Renewable and Sustainable Energy Reviews 72 (2017) 950–960

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Hybrid pluripotent coupling system with wind and photovoltaic-hydrogen energy storage and the coal chemical industry in Hami, Xinjiang

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ARTICLE INFO

Keywords:
Hybrid pluripotent coupling system
Wind power
Photovoltaic
Hydrogen energy storage
Coal chemical industry

ABSTRACT

Hami in Xinjiang is one of China's comprehensive energy bases. However, in recent years, this region has been plagued by some problems affecting the development of the energy industry. For example, wind and solar power generation is facing serious curtailment. The region is also characterized by significant pollution because of the coal chemical industry. Hydrogen energy storage has wide application potential and has become a hot research topic in the field. Building a hybrid pluripotent coupling system with wind power, photovoltaic (PV) power, and hydrogen energy storage for the coal chemical industry is an effective way to solve the above-mentioned problems. In this paper, a hybrid multi-energy coupling system is established, which includes a wind energy and PV complementary system, power distribution system, hydrogen energy storage system, gas distribution system, coal chemical industry system, waste heat utilization system, and methanol, O_2, and H_2 hybrid power generation system. Based on the wind and solar energy resources in Hami, the optimization model of the wind and solar power system is established. The hydrogen energy storage system model is obtained using energetic macroscopic representation. Finally, the economic performance of the system is studied. Results show that the integrated system of wind power, solar power, PV power, and hydrogen energy storage for the coal chemical industry can meet the current situation of China's energy development. The system can also make full use of new energy sources, such as wind power, PV energy, and other forms of energy, thereby reducing the environmental pollution caused by the coal chemical industry and minimizing the industry's ecological impact. In addition, hydrogen energy storage can also be applied to the new energy automotive industry. The findings of this study are of great strategic significance to China's energy system.

1. Introduction

Xinjiang is located in the northwest of China. With an area of 1.66×10^6 km^2, Xinjiang is the largest province in the country. It is characterized by varied surface topography and abundant energy resources. Xinjiang is listed as one of the five comprehensive strategic energy bases in China. Its abundant fossil fuel reserves of coal, oil, and natural gas ranked third in the country, and its renewable energy resources, including wind energy and solar energy, are among the highest in China. In 2006, the National Development and Reform Commission identified the three major oil fields in Xinjiang. In 2010, Xinjiang was listed among the nine wind power bases in China. In 2013, it was ranked as the fourteenth largest coal base in the country. In 2014, the national development strategy, called *The Belt and the Road*, was implemented in China, and Xinjiang was named as one of its core areas. A clear path toward the development of the energy industry in Xinjiang has been established in the Central Xinjiang Development Forum as “three bases and one channel.” In particular, “three bases” refer to the large coal, oil/gas, and wind power bases, whereas “one channel” denotes the national land energy channel [1–3].

To achieve clean and sustainable development of the energy industry in Xinjiang, the state places considerable importance to the development of wind energy and solar energy in Xinjiang. It supports the wind farm construction in Hami and Dabancheng, as well as promotes the development of a national large-scale wind power base in Xinjiang [4–6]. The development of wind power in Xinjiang has been progressing rapidly since 2009. In 2013, the installed capacity of wind power grids has overtaken that of hydropower. By 2014, the grid capacity of wind power ranked first among potential renewable energy sources in Xinjiang, as shown in Fig. 1.

In 2014, cumulative power generation in Xinjiang exhibited an increase of 30.16%. Wind power generation capacity (135.47 kW h) accounted for 6.89% of the total power generation, as shown in Fig. 2. The proportion of wind power in the total power generation of Xinjiang

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http://dx.doi.org/10.1016/j.rser.2017.01.085
Received 1 November 2015; Received in revised form 5 December 2016; Accepted 15 January 2017
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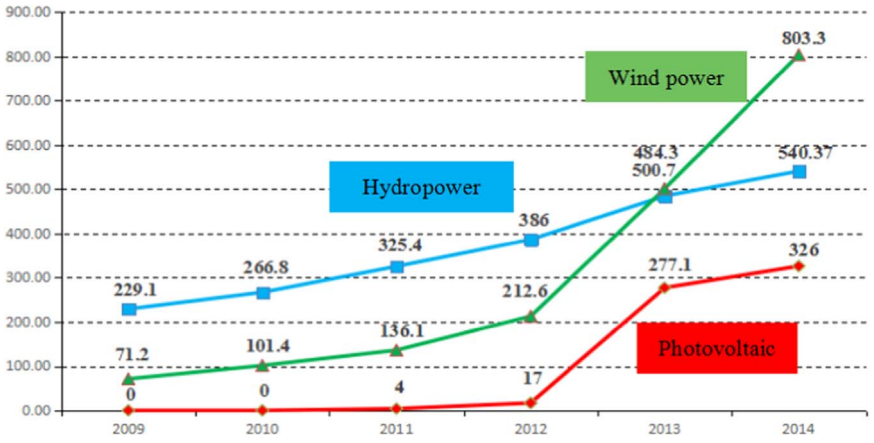


Fig. 1. Situation of renewable energy grids in Xinjiang (2009–2014, 10^4 kW).

has been increasing annually and has maintained a good momentum of development.

As of 2014, the total installed capacity of the power supply in Xinjiang reached 55,486 MW. Among which, the installed capacity of wind power reached 8030 MW, accounting for 14.47%. The structure of the power assembly machine capacity in Xinjiang is shown in Fig. 3 [7,8].

As shown in Fig. 3, the capacity of new energy grids in Xinjiang accounted for nearly 30%, with wind power garnering the highest proportion at 14.47%. The installed capacity of wind power in Xinjiang from 2010 to 2014 is presented in Fig. 4 [9,10].

Xinjiang solar energy resources are very rich, the annual sunshine time number is 2550–3500 h, the percentage of sunshine is 60–80%, the annual total radiation 5000–6670 MJ/m^2, ranking second in the country, second only to the Tibetan Plateau, the specific distribution and the reserves are shown in Table 1.

Hami, the east gate of Xinjiang, is the throat of Silk Road. This region is rich is energy resources. Hami is one of China's five largest integrated energy supply bases, where coal and wind energy resources account for 12.5% and 1/20 of the country's supply, respectively. Moreover, among the regions in Xinjiang, the annual total solar radiation ranks first in Hami. “Rapid development of wind power, photovoltaic (PV) power, and coal into electricity” is the energy industry structure in Hami. Hami's new energy industry has rapidly developed in recent years. Toward the end of July in 2015, the total installed capacity of wind power in Hami reached 3,869,000 kW, whereas the total installed capacity of PV power was 670,000 kW.

However, in the past two years, the phenomenon of wind power and PV curtailment has become highly serious in Xinjiang [11]. In 2015, Xinjiang wind power generating capacity was 148 billion kW h, wind power curtailment reached 71 billion kW h, abandoned wind rate was the highest 31.84%, in 2011–2015 Xinjiang abandoned wind curtail-

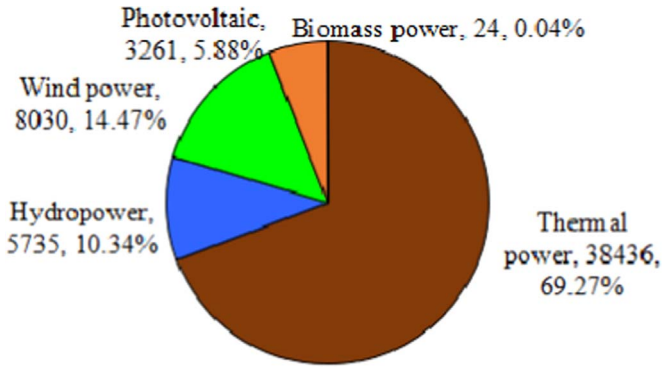
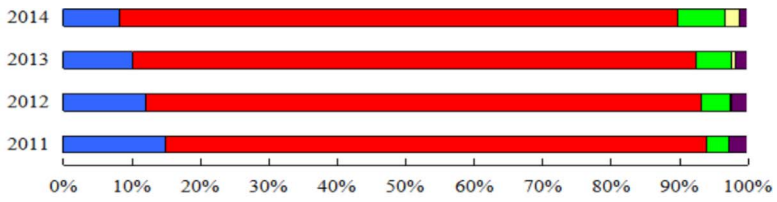


Fig. 3. Structure of the total installed capacity (MW) of grid connections in Xinjiang in 2014.

ment is shown in Table 2. Xinjiang photovoltaic power generation was 46 billion kW h in 2015, abandoned PV reached 15.1 billion kW h, abandoned PV rate was the highest 24.8% [12,13]. The Hami area is the focus of the wind power and PV curtailment in 2015, the amount of wind power curtailment reached up 31.26 billion kW h, accounting for 43.97% of the total amount of Xinjiang curtailment. Energy curtailment is due to two main reasons: (1) affected by the decline in the economy, Xinjiang's electric power market space is relatively small, with a high proportion of corporate-owned power plants crowding out the public market, resulting in limited power consumptive capacity; and (2) the influence of supporting transmission project construction lag [14–16].

Therefore, under the conditions of the existing Hami regional power grid, making use of the region's wind and solar energy and improving the levels of wind and PV power to reduce wind waste, light waste, and coal chemical pollution are very urgent problems that need



	2011	2012	2013	2014
Hydropower	14.94	11.95	10.17	8.21
Thermal power	78.94	81.17	82.29	81.47
Wind power	3.34	4.26	5.17	6.89
Photovoltaic	0	0.13	0.49	2.05
Others	2.78	2.48	1.89	1.38

Fig. 2. Power generation situation in Xinjiang (2011–2014).