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System Dynamics Modeling and Analysis of Regional Carbon Emission from Electric Vehicle Grid in Clean Energy Development Scenario

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Abstract

In the context of "carbon peak and carbon neutral" development, the promotion of electric vehicles provides strong support for the realization of dual carbon goals. In order to study the impact of electric vehicles on carbon emissions, the coupling relationship between EV scales, regional energy composition, vehicle network interaction technology and carbon emissions was analyzed. Then, the development path of regional clean energy is constructed according to the development law of clean energy. Finally, based on the system dynamics principle, a dynamic feedback model of the regional carbon emission evolution caused by EV entry into the grid considering the change of clean energy was established. Finally, the dynamic evolution simulation is conducted with the data of a city in southwest China as an example, in which the development scale of electric vehicles and the development path of clean energy are taken as the main variables to analyze the impact of electric vehicles on regional carbon emissions in various scenarios. In addition, the sensitivity test verifies that EV grid access has certain carbon emission reduction benefits. The above simulation results show that the development of clean energy has the most significant impact on carbon emission reduction, and the interactive technology of electric vehicle network has a huge potential for carbon emission reduction.

Introduction

In the context of Vigorously promoting the development of new energy vehicles in China, the scale of replacing traditional fuel vehicles (CV) with electric vehicles (EV) is gradually expanding, providing strong support for the realization of the dual carbon goal of "carbon peak and carbon neutral" [1, 2]. On the other hand, the development of vehicle to gird (V2G) and the steady increase in penetration of clean energy further undergird the carbon reduction target [3, 4]. Therefore, it is of far-reaching significance to further explore the development trend of electric vehicles, regional energy network structure, vehicle network interaction potential and relevant policies, etc. for promoting carbon emission reduction and building smart clean energy.

At present, domestic and foreign scholars have conducted a lot of exploration on the interaction between EV and power grid, such as EV load prediction, charging station pile planning scheme, charging electricity price pricing mechanism and other relevant studies [5, 6, 7, 8]. These literature all need to take urban EV scale as their research foundation, so it is necessary to explore the development trend of EV scale. In literature [9], Bass diffusion model was used to simulate the development trend of EV retention. Literature [10] analyzes the hindering factors in the development process of EV industry and studies the internal and external factors that influence the purchase decisions of EV users. Based on the multi-agent technology and consumer behavior theory, the vehicle purchase model of EV users is established in literature [11], and the influence of individual users on the development of EV scale is analyzed from a micro perspective. The above literature mainly predicted the development of EV through mathematical methods, but limited to the fact that the interaction between carbon emission reduction and the evolution of EV scale was not considered, so the contribution degree of EV to the carbon emission reduction target could not be quantitatively analyzed. In addition, driven by relevant policies, the trend of clean energy in regional energy networks is becoming more and more significant. EV can reduce carbon emissions by absorbing clean energy. As for the relationship between power system and carbon emissions, some domestic scholars have put forward the carbon emission flow theory to conduct basic research [24] on the carbon emissions of power system. Literature [12] analyzed the carbon emissions in the operation of power system based on the carbon emission flow theory. Literature [13] focuses on the direction of carbon emission flow and traces the source of electric energy, so as to further popularize the carbon flow theory into production practice and track the direction of carbon emission in the system, providing a basis for the calculation of carbon flow [25].

In order to further explore the significance of EV's contribution to carbon emission reduction in the energy grid as a demand response resource, this paper further considers the

the participation of EV users. Therefore, it is suggested to vigorously develop vehicle network interaction technology and encourage EV users to participate in demand response, so as to give full play to the role of EV under the dual carbon goal.

In this paper, we build a regional carbon emission model based on the change of EV input and clean energy proportion, and analyze the influence of different factors on carbon emission, which provides a reference for achieving the goal of carbon neutralization from 30 to 60. In the future research, participation modeling is carried out, and comprehensive benefits of users of V2G technology are also analyzed.

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