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A comprehensive study on low-carbon impact of distributed generations on regional power grids: A case of Jiangxi provincial power grid in China

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ABSTRACT

Electric power industry is a key to achieve the low-carbon social and economic development. Distributed generation (DG) has great potential in the development of low-carbon power grid because of its non-polluting property and large reserves. Therefore, it is of great importance to have a comprehensive investigation on low-carbon impact of DG on power grids. In this paper, regional power grids are focused as they are crucial supporters of regional economic and social activities and the primary undertakers of low-carbon development. Specifically, first, the carbon dioxide emission coefficient and energy consumption of DG are evaluated from the aspect of its life cycle. Then, the wind farm and photovoltaic power station are compared in terms of carbon dioxide emissions and energy consumption, indicated that wind power is superior in reducing the carbon dioxide emissions. Finally, the carbon intensity of provincial power grid is evaluated by grey prediction model with historical data such as electricity consumption, gross domestic product (GDP), carbon dioxide emission coefficient. Taking Jiangxi provincial power grid as the example, the results demonstrate that the proposed prediction method is of high accuracy and the integration of DGs can effectively reduce carbon dioxide emissions and carbon intensity, thus, DG should be widely integrated into provincial power grids.

Contents

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1. Introduction

As energy crisis and climate change have been widely concerned, it has become the consistent objective of each country and industry to achieve low-carbon social and economic development and lower the excessive consumption of fossil energy. In recent years, the growth rate of carbon dioxide emissions of China has increased significantly. Fig. 1 shows the energy mix of China's electricity generation in 2013 [1], where the thermal power accounts for 71.48% of the sources of electricity generation. The carbon dioxide emissions of China took up 27.1% of the world [2], ranking the first among all countries. Power industry which uses coal as the primary energy is the largest carbon dioxide emission department in national economy [3]. Therefore, power industry is a major department has the greatest potential to reduce carbon dioxide emissions.

Distribution generation (DG) usually refers to the decentralized, modular and more flexible generation units with the capacities ranging from a few thousand kilowatts (kW) to a few hundred megawatts (MW), which are located close to the load they serve [4,5]. Wind power, photovoltaic power, biomass power and other forms of renewable energies are generally used, greatly reducing the emissions of harmful gases like carbon dioxide, sulfur dioxide and nitrogen oxide [4,6]. Due to the close distance between the DG and the users, there is no need to build more large capacity transmission lines [6]. If DG is integrated into the power grids, the transmission and distribution power flow can be reduced and the system loss can be decreased [7]. The heat that DG produced can be reused, thus achieving the rational use of energy [8,9]. Moreover, when a power grid is faced with accidents or failures, DG with a back-up power system is able to maintain operation without affecting the normal lives of residents [7–11]. Thus, it can improve the flexibility and security of power supply.

China has abundant wind power and solar power resources, both of which boast the largest reserves and exploitable capacity in the world, giving China huge potential in developing these two renewable energies [12]. The technologies of exploiting wind power and photovoltaic power are relatively advanced and mature. At present, China State Grid is vigorously promoting DGs like wind and photovoltaic power generations to integrate into provincial power grids, so that the low-carbon development can be promoted [13]. Thus, most provinces of China have built local wind farms and photovoltaic power stations. Jiangxi Province is located at southeast of China, as shown in Fig. 2, where the application of renewable energy is typical. It has already built wind power generation demonstration areas around Boyang Lake and photovoltaic power generation demonstration areas in Xinyu City [14,15]. The wind annual utilization hours of Jiangxi Province ranked the third nationwide, which is 26% higher than the national average [16]. Xinyu City, Ganzhou City and Shaorao City of Jiangxi Province have been named as national PV renewable energy demonstration cities [17]. Besides, Jiangxi Province plans to install another 0.5 million kilowatts of wind power capacity and 0.5 million kilowatts of photovoltaic power capacity, striving to achieve the goal that both the installed capacities of wind power and photovoltaic power surmount one million kilowatts by the end of 2015 [18]. For this reason, two representative DGs, wind power and photovoltaic power, are focused in this paper. The carbon emission intensity factors of these two DGs based on LCA are calculated. With the carbon emission intensity factor of traditional thermal power and the comparison of carbon dioxide emission reduction between these two DGs under the same circumstances, the DG with better carbon dioxide emission reduction effect can be obtained. This paper also adopts grey forecasting method to predict the carbon dioxide emissions from 2014 to 2018 of Jiangxi Province in China in different scenarios by using the Jiangxi historical electricity consumption data and carbon emission intensity factor of thermal power. The results indicate that DG can effectively reduce carbon dioxide emissions and benefit the construction of provincial power grids in China.

2. Calculation of carbon emission intensity factor of DGs

The renewable energies used in the electricity generation do not directly produce the carbon dioxide, as opposed to the fossil energy. Since the carbon dioxide emissions of renewable energies are much smaller compared to that of the fossil energy, they were sometimes ignored in studies. Besides, some studies only consider the carbon dioxide emissions at the power generation side of DG. Different from that, this paper studies the carbon dioxide emissions of the DG from an environmental point of view. The total carbon dioxide emissions are calculated during the whole life cycle of DG, which includes construction, transportation, operation and waste disposal of the DG power plants. Combined with the historical data of electricity generation, the carbon emission intensity factor, defined as the carbon dioxide emissions per electricity (g/kW h) can be derived. The calculation results are compared with conventional coal-fired power so that the abatement potential of DGs can be obtained.

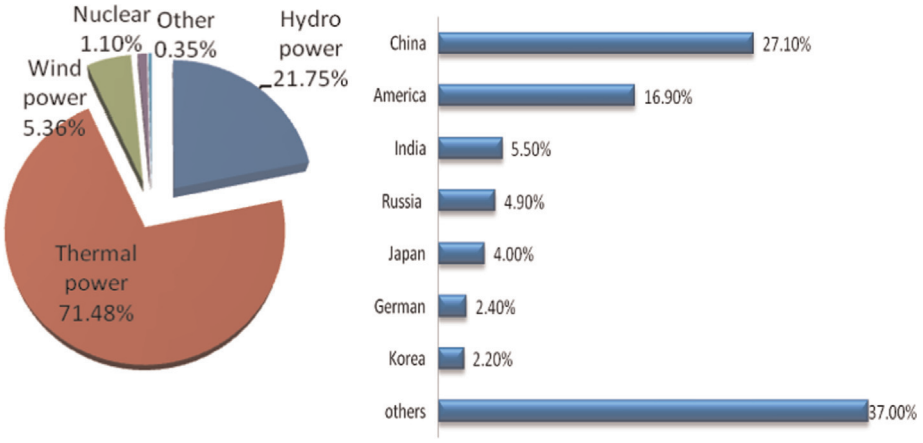

Fig. 1. Energy mix of China's power industry and global proportion of carbon dioxide emissions in 2013.