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Comprehensive assessment of wind resources and the low-carbon economy: An empirical study in the Alxa and Xilin Gol Leagues of inner Mongolia, China

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ABSTRACT

Due to atmospheric pollution from fossil fuels, the reduction of wind turbine costs, and the rise of the low-carbon economy, wind energy conversion systems have become one of the most significant forms of new energy in China. Therefore, to reduce investment risk and maximize profits, it is necessary to assess wind resources before building large wind farms. This paper develops a comprehensive system containing four steps to evaluate the potential of wind resources at two sites in Xilin Gol League and at additional two sites in Alxa League of Inner Mongolia, China: (1) By calculating the total scores of three indexes, including the effective wind power density (EWPD), wind available time (WAT) and population density (PD), an indexes method is applied to assess the theoretical wind energy potential from 2001 to 2010. (2) To judge the fluctuations in the wind speed, the Fisher optimal partition method and the Jonckheere–Terpstra test are used to analyze the changes in the average monthly and yearly wind speeds from 2001 to 2010. (3) Three probability density functions, i.e., Weibull, Gamma and Lognormal, are used to assess the wind speed frequency distribution in 2010. To enhance the evaluation accuracy, three intelligent optimization parameter estimation algorithms, i.e., the particle swarm optimization algorithm (PSO), differential evolution algorithm (DE) and ant colony algorithm (ACO), are used to estimate the parameters of these distributions. (4) It is helpful to analyze the wind characteristics when assessing wind resources and selecting wind turbines. Therefore, the optimal frequency distribution based on the best parameter estimation method can be chosen to calculate the wind power density, the most probable wind speed and the wind speed carrying the maximum energy. The experimental results show that Site 1 and Site 4 are more suitable for large wind farms than Site 2 or Site 3.

Contents

Abbreviations: EWPD, effective wind power density; WAT, wind available time; PD, population density; MM, method of moments; MLE, maximum likelihood estimation; PSO, particle swarm optimization algorithm; DE, differential evolution algorithm; ACO, ant colony algorithm

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1. Introduction

China is currently the world's largest energy producer and consumer. It is also one of the few countries in the world with coal as its main energy source: Coal accounts for approximately 75% of the national energy production. Currently, coal resources are mainly used for thermal power, and thermal power provides the majority of the electric energy supply. In 2011, thermal power generation accounted for approximately 80.8% of all types of generation capacity. Therefore, it is generally considered that the proportion of coal in the energy and electricity supply is quite large. In addition, coal mining and burning have large negative environmental impacts [1,2]. To be specific, the national electricity coal consumption rate was approximately 333 g/kW h in 2010, while the pollutant emissions produced per ton of coal burned are very large and the governance costs of the various pollutants are pretty high (see Table 1). In fact, China is already ranked the world's second largest producer of carbon emission, behind only the United States. It is estimated that by 2020 the emissions of carbon dioxide and other greenhouse gases will surpass that of the United States' [3]. Consequently, based on increasingly serious environmental damage, the development of the low-carbon economy and renewable energy is a critical and effective way to reduce environmental pollution, promote energy conservation and generate green electricity.

Wind energy, which is a type of free, clean and environmentally friendly energy, is currently used by many leading developed and developing nations to fulfill their electricity demands. The wind energy situations all around the world can be seen in Fig. 1 [4,5]. Wind power has some advantages, including a short construction period, large reserves, renewable, nonpolluting, flexible investment and small operations and management staff compared with traditional power sources. The cost of producing wind energy has come down steadily over the last few years. The main cost is the installation of wind turbines, which is far below the cost of other renewable energy power generation techniques, such as biomass and solar. Moreover, wind turbines are an excellent method for the generation of energy in remote locations, such as mountain communities and remote countrysides. Considering these advantages of wind power, exploring new areas in which build wind farms is necessary. China's wind power industry emerged over 20 years ago and entered a phase of particularly rapid growth in 2005 (see Fig. 2) [6].

To reduce investment risk and maximize profits, accurate wind energy resource assessment plays a vital role in wind farm planning. A large number of researchers have paid significant attention to wind energy assessment. Generally, a probability density function is a useful method to describe wind speed frequency distributions. For example, Ucar and Balo employed a Weibull distribution to perform wind energy potential assessments using the wind speed data collected by the six meteorological stations in Turkey and calculated the yearly energy output and capacity factor for four different turbines [7]. Pishgar-Komleh et al. used Weibull and Rayleigh distributions to evaluate wind speed and power density in Firouzkooh county of Iran [8]. Chang applied several types of mixed probability functions including the bimodal Weibull distribution and the mix Gamma–Weibull function to estimate wind energy potential in Taiwan [9].

The assessment of wind resources on a wind farm is the basis of wind power projects. Accurate and reasonable descriptions of wind energy resources will directly affect the wind turbine selection, generation capacity estimation and economic benefits. In many of China's completed wind farms, there are significant differences between the actual generation capacity and the designed capacity [10]. One of the main reasons is the inaccuracy of traditional assessment method for the potential of wind resources. Therefore, this paper proposes a comprehensive method containing four steps to assess the potential of wind resources in Inner Mongolia of

Table 1
Pollutant emission rates and control costs of the coal-fired power plants.

	XO_2	NO_X	CO	CO_2	Dust	Dregs
Pollutant emission rates (kg/t)	18	8	17.31	0.26	110	30
Pollutant control costs (Yuan/kg)	6.53	6.29	1.00	0.02	0.12	0.10