2024 Volume 2, Issue 1

Progress of Electrical and Electronic Engineering

ISSN: 2630-4643

The Current Status and Prospect of Geothermal Power Generation in China under the Goal of Carbon Neutrality

Zhen Wang[1], Binbin Peng[2], Zixiang Li[3]*, Yajun Wang[2], Zhen Chen[1], Baosheng Diao[1]

[1]Taizhou Power Generation Co., Ltd. of CHN Energy, Taizhou 225327, Jiangsu Province, China

[2]East China Electric Power Design Institute Co., Ltd. of China Power Engineering Consulting Group, Shanghai 200063, China

[3]School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

***Corresponding author:** Zixiang Li, 21558316@qq.com

Abstract:

Building a new power system with new energy as the main body is an important way to achieve the goal of carbon neutrality in China. Geothermal resources are clean and renewable energy, with rich reserves and wide distribution, and the carbon emission coefficient of geothermal power generation is far lower than that in the process of thermal power generation, which should play an important role in the process of carbon neutrality. However, China is rich in geothermal resources, but the development of the geothermal power generation industry is extremely slow. To promote its development, this paper first reviews the development status of geothermal power generation in China, then analyzes the main factors restricting its development, and finally discusses the development direction of geothermal power generation in China under the carbon neutral goal.

Keywords:

Geothermal resource
Geothermal power generation
Limiting factor
Development direction

Online publication: June 28, 2024

1. Introduction

Since the advent of the electrical era, substantial fossil fuel resources have been used for thermal power generation to support rapid socioeconomic development. However, the massive consumption of fossil fuels has led to severe environmental issues, most notably global warming due to CO_2 emissions. In response, countries worldwide have committed to achieving carbon neutrality, and building a new energy-based power system has become a primary pathway for carbon reduction efforts.

Geothermal resources, derived from the Earth's interior, have a vast, widely distributed supply, and the carbon emission factor for power generation from geothermal energy is significantly lower than that of coal-, gas-, or oil-based thermal power. This makes geothermal energy an ideal renewable and clean energy source. Although China possesses abundant geothermal resources, the development of geothermal power generation has been slow, lagging behind other geothermal-rich countries. For instance, while China's geothermal resources are comparable to those of the United States, its installed geothermal power capacity is less than 1.5% of that of the U.S.

This article reviews China's geothermal resource endowment and current utilization status, analyzes the main factors restricting the development of the geothermal power industry, and explores the direction for geothermal power development under the carbon neutrality goal. This analysis aims to provide guidance for the accelerated development of geothermal power in China and enable it to play a more significant role in the nation's carbon neutrality journey.

2. China's geothermal resource endowment and utilization status

2.1. Geothermal resource classification

Geothermal energy is a natural energy source originating from high-temperature molten rock and radioactive decay within the Earth's interior [1]. Geothermal resources refer to the heat contained in water, steam, and rock within certain depths from the Earth's surface (< 10 km) that can be economically developed given current technological and geological conditions. As shown in **Figure 1**, geothermal resources can be categorized based on their storage form, depth, and temperature range as follows:

(1) Shallow geothermal: Low-temperature geothermal resources with temperatures not exceeding 25°C, primarily used directly for heating and cooling processes.

(2) Hydrothermal geothermal: Medium- to high-temperature geothermal resources with temperatures ranging from 25°C to 200°C, which can be used directly or for power generation.

(3) Hot dry rock (HDR) geothermal: Heat contained in high-temperature rock masses located deep underground with little or no fluid content, which is currently challenging to exploit.

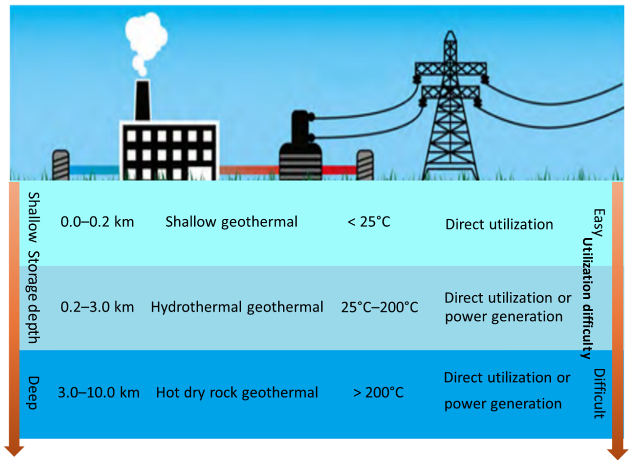

Figure 1. Classification of geothermal resources

2.2. Geothermal resource endowment and distribution in China

Located on the eastern Eurasian Plate and adjacent to the Indian Ocean and Pacific Plates, China has abundant geothermal resources, accounting for about 8.0% of the global total [2]. It is estimated that the geothermal resource reserves within 10 km of the Earth's surface in mainland China are equivalent to approximately 860 trillion tons of standard coal [3]. Based on current technology, the exploitable geothermal resource volume is more than 3,500 times China's total primary energy consumption in 2021 [4]. However, most geothermal resources that can be exploited in China are shallow geothermal and hydrothermal types, while HDR geothermal is rarely utilized due to high development difficulty.

The distribution of geothermal resources in China shows distinct regional characteristics. For instance, Tibet, Sichuan, and Yunnan, as well as the coastal regions of Fujian and Guangdong, are rich in geothermal resources, predominantly high-temperature geothermal sources [5]. In contrast, the geothermal resources in China's northwest are relatively sparse. Additionally, significant amounts of medium- and low-temperature geothermal resources exist in basins and plains within inland China, such as the North China Plain, Huai River Plain, and Fen-Wei Basin, offering substantial development potential [6]. See **Figure 2** for more details.

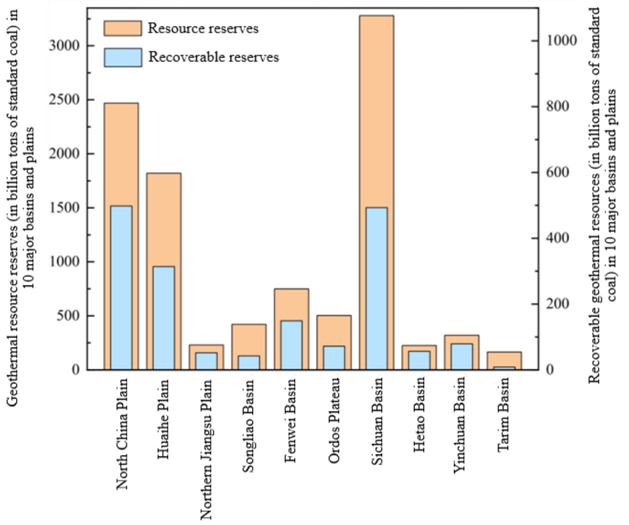

Figure 2. Geothermal resource reserves in China's 10 major basins and plains

2.3. Geothermal resource development and utilization in China

Geothermal resources have a wide range of applications, including direct use for heating and cooling, agriculture, aquaculture, spa and health purposes, as well as power generation. China began utilizing geothermal resources for direct applications early on, and in recent years, with the advancement of heat pump technology, large amounts of shallow and hydrothermal geothermal resources have been used for building heating and cooling. China's installed capacity for direct geothermal use now exceeds 40.6 GW, maintaining a global lead for several years [7]. In contrast, geothermal power generation in China developed later and at a slower pace. The estimated potential for power generation from high-temperature geothermal resources in southwest China alone is as high as 7 GW [8]. However, the current installed capacity of geothermal power in China is less than 60 MW. Despite holding nearly 8.0% of the world's geothermal resources, China's installed geothermal power capacity is less than 0.4% of the global total [2], far behind countries like the United States, Australia, and Japan.

3. Current status of geothermal power generation in China

3.1. Development history of geothermal power generation in China

China's utilization of geothermal resources for power generation has a history of over half a century. In 1970, the operation of the 86 kW geothermal power station in Tangxi, Fengshun, Guangdong, made China the eighth country in the world to successfully use geothermal energy for power generation [9]. Subsequently, several small- and medium-temperature geothermal power stations were built across China. However, most were shut down due to poor economic performance. In 1977, the completion of a 1 MW high-temperature geothermal power unit at the Yangbajing Geothermal Power Station in Tibet marked a short period of rapid growth for geothermal power generation in China. During this period, several megawatt-level geothermal power stations were constructed in Tibet, with Yangbajing alone achieving an installed capacity of over 24 MW.

Despite this early development, China's geothermal power industry has since stagnated, with installed capacity remaining around 26 MW. Other than the commissioning of a single 16 MW high-temperature geothermal unit at the Yangyi Geothermal Power Station in Tibet in 2019, few new units have been commissioned and consistently operated. As a result, the target of adding 500 MW of geothermal power capacity outlined in the "13th Five-Year Plan for Geothermal Energy Development and Utilization" remains far from being met.

3.2. Issues limiting the rapid development of geothermal power generation in China

Although China possesses abundant geothermal resources and has conducted geothermal research for over five decades, the geothermal power industry has developed slowly. This slow progress is due to unresolved issues related to policy, financial support, infrastructure, talent, and technology.

3.2.1. Lack of policy and financial support

Compared to other renewable energy sources like wind and solar power, geothermal power generation requires high investment, involves considerable risk, and has a long payback period. However, China has yet to introduce specific policies or regulations for geothermal power, and the importance of geothermal energy is not clearly established. Additionally, geothermal power is not eligible for grid connection subsidies, further diminishing its economic viability. Consequently, investment enthusiasm and confidence among relevant companies are lacking.

3.2.2. Delayed resource exploration and infrastructure development

Accurate knowledge of geothermal resource locations and thermal reservoir characteristics is essential for building geothermal power stations. However, no nationwide geothermal resource exploration project has been conducted in China. If geothermal power companies were to undertake this exploration themselves, their investment costs would significantly increase. Furthermore, China currently lacks a national comprehensive platform for geothermal resource development and utilization, leaving the industry without guidance on technology development and strategic planning. This has slowed the growth of the geothermal power industry.

3.2.3. Insufficient capacity for independent technological innovation

Geothermal power generation is a technology-intensive industry, and market competitiveness depends on independent innovation. However, most universities in China have not established dedicated geothermal studies programs, leading to a shortage of skilled professionals. Additionally, geothermal technology development requires significant human and financial resources, but investment in geothermal technology remains relatively low, hindering breakthroughs in independent innovation.

3.2.4. Inadequate regulatory and supervisory mechanisms

The healthy development of the geothermal power industry requires a sound regulatory framework to prevent excessive, unregulated exploitation of geothermal resources. However, there are issues in China's geothermal resource development process, including the absence of specific laws, unclear authority assignments, and overlapping enforcement by different entities. This has led to disorderly and chaotic development in some regions. Large-scale, unregulated geothermal exploitation not only wastes resources but also causes severe environmental pollution.

4. Development path of geothermal power generation in China under the carbon neutrality goal

4.1. Short-term: efficient power generation from hydrothermal geothermal resources

In the near term, China's geothermal power generation efforts should focus on maximizing the efficient utilization of mid- and high-temperature hydrothermal geothermal resources for power generation. Drawing from China's existing geothermal power experience, hydrothermal geothermal resources can be harnessed efficiently in two main ways.

First, geothermal resources can be coupled with other renewable energy sources for power generation. For instance, hybrid systems such as solar-geothermal or biomass-geothermal power plants can not only improve the efficiency and capacity of geothermal power stations but also allow additional use of other renewable energy sources, reducing the operational load on geothermal units and thus extending the lifespan of geothermal facilities. Second, a cascading utilization model for the residual energy post-geothermal power generation should be developed. Typically, the discharge water from geothermal power generation remains at high temperatures, and direct reinjection of this water leads to wasted resources. Therefore, this high-temperature discharge water can be repurposed for industrial, agricultural, and residential uses, enhancing the overall efficiency of geothermal energy utilization.

4.2. Medium-term: Low-temperature geothermal power generation technology

In the medium term, the focus of China's geothermal power industry should be on developing and refining low-temperature geothermal power generation technology. China possesses abundant low- and medium-temperature geothermal resources; however, these resources are mainly used in low-efficiency applications, such as hot spring resorts and building heating/cooling systems, with minimal usage in power generation. The low-temperature (67°C) geothermal power station established in Yichun, Jiangxi, in 1971, though no longer operational, demonstrated the feasibility of using low-temperature geothermal resources for power generation in China.

Recent advances in Kalina cycle power generation technology have provided a promising direction for low-temperature geothermal power in China. The Kalina cycle can modify the boiling point of a working fluid by adjusting the ammonia-water mixture, allowing it to better match the heat release characteristics of low-temperature geothermal water [10], thereby significantly improving the cycle's power generation efficiency. Therefore, China should actively promote the development of Kalina cycle power generation technology to facilitate efficient power generation from low-temperature geothermal resources.

4.3. Long-term: enhanced geothermal systems for hot dry rock utilization

In the long term, developing and refining power generation technology for HDR resources is paramount for the growth of China's geothermal power industry. China's HDR resources are extremely abundant, with a power generation potential far exceeding that of hydrothermal geothermal resources and offering higher efficiency. If HDR technology matures, and considering that its generation cost would be approximately 3 to 4 times that of wind power, HDR-based power could become economically competitive, with costs close to wind and well below solar.

Currently, China's HDR power generation is still in the exploratory stage, with only a few experimental units in operation, and no large-scale HDR plants connected to the grid. Although some countries have engaged in long-term research on HDR power generation, significant breakthroughs remain elusive. Given China's vast HDR potential, efforts should be accelerated to establish a strategic layout and achieve key breakthroughs in site selection, high-temperature drilling, fracture stimulation, reservoir construction, micro-seismic monitoring, and efficient heat exchange technologies for HDR plants. At the same time, measures must be taken to address high investment costs, substantial risks, and long payback periods associated with HDR power generation projects.

5. Conclusion

China has abundant geothermal resources and significant potential for power generation. In the future, geothermal power should play a critical role in the new energy-dominated power system. However, China's installed geothermal power capacity currently lags far behind other countries. To promote the healthy development of the geothermal power industry, efforts must be coordinated among the government, universities/research institutes, and enterprise users to seamlessly integrate resources, technology, and the market. As technologies for efficient hydrothermal geothermal power generation, low-temperature geothermal power generation, and dry hot rock power generation advance, geothermal power will undoubtedly contribute significantly to China's carbon neutrality goals.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Zhang S, Miao S, Yin B, et al., 2022, Economic Analysis of Multi-Type Energy Storage Considering Deep Peak Regulation in Thermal Power Plants. Electric Power Construction, 43(1): 132–142.

[2] Zhu J, Hu K, Lu X, et al., 2015, A Review of Geothermal Energy Resources, Development, and Applications in China: Current Status and Prospects. Energy, 93(Part 1): 466–483. https://doi.org/10.1016/j.energy.2015.08.098

[3] Wang G, Lu C, 2022, Progress in Geothermal Resource Extraction and Utilization Technology Driven by Carbon Neutrality Goals. Geology and Resources, 31(3): 412–425 + 341.

[4] BP, 2022, BP Statistical Review of World Energy 2022, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf

[5] Wang G, Zhang W, Ma F, et al., 2018, Overview on Hydrothermal and Hot Dry Rock Researches in China. China Geology,

1(2): 273–285. https://doi.org/10.31035/cg2018021

[6] Zhang L, Chen S, Zhang C, 2019, Geothermal Power Generation in China: Status and Prospects. Energy Science & Engineering, 7(5): 1428–1450. https://doi.org/10.1002/ese3.365

[7] Liu Y, Wang G, Zhu X, et al., 2019, Occurrence of Geothermal Resources and Prospects for Exploration and Development in China. Energy Exploration & Exploitation, 39(2): 536–552. https://doi.org/10.1177/0144598719895820

[8] Jia Y, Chang Q, Wang Y, et al., 2021, Current Status of Geothermal Energy Development and Utilization in China and Development Trends Under the Dual Carbon Background. Green and Low-Carbon Oil & Gas, 6(6): 5–9.

[9] Chen C, Xu X, 2015, Global Geothermal Power Generation Status and Prospects. Solar Energy, 2015(1): 6–10.

[10] Xu Y, Wang M, Pan J, et al., 2012, Characteristics and Development Direction of Geothermal Resource Power Generation Technology. Energy from Home and Abroad, 17(7): 29–34.