EnergyPLAN-based Planning and Modeling for Renewable Energy System in Beijing

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Abstract. Despite government efforts toward encouraging the rapid growth in renewable energy in Beijing, the gap between energy supply and demand is aggravated, and the energy structure has yet to be optimized. This paper simulates the energy system of Beijing in 2012 from the perspective of wind power by using the advanced energy planning model--EnergyPLAN. Analysis shows the optimal penetration proportion of wind power in Beijing is 18%. The results further indicate that there is a large gap between the existing proportion of renewable energy and the optimal penetration proportion. There are many obstacles in resource development, grid construction and structure optimization that limit the development of renewable energy. This paper explores solutions to improving the resource imbalance in Beijing and its surrounding area by examining the state policy and the technology approaches.

Introduction

As the capital city and the most prosperous metropolitan area in China, Beijing strives to enhance its capability to develop renewable energy for "humanistic Beijing, scientific and technological Beijing, green Beijing". In the new round of international competition, optimizing the energy structure of Beijing has provided an important support for the city’s technical innovation, economic growth and social progress, so as to make greater contributions to the China’s economy and prosperity.

Denmark leads the way in renewable energy and its experience can be utilized by Beijing. Mathiesen designed a set of power system based on 100% utilization of renewable energy, and analyzed the energy system hourly by using the EnergyPLAN model [1]. He proved that 100% renewable energy system is practical in Denmark [2]. Liu studied the maximum wind power penetration in China from the perspective of technology and economy [3]. Liu also redesigned the existing rules in wind power, integrated heat pump and heat storage technology in China’s existing system, in addition, he developed the tram to increase the electricity used in non-peak time. Zhang is focused on the key problems and solutions to the energy system in Beijing [4]. Ye proposed the key development strategy of renewable energy in Beijing, and advocated to improve relevant laws and regulations to support and encourage the renewable energy industry [5].

The paper is focused on the current situation of Beijing's energy development and aims to provide suggestions to optimize the energy system in Beijing, and gives further ideas on government reforms. The author believes it is important to enhance the competitiveness of wind power in electricity market in order to solve the problem of imbalance resources in Beijing and its surrounding areas, so as to make a greater contribution to Beijing’s energy system optimization.

The Energy Systems in Beijing

Energy Supply

In 2012, the total energy supply in Beijing is 3,769 tce, among which the primary energy is 501.8tce, accounting for only 13% of the total production volume. As the economic and political center of China, Beijing's energy supply mainly relies on other provinces--94% of coal, 67% of

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electricity, 100% of natural gas and 100% of the crude oil are transferred from outside Beijing [4].

Energy consumption

From 2006 to 2012, the number of total energy consumption increased from 59.041 million tce to 71.777 million tce. The average annual growth rate was 3.3%. The top three energy consumptions were coal, natural gas and electricity. At the same time, the energy efficiency increased year by year. The energy consumption per ten thousand yuan GDP fell by about 42%, from 0.75 in 2006 to 0.436 in 2012.[6]

Renewable energy

Beijing has a full range of renewable energy resources. However the utilization is relatively less. In 2012, the total amount of renewable energy production and utilization was 2.23 million tce, accounting for 3.2% of the city's total energy consumption. Among them, the installed capacity of wind power reached 150,000 kilowatts and the electricity generation was 310 TWh; thus, wind power becomes the third power resource other than hydro power and thermal power in Beijing.

Methodology

Research Approach

Firstly, we use the EnergyPLAN model to simulate the energy system of Beijing in 2012.and the research tests the accuracy of the model. Next it takes wind power as a case study and then through the analysis of the influencing factors, it determines the maximum wind power penetration proportion. Finally it proposes policy suggestions on resource development, grid construction and structural optimization.

EnergyPLAN

EnergyPLAN is a model developed by Aalborg University in Denmark, using the computer to analyze the inputs and outputs of regional or national energy system [7]. The model is a deterministic model, which can be used to do simulation per hour and analyze the influence of the renewable energy fluctuation within the system. It can also summarize and optimize the whole system. All the advances make it a suitable model for this research.

Results and analysis

Accuracy of the reference model

Electric power demand. In 2012, the total electricity demand is 91.19 TWh. Through the simulation, we get the monthly distribution of electricity demand in Beijing as below.

Tab. 1 Actual distribution compared with simulated distribution of Beijing in 2012

Month	1	2	3	4	5	6	7	8	9	10	11	12
Actual demand[MW]	8770	9683	10114	9639	10175	10838	11438	12110	10175	10066	10672	10838
Simulated demand[MW]	8770	9684	10114	9641	10177	10843	11438	12111	10177	10067	10672	10842
Difference		-1		-2	-2	-5		-1	-2	-1		-4

Simulation shows that the electricity distribution in each month has a high degree of similarity to the actual distribution; the simulation model can correctly reflect the actual distribution of wind power.

Electricity Supply. In 2012, the total electricity generation in Beijing is 29.1TWh. There are small differences between the simulated data and the actual data distribution in different departments, as showed in Table 2. The main difference is in thermal power plant.

Tab. 2 The distribution of electricity generation in different departments

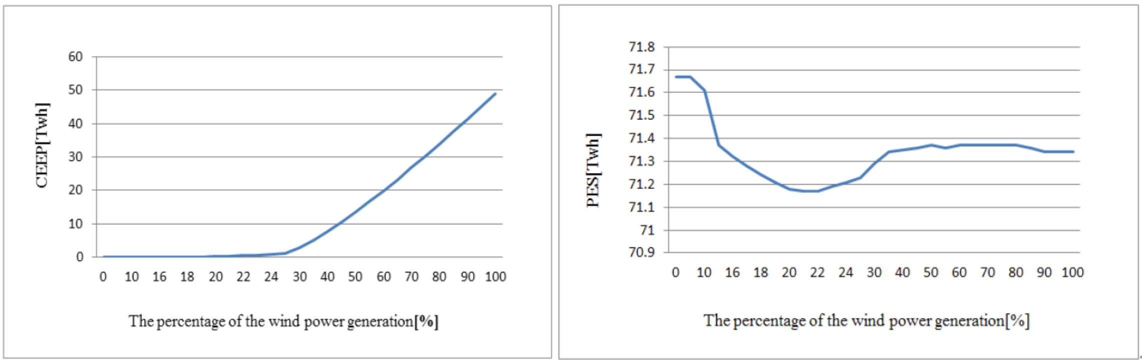
Power generation	PP	CHP	RES	Water
Simulated Value[TWh]	32.5	2.64	0.56	0.40
Actual Value[TWh]	32.47	2.63	0.40	0.44

After these comparisons, there are small differences between actual value and simulated value. It can be concluded that the model can simulate Beijing's energy system in 2012 correctly. Therefore the model can be used to simulate the wind power penetration proportion in Beijing energy system.

Optimization Analysis

Changes in the proportion of renewable energy will cause corresponding changes in the other two variables--Critical Excess Electricity Production (CEEP) and Primary Energy Supply (PES) in the model. Given that the total electricity demand of Beijing in 2012 was 91.19 TWh, we calculate the amount of wind power penetration from 0% to 100%.

As shown in Figure 1a, with the increase of wind power penetration amount, the CEEP is gradually on the rise. It starts to increase at 16%. When the penetration amount accounts for 100%, the CEEP accounts for 54% of the total electricity generation, namely 49TWh. With the increase of penetration amount, the number of CEEP increases accordingly. Therefore the local power station needs to output the electricity or to close the wind power generator.



a b

Fig. 1 CEEP and PES in different wind penetration proportion

Figure 1b shows the changing process of PES. The lowest point is 22% and the PES is 71.17TWh. This curve illustrates the process that the energy efficiency is improved. With the increase of the amount of renewable energy penetration, fossil fuel inputs have been reduced. However when the CEEP continuously increases, the energy efficiency is gradually reduced. At the same time, in order to determine the optimal amount of wind power penetration we need comprehensive consideration of the effects of CEEP and PES Thus we use the coefficient (COMP) to illustrate the combined effects of the increase of wind power penetration.

$$COMP=-\Delta PES/\Delta CEEP \quad (1)$$

ΔPES shows the reduction of PES, ΔCEEP shows the increase of CEEP. When COMP is 1, the wind power penetration reaches the highest point. When COMP is less than 1, it means that the increase of CEEP is more than the reduction of PES--thus the wind power should not be integrated to the system; When COMP is greater than 1, it means that the increase of CEEP is less than the reduction of PES, thus the wind power should be integrated to the energy system.

When the wind power penetration proportion increases from 17% to 18%, the CEEP increases 0.04 TWh and the PES decreases by 0.04 TWh. When the penetration proportion is greater than 18%, the increase of wind power investment has exceeded the fuel cost savings. Therefore we make conclusion that the maximum wind power penetration proportion of the energy system in Beijing in 2012 is 18%.

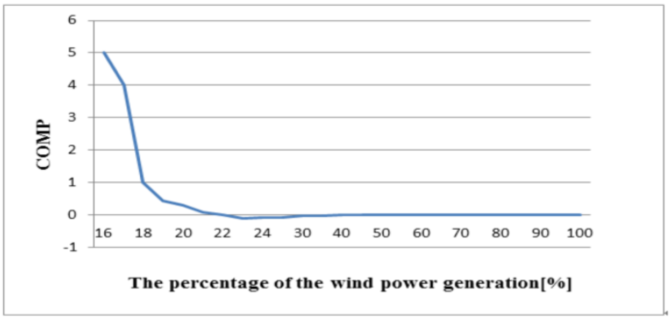


Fig.2 COMP variation tendencies in different wind power penetration proportion

Policy Implication

1) Strengthen policy guidance and support scientific researches. The state needs to make practicable plans and guidance regarding to the regional development of renewable energy. At the same time, the state should increase its efforts for scientific researches and researchers in renewable energy, speed up technology innovation in wind power and explore the resource advantages of wind power in Beijing.

2) Refine the power grid construction and invest on supporting facilities. The state should increase investments on power grid construction, so that the electrical generation from wind power can be utilized in the nearest region. The wasted wind power in other provinces can be integrated in the grid. In areas with rich wind power resources far from Beijing, the state should invest on supporting facilities and relocate the high power consumption enterprise in these areas, so as to match the supply and demand.

3) Optimize the energy structure in phases and develop complementary advantages, gradually balance the interests of all parties. At the earlier stage, the government needs to establish policies to increase supports for wind power industry through low tax, price regulation, so as to improve the competitiveness of wind power in electricity market. Next, the state should refine and upgrade the complementary supporting grid for renewable energy according to its penetration proportion, and ensure the security and stability of the grid. At last, the market structure of electricity should be changed into free competition.

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