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Temporal-spatial analysis and improvement measures of Chinese power system for wind power curtailment problem

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ABSTRACT

The Chinese wind power industry has experienced a period of rapid development for the past 10 years, but the utilization hours of wind power equipment started to drop abruptly since 2011, and the curtailment problem has become worse year by year. Throughout the year of 2012, Chinese wind power sector lost about 20 million MWh in electricity from wind curtailment. For regions that experienced the most serious curtailment problems in China, the percentage of wind power installation and consumption have been relatively low compared to other countries. Although previous studies have so far proposed many explanations, the main characteristics and most critical factors of the curtailment problems are not very clear. To fill this gap, we have performed a detailed study on the wind power curtailment problem from the perspective of the whole of China by analyzing a large amount of wind power curtailment data and the characteristics of wind power curtailment in China have been addressed from temporal-spatial perspective. According to the characteristics and curtailment data, we propose that the curtailment is rooted in unreasonable power source structure and long chain power grid network structure. Based on the above two reasons, this study has proposed further improvement measures in terms of the power source structure, consumption structure, the grid structure. Relative market and policy suggestions are proposed to provide guidance for the further development of wind power.

Contents

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1. Introduction

Nowadays the concerns about global warming and shortage of the fossil resources are creating a strong tendency towards the use of wind power and other renewable energy sources all over the world. In recent years, China has identified wind energy as an important alternative power source to rebalance its energy mix [1–4]. According to the World Wind Energy Association (WWEA), worldwide installed wind capacity reached 282.5 GW in 2012 [5], China ranking first in the world in cumulative terms with a total installed wind capacity of 75.32 GW, accounting for more than 20% of the world market [6]. In 2012 annual wind power generating capacity of 100.4 million MWh more than 98.2 million MWh of nuclear power generating capacity, wind power has become the third-largest power source following the thermal power and hydropower in China [6].

Moreover, in order to achieve the Chinese government's commitment on non-fossil energy accounting for 15% of primary energy consumption for the issue of Climate Change, the wind power development is still accelerating [7,8]. More and more supportive regulations and policies have been introduced by government to support wind power development [9–13]. According to Chinese Wind Energy Association (CWEA), national newly installed power capacity reached to 18 GW in 2013 [14]. According to the wind power development during the 12th Five-Year-Plan (2011–2015) by National Energy Administration (NEA) [15], the installed capacity of wind power will reach 100 GW as well as the annual power generation will reach 190 million MWh [15].

Despite the rapid development of wind power in China, wind power curtailment problem is increasingly plaguing China's government, wind power operators, and investors. Curtailment of wind farm output due to transmission inadequacy, minimum generation limits, and other forms of grid inflexibility has become more common across China while wind power development has become more significant and widespread.

The national Average Utilization Hours of Wind Power Equipment (AUHWPE) was 1890 h in 2012, decreasing by 30 h in comparison with 2011. Especially, in the Northeast, Northwest and North China which are wind power concentrated areas, the average utilization hours of local wind equipment were about 1600 and the lowest were only 1300 [16–18].

The wind power curtailment problem in China has recently received a great amount of attention in fields of policy-making, academia and the media. Some studies analyzed the challenges that China faces in the development of wind power, and concluded that the wind power industry had developed too fast with too many wind turbines installations, while turbine performance needs to be improved further [19]. Some studies summarized the key factors which impact on wind power integration, including system regulation capability, transfer capability, wind power dispatch levels, etc. and proposed that the storage for wind power needs to be increased, and that more flexible operation modes are needed to put forward [20]. Some studies explored the factors directly related to constraints on the effective utilization of wind power in China [21], especially in the Northeast China grid [22], including grid structure, power source structure, market structure, power price mechanism, dispatch mode arrangement, wind power integration codes, and wind power forecast. A few studies concluded that the main problem of the Chinese wind power curtailment is not only technological but also involves market mechanism and interest distribution [23]. Even though the present market mechanism and interest distribution management is yet unmatured, under the strong pushes from the Chinese government's determination and policies on energy saving and emission reduction, every group has been speeding up construction and adjusting operation modes to solve the wind power curtailment problem.

Although the effective utilization of wind power was constrained by various factors mentioned in these studies, solving only some of the problems might ease the current curtailment problem but would not be able to turn the whole situation and trend around. Therefore, the urgent need now is to perform more detailed studies and further sort out the curtailment problem's main characteristics and key factors to facilitate propositions for future improvement measures and policy mechanisms. We have performed a more detailed study on the wind power curtailment problem from the perspective of the whole country. By analyzing a huge amount of wind power curtailment data, the characteristics have been addressed from a two-dimensional perspective (temporal-spatial). The results show that the Chinese wind power curtailment problem has distinct spatial and temporal domain characteristics. We propose that wind power has rigid restrictions imposed by the power sources structure (percentage of various power sources) and power grid structure: (1) In terms of the time domain, the 'Three North' (Northwest China, North China, Northeast China) and Southwest regions have unreasonable power source and consumption structures, leading to a mismatch between wind power and other power source outputs and consumption in the temporal domain, and therefore, tremendous wind power be curtailed when mismatch. (2) In terms of the spatial domain, the grid structure is fragile for large scale wind power delivery: the congregated regions associated with wind power have an inconsistent spatial distribution compared with the centralized electrical load regions, and transmission corridors that connect over several provinces are very scarce. This distribution results in a fragile long-chain structure for wind power delivery in terms of the geographic distribution, leading to great limitations on wind power delivery. Due to the above two reasons, this study has proposed further improvement measures in terms of the power source structure, consumption structure, and the grid structure. Also, the corresponding market and policy suggestions were proposed to provide guidance for the further development of Chinese wind power.

2. Temporal-spatial characteristics of wind resources, development and curtailment in China

2.1. Temporal-spatial characteristics of the China wind resource

Wind energy is abundant in China, especially in the North and the Southeast along the coastline. According to the most recent survey of national wind resource [24], China's wind power resources have been mapped by China Meteorological Administration Wind and Solar