use (TOU) price

I. INTRODUCTION

Greater attention has been paid to the energy-saving and emission-reduction in the recent few years because of the shortage of resources and the increasing pressure on the environment. As a result, development of Electric Vehicles (EV) has become increasingly necessary[1], [2]. The development of battery technology and the development of EV have been highly complementary, with each encouraging mutually beneficial evolution. The planning of EV charging stations has begun to catch eyes of many experts and scholars at home and abroad. In [3], [4], authors planned charging station from the economic point of view. A model for the fast charging station planning aiming to minimize both total costs of line installation and line losses on the distribution system is proposed in [3], while a method to determine the optimal size and location of PHEV charging stations to maximize the distribution system manager benefit is presented in [4]. The multi-objective ant colony optimization (MOAOCO) and the Data Envelopment Analysis method is implemented to find a set of optimal solutions respectively in [3], [4]. In [5], a multi-objective decision-making model for optimal planning of EV charging stations is developed, in which the objective functions are defined to respectively maximize the captured traffic network flow, to minimize the network loss, and to minimize the average voltage deviation. And then the cross-entropy method is used to solve the planning problem. In [6], the proposed algorithm takes into consideration the stochastic nature of PEV mobility. The objective of the planning algorithm is to jointly determine the optimal number of deployed electric chargers and waiting space size in the charging facility so as to maximize the operator's expected profit. The planning approach exploits the M/M/C/S queue structural properties to reach the optimal solution.

In this context, new ideals for the planning of charging stations are proposed, in which the planning models are formulated from the perspective of economic and road traffic information. However, in most literature, the charging station is planned as an ordinary electricity facility, in which the influence of EV user charging behaviors on charging station planning is ignored. In fact, the charging requirements of increasing numbers of EV is imposing-pressure on the operation of the electrical distribution network, a problem exacerbated by their uncontrolled charging behavior. In order to reduce adverse impacts of EV, an intelligent charging strategy is proposed in [7], [8], in which Time-of-Use (TOU) price policy is utilized to lead users to control their charging behavior. In fact, EV charging station is not only a part of the regular electricity grid infrastructure, but also forms part of an urban traffic management facility providing service for the EV. Therefore, the problem of locating the charging station to provide a convenient service while ensuring the safety of power grid has become a particularly important and urgent issue. Motivated by above discussion, this paper provides an optimal planning method for EV charging stations, in which the impact of charging behavior on planning is considered with the incentive of TOU price. A new multi-objective charging station planning method is proposed which is aimed at maximizing the charging demands captured by EV charging stations, minimizing the total cost during charging, and minimizing the electrical load variance. The Particle Swarm Optimization algorithm with constriction factor (PSOCF) is utilized to solve the multi-objective planning model and obtain the Pareto planning solutions. A data-envelopment analysis (DEA) method is then used to make the final planning decision among the Pareto solutions to determine the optimal charging station location. The effectiveness of the proposed method has been demonstrated through a case study based on a test system consisting of IEEE 33-node distribution system and a 33-node traffic network system.

II. ANALYSIS OF TIME-OF-USE PRICE

EV charging strategy can be divided into two categories, disordered charging and ordered charging. Disordered charging refers that EVs connect grid by the way of unplugged plug and

* Corresponding author.
E-mail address: xabai@sdust.edu.cn.

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