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Collaborative Planning Model for Charging Station and Distribution Network Considering User Benefits

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Abstract

With the increasing of electric vehicles (EVs) users, a large amount of reserve charging infrastructure have to be deployed in distribution systems to the uncertain charging demand, which may lead to redundant investment. In order to reduce unnecessary investment and optimize the plan of charging station and distribution network, a multi-objective planning model is proposed. The objectives of planning model include the benefits of both distribution network and EV user. The proposed method has been verified on a modified 54-bus distribution and 19-node road system. The results shows that the proposed model can give collaborative plan, and ensure the benefits of both the distribution side and user side.

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Keywords: charging station, distribution network, user benefits, distribution benefits, multi-objective model

1. Introduction

With more research and incentives on EVs, people are supposed to break the dependence on oil and have a greener way to travel [1]. However, charging service network is urgently developed to meet the needs of user side, and the corresponding charging stations and distribution network should be developed appropriately [2]. Therefore, a collaborative planning model considering the increasing charging demand and balancing the benefits of distribution network and EV user is of much significance.

Nowadays, many research have been devoted to analysing how modern power system can be developed to adapt EV charging demand. Planning and operation of charging stations are introduced in [3-4], without considering the constraints of distribution system. Taking distribution constraints into consideration, [5-6] analyse the effect of charging load on distribution networks. Based on above considerations, collaborative plan methods for distribution

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networks and charging service networks are proposed in [7-8]. Besides, as charging demand is not static, the benefits of distribution side and user side are supposed to be satisfied over time. The innovation and the main contributions of this paper are the following:

A multi-objective planning model is proposed, which considers the benefits of both distribution system and EV user. For the distribution network operators, when deploying charging stations and associated infrastructure, the connection cost and reinforcement are considered. For EV users, travel distance, travel time and charging price are taken as their main benefits.

2. Demand analysis of fast charging infrastructures

2.1 Charging load forecasting

Based on improved Voronoi diagram the study district is divided into several parts. Each of the part has its mainly load characteristic and its corresponding load template (commercial, residential and industrial). The number of EV is estimated based on the factors including penetration rate, increasing rate, household EV ownership, and number of households [2], the exact number of EV in each plan year and its charging demand and charging plies are given in Appendix Table I. Other sample parameters, namely, charging mode classification and charging demand proportion of different EV are given in Appendix Table II and Table III. The forecasting results and corresponding underlying factors are shown in Fig. 1.

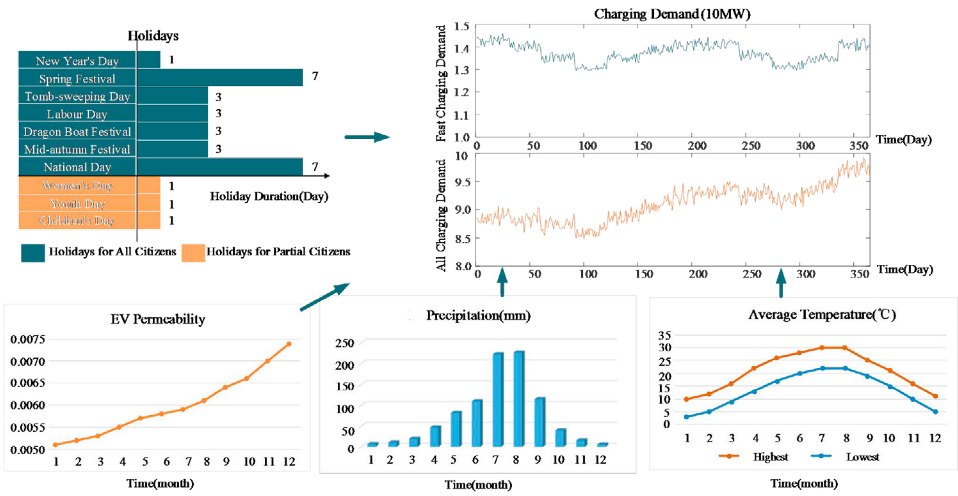

Fig. 1. Charging demand forecasting and corresponding data

2.2 Number of charging infrastructures

When doing infrastructures forecasting, the regular and slow charging demand are input as base factors. The fast charging demand is the main part that considered when planning charging stations and setting associated facilities. In equation (1), Q_{β}^{t} is the demand quantity of β type fast charging piles for studied district in t year.

$$Q_{\beta}^{t}=\frac{CD_{U}^{day}(1+\sigma)}{PR_{\beta}T_{\beta}^{day}\left(1-VR_{\beta}\right)} \tag{1}$$

where σ is redundancy (0.05), CD_{U}^{day} is the beginning value of the year; PR_{β} is the rated charging power of charging piles, and $PR_{\beta}=RC_{\beta}PV_{\beta}$, which are rated charging current and rated charging voltage; T_{β}^{day} and VR_{β} are the day available hours and vacancy rate of pile β. The calculation demand results of the plan district are given in Appendix Table I.