

Development Status of Nuclear Power in China and the World

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Abstract

This paper introduces the development status of international nuclear power and China's nuclear power, and analyzes the development trend of global nuclear power. The current situation of nuclear power development in the United States, Russia, France, Germany, The United Kingdom, Ukraine, Japan, South Korea, India, and China was compared by country comparison to analyze the deficiencies and existing problems in the current development of China's nuclear power industry.

Keywords

Nuclear power, development status, country comparison, China.

1. Introduction

Nuclear power started in the 1950s. Compared with traditional energy forms, nuclear power has the attributes of low carbon, clean, high efficiency and low operating costs [1]. It is the only energy form that can replace fossil energy on a large scale at present. Nuclear power avoids the disadvantages of traditional fossil fuels and renewable energy. On the one hand, nuclear power does not need to add fuel frequently and does not release greenhouse gases in the process of generating electricity. On the other hand, nuclear power is basically unaffected by the natural environment and has strong peak-regulating capacity. Actively developing nuclear power is an inevitable choice to achieve sustainable development of energy and power [2].

This paper uses the method of country comparison to analyze the development trend of my country's nuclear power industry by comparing international nuclear power construction with the status quo of China's nuclear power.

2. Development Status in the World

According to the statistics of the International Atomic Energy Agency (IAEA), as of the end of June 2019, a total of 449 units were in operation worldwide, distributed in 30 countries, with a total installed capacity of nearly 400 million kilowatts, and another 54 units are under construction, with an installed capacity of approximately 55 million kilowatts^[3]. The annual report of the World Nuclear Association shows that in 2018 global nuclear power generation exceeded 250 billion kWh, accounting for 10.5% of the global electricity supply. Thus, the scale of nuclear power in the world is still expanding year by year. But countries around the world have two diametrically opposed views on the development of nuclear power.

2.1. United States

The United States currently has 97 units in operation, and two AP1000 units are under construction. For a long time, the proportion of nuclear power generation in the United States has remained at around 20%, and the proportion of nuclear power generation in 2018 was 19.32% [3]. Since the 1990s, the United States has upgraded and increased its power generation capacity, which is equivalent to building 6-8 million-level nuclear power plants. The US is

constantly improving the operating level of nuclear power, and the effective utilization of nuclear energy is extremely good, and it still maintains a leading position in nuclear power. However, the United States has adopted a series of external protection policies. For example, in 2018, it released a new version of the "Nuclear Situation Report", which regarded China and Russia as strategic competitors and adopted a series of nuclear power export restrictions [4]. This move is ostensibly to protect the development of nuclear power industry in the United States, but in fact is an obstacle to the common development of nuclear power worldwide.

2.2. Russia

Based on the exploration of nuclear power in the former Soviet Union, Russia has historical advantages in nuclear power industry. Since the beginning of the 21st century, Russia's nuclear power industry has been in a stage of rapid development, with an average annual nuclear power growth rate of up to 2.4%. Currently, Russia has 35 units in operation, with another six under construction. In 2018, nuclear power accounted for nearly 18% [5]. Moreover, Russia attaches great importance to the global strategic layout of nuclear power and provides special loans for nuclear power construction of other countries to fund the development of nuclear power industry in other countries. Russia's nuclear exports now account for most of the world's emerging markets, with a reported order book of nearly 40 units.

2.3. France

France is currently the country with the highest utilization rate of nuclear power. Currently, it operates 58 nuclear power units and one EPR unit is under construction. For many years, its nuclear power generation ratio has been around 75%. After the Fukushima nuclear leakage event, the French government repeatedly said that it would reduce the proportion of nuclear power as soon as possible and ensure energy security by using renewable energy. However, renewable energy cannot replace nuclear power to provide sufficient and low-cost electricity to maintain the normal operation of French society. Therefore, in the future energy planning, France plans to develop a large number of low-carbon energy sources including nuclear energy and renewable energy. In 2035, the nuclear power generation scale will remain around 50% [6]. It can be seen that France's nuclear power still has development prospects in the short term, but in the long run, France will certainly embark on the road of denuclearization.

2.4. Germany

Germany is one of the countries that support denuclearization. There are 7 units in operation in Germany. According to the shutdown plan, two units will be shut down this year, three units will be shut down in 2022, and the last one will be shut down in 2022^[2].

2.5. United Kingdom

Unlike France, Germany and other countries that support denuclearization, Britain has a positive attitude towards nuclear power development. The UK already has 15 nuclear reactors in operation. Nuclear power accounts for 19% of the country's electricity generation and is the country's main source of low-carbon electricity [7]. But Britain's nuclear industry is facing the fallout from Brexit. In the past, most of Britain's nuclear plants imported nuclear material from the European Union, which also conducted safeguards inspections. After Brexit, the UK needs to make up for the lack of talents in nuclear safeguards to meet the IAEA and re-sign nuclear cooperation agreements with other countries. Therefore, the UK needs to take more effective measures to deal with the impact of the current political changes.

2.6. Ukraine

The Chernobyl nuclear accident occurred in Soviet Ukraine in April 1986, and was permanently sealed after the accident. At present, Ukraine's main source of energy is still nuclear power. It

has four nuclear power plants with 15 units in operation and an installed capacity of 1,3835MW. In 2017, nuclear power accounted for over 55% of the total [3].

2.7. Japan

As the first country in Asia to explore nuclear power, Japan had 54 nuclear power plants before the Fukushima disaster in 2011, accounting for about 10 percent of the world's electricity. But the Fukushima nuclear accident forced Japan to shut down most of its nuclear power plants, and Japan's nuclear power industry was hit hard. In recent years, Nuclear power in Japan has been gradually restarted due to concerns about long-term energy supply stability. At present, Japan has eight nuclear power units in operation, 15 nuclear power units have passed the safety review of the Nuclear Force Rules Commission, and the plan is to achieve nuclear power generation of 20-30% of the country's total electricity by 2030[8]. Internationally, Japan has been actively resuming nuclear power trade cooperation and has successfully drawn up nuclear power construction plans with Turkey, Britain, and other countries. But many obstacles still stand in the way of Japan's nuclear restart. On the one hand, it is influenced by the anti-nuclear voice of the domestic people; on the other hand, it faces competition from Russia, China, and other new nuclear power countries in the international trade market.

2.8. South Korea

South Korea's nuclear power technology was imported from the United States, but after decades of effective digestion, absorption, and innovation, it successfully developed its own three-generation technology APR1400, and the first unit was put into operation in 2016. With its own three-generation technology, South Korea won an order for the first batch of 4 units from the UAE and started construction in 2012. South Korea currently has 25 nuclear power units in operation and 4 units are under construction. In 2018, nuclear power generation accounted for nearly 24% [7]. After the Fukushima accident, with the increasing domestic anti-nuclear forces, government departments are adjusting the original relatively large nuclear power plan, but nuclear power as an important clean and low-carbon energy source will still occupy an important position in its energy structure.

2.9. India

As one of the emerging countries in Asia, India has experienced rapid economic development in recent years and its electricity demand has also increased. Due to the energy structure of oil and gas shortage, India has always been committed to the development of new energy sources such as nuclear power to reduce its dependence on external energy. At present, India has 22 units in operation and 7 units under construction. The proportion of nuclear power is not high, remaining at about 3.2% [3, 6]. The main energy source is still fossil energy. Nuclear power in India started early and India has nuclear power design and construction capabilities, but its nuclear power unit capacity is relatively small. In recent years, India has cooperated with Russia to build a million-kilowatt nuclear power unit, and some units have been put into operation. India's nuclear power industry is in a stage of rapid growth, and the scale of nuclear power is rapidly expanding.

3. Development Status in China and International Comparison

3.1. Development Status in China

As of June 30, 2019, China has 47 nuclear power units in operation in 8 coastal provinces and regions, including Zhejiang, Guangdong, Fujian, Jiangsu, Liaoning, Shandong, Guangxi, and Hainan, and 13 nuclear power bases, with an installed capacity of 48.73 million kW[9]. Eleven units are under construction, with an installed capacity of 11.34 million kW, which has been the world's largest for many years. According to the statistical report of the China Nuclear Energy

Industry Association, in 2018, there were 44 commercial nuclear power units on the Chinese mainland with a total installed capacity of 44,645,516 kW, accounting for 2.35 percent of the country's total installed power capacity. The annual nuclear power generation was 286.511 billion kWh, accounting for 4.22 percent of China's cumulative power generation. The average utilization hours of nuclear power equipment were 7,499.22 hours, and the average utilization rate of equipment was 85.61 percent. Compared with coal-fired power generation, nuclear power generation is equivalent to reducing the combustion of 88.2454 million tons of standard coal, 231.2029 million tons of carbon dioxide, 751,0100 tons of sulfur dioxide, and 653,000 tons of nitrogen oxide [3].

China's nuclear power industry has obvious advantages as a latecomer and has made remarkable achievements in many fields. After more than 30 years of continuous development, China's nuclear power industry has grown from scratch and from small to large. For a long time, China's nuclear power safety operation has maintained good performance. According to the comprehensive index statistics of the World Nuclear Power Operation Association (WANO), in the past 27 years, 55 or 7 nuclear power units around the world have scored A full score of 1.0, and China has 11. In 2012, 53 units worldwide received a full score of 100, including 12 units in China. China is one of the few countries in the world with a complete nuclear fuel cycle system [10, 11]. For decades, China has not stopped its nuclear power construction, and its accumulated nuclear power construction capacity ranks among the top in the world.

Due to the short history of nuclear power development in China, there are still some areas to be improved. At present, China's nuclear power plants are distributed in coastal areas, although the inland nuclear power plants have been put on the agenda, there has been no substantive progress. With the further development of China's inland economy, the electricity demand also increases significantly, so the construction of inland nuclear power plants is in urgent need.

3.2. International Comparison

In terms of the utilization of nuclear power, the proportion of nuclear power generation in China is only 4.1%, far lower than that of the United States, France, Russia, and other countries, and higher than That of Japan, which is restarting nuclear power. However, China's coal power generation accounts for 64.7% of total energy consumption in 2019, far higher than that of other nuclear power countries (Table 1[12]). This means that although China's nuclear power generation scale ranks in 5th the world, compared with China's huge demand for electricity, nuclear power, and other new energy norms are not enough to support the optimization of China's energy consumption structure.

Table 1. Proportion of nuclear power generation in various countries

	Year	China	US	Russia	UK	Germany	Japan
Nuclear power	2018	4.1	19.1	18.4	19.6	11.8	4.6
	2019	4.6	19.4	18.7	17.4	12.3	6.3
Coal	2018	66.5	28	17.2	5	35.5	30.6
	2019	64.7	23.9	16.3	2.1	28	31.5

In terms of the development environment, as shown in Table 2[6], the United States, Russia, and China are actively promoting the construction of the nuclear power industry and actively participating in the international nuclear power market. The French and German governments have shown a willingness to do so. On the one hand, France and Germany have small economies and relatively low electricity consumption. In the future, sustainable energy may completely replace nuclear power and realize their own low-carbon energy structure. On the other hand,

it is also because the public in France and Germany are strongly against nuclear power. However, the United States, Russia, and China have a huge economic scale and need to balance the relationship between economic construction and environmental protection by developing nuclear power. Although the Japanese government has been committed to the restart of nuclear power, the local people and local governments hold a firm attitude against nuclear power, which is challenged by other emerging nuclear power countries in the international market. So the path back to nuclear power in Japan will be difficult.

Table 2. Nuclear power development environment in various countries

Country	The domestic environment	Foreign trade environment
China	Strong support Build nuclear power equipment manufacturing bases in Northeast, Sichuan, and Shanghai.	Cooperate with "Belt and Road" countries and developing countries in technology export; Cooperate with Kazakhstan and other countries in uranium mining
US	"Fulfill the nuclear power plan" to reduce costs and increase efficiency; domestic state governments have mixed praise and criticism for nuclear power, and the construction of new nuclear power plants is blocked	Trade cooperation with Japan, India and other countries. Introduced a series of export restrictions and listed China and Russia as strategic competitors
France	Expressed the intention to reduce nuclear power, but due to the constraints of renewable energy technology in the short term, the scale of nuclear power will not be reduced temporarily	Relevant international trade cooperation with many countries such as China and the United Kingdom
Russia	Strong support. Regard nuclear television as a strategic industry.	Established the world's first nuclear fuel bank to provide loans for nuclear power projects. International trade cooperation with many countries
Germany	Denuclearization is expected to be achieved in 2035	None
Japan	The government tried to restart nuclear power plants and restore 20% of nuclear power, but domestic people and local governments opposed strongly	Signed nuclear power trade agreements with Turkey and the United Kingdom, but lost the Vietnamese market and faced challenges from emerging nuclear power countries such as Russia and China in the international market

4. Conclusions

Nuclear power avoids the disadvantages of traditional fossil fuels and renewable energy and is the cheapest and most efficient energy source for generating electricity and reducing carbon emissions. Although nuclear power development faces many challenges such as nuclear safety and public acceptance, and a small number of countries support denuclearization due to nuclear safety and other issues, the vast majority of countries are still developing and building nuclear power [13]. In the long run, with the progress of science and technology and the upgrading of management, nuclear power will become safer and safer. It is foreseeable that nuclear power will be organically combined with clean energy such as hydropower, wind power, and solar energy as well as traditional fossil energy to provide more secure and stable energy supply for human society. The future of nuclear power is closely related to the harmonious development of human society and has a bright future.

Although China's nuclear power has strong comprehensive strength, independent innovation ability and good development environment at home and abroad, compared with other nuclear power countries, China's nuclear power utilization is relatively low and the industrial layout is relatively narrow [6], which means that China's nuclear power industry still has a large space for development.

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