Research on the Countermeasures of China's Nuclear Power Development under the Constraint of Carbon Emission

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Abstract: Due to the Massive Development of Fossil Energy, Serious Ecological and Environmental Damage Has Been Caused, and Clean and Low-Carbonization Have Become the Development Strategies of Countries All over the World. Based on the Advantages of Resources, China Has Formed a Coal-Based Energy Structure. Carbon Emissions Rank First in the World for Many Years. the Pressure of Emission Reduction is Huge, and Energy Transformation is Imminent. in Recent Years, China's Renewable Energy Has Been Greatly Developed, But It is Difficult to Become the Main Energy Source in the Short Term Due to Its Intermittent Nature, Immature Supporting Industries, and Excessive Systemic Economics. as a Clean and Low-Carbon Nuclear Power Has Great Room for Development, But Due to the Fukushima Accident, Nuclear Power Development Has Encountered Unprecedented Difficulties, Especially the Development of New Sites is Very Difficult. This Paper Discusses the Idea of Cluster-Based Development of Nuclear Power.

1. Introduction

This paper starts from the specific quantity of energy development in China and discusses the development mode of nuclear power. It can be seen from the analysis that with the increase of energy demand rigidity, the increase of carbon emission pressure, and the difficulty of meeting renewable energy requirements, nuclear power is an important option for China's energy structure adjustment, and the cluster nuclear power development model is a feasible idea for nuclear power development.

2. China's Energy Development Trend

2.1 China's Energy Development 2030

According to GDP, population, energy consumption, and engineering practice, this paper predicts the development of China's energy in 2030, as shown in Table 1.

Table 1 China's Energy Development Forecast Results Million tons of oil equivalent

years	Total amount	oil	natural gas	coal	Non-fossil
2018	3243.6	640	214.5	1907	482.1
2019	3345.8	651.7	243.4	1927	523.9
2020	3446.1	662.5	273.4	1943.6	567
2021	3544.4	672.3	304.6	1956.5	611.3
2022	3640.1	681.2	336.9	1965.7	656.8
2023	3732.9	689.1	370.1	1971.2	703.2
2024	3822.5	696	404.3	1972.7	750.4
2025	3908.5	701.7	439.2	1970.3	798.4
2026	3990.6	706.3	474.8	1963.9	846.9
2027	4068.4	709.7	510.9	1953.5	895.7
2028	4141.6	712	547.4	1939	944.8
2029	4209.9	713	584.3	1920.6	993.8
2030	4273.1	712.9	621.3	1898.3	1042.7
Compared to the growth rate of 2018	35.2%	11.39%	189.63%	-0.46%	116.28%

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2.2 Installed Capacity Forecast

The author predicts that China's power installed capacity in 2030 is shown in Table 2. According to forecasts, by 2030, the total installed capacity will reach 2.9 billion kW, including 490 million kW of hydropower, 140 million kW of nuclear power, 500 million kW of wind power, and 480 million kW of solar energy. Thermal power will continue to develop at a certain speed of 1.21 billion kW. It is worth noting that some institutions and scholars believe that the economically developable capacity of wind power and solar energy in China is about 300 million kW and 400 million kW respectively. In this case, the 280 million kW capacity of wind and photovoltaic is in need of nuclear power or other forms of supplementation, and the nuclear power capacity is about 0.7 billion kW in terms of equipment utilization of 280 million kW. For thermal power, this paper measures the total coal consumption from 3.9 billion tons to 4.2 billion tons. The small proportion of thermal power is increasing. However, if it continues to maintain the zero state, the incremental part still needs to be replaced by nuclear power, and the nuclear power installed capacity is converted according to the equipment utilization rate. At about 35 million kW, it can be seen that nuclear power installed capacity or demand will reach about 250 million kW. This is basically consistent with the judgment of the Chinese Academy of Engineering predicting the development of nuclear power in China before the 2011 Fukushima nuclear accident.

Table 2 Power Generation Capacity Prediction Model and Results Ten thousand kW

	2018 installed capacity	Power generation growth ratio	2030	Proportion
Total amount	189948	40%	288586	100%
Hydropower	35226	43%	48717	17%
Thermal power	114367	6%	121421	42%
Nuclear	4466	193%	14375	5%
Wind power	18426	262%	50866	18%
Solar energy	17463	262%	48207	17%
Other			5000	2%

3. Analysis on the Development Mode of Nuclear Power

3.1 Developing Nuclear Power is a Strategic Choice for Reducing Emissions

The International Energy Agency's “Nuclear Power in Clean Energy Systems: A Key Source of Low-Carbon Power Generation” points out that nuclear power can make an important contribution to global energy transition. At present, nuclear power is the world's second-largest low-carbon energy source, accounting for 10% of power generation. However, due to various economic and regulatory reasons, the nuclear power plants in service in developed countries have begun to gradually retire at the end of their life, and there are no new nuclear power projects to supplement. In the case of nuclear power generation, there may be a sharp decline, which will seriously threaten energy security and climate control objectives. According to current trends, the installed capacity of nuclear power in developed countries will be reduced by a quarter by 2025 and by two-thirds by 2040, which will increase global carbon emissions by 4 billion tons, exceeding the current 10%.

The goal of the Paris Agreement is to control the global temperature rise to no more than 2 ° C, and strive to control within 1.5 ° C. If this goal is to be achieved, global net greenhouse gas emissions will be achieved by the second half of the century. From the current situation in various countries, it is getting farther and farther away from the target. In 2030, the target CO2 emission of 2 °C will be reduced by 20% compared with the current one, but the current trend will increase by 10%. Therefore, according to the current trend, by the end of the century, the global temperature rise is likely to exceed 3-4 °C, which will bring the earth into the climatic zone that has not entered for millions of years, which will be catastrophic damage to human society. Therefore, all countries in the world must now explore a development path that achieves a win-win situation for economic and social development and carbon emission reduction. Nuclear power is an ideal low-carbon energy source. The IAEA's forecast for nuclear power, under high-value mode, will increase global

nuclear power by 80% by 2050 [1].

3.2 The Importance of Developing Nuclear Power in China

Nuclear energy is a high-tech industry that is a must for the world's major powers. For example, the United States, Russia and other countries, despite sufficient energy, continue to develop nuclear energy in order to maintain competitiveness and sustainable development of the industry. China's nuclear industry system is sound, technology and experience have been globally leading, and nuclear safety is fully guaranteed. The author believes that nuclear power is an important strategic choice in China's energy structure transformation, especially in response to emission reduction pressures. In 2018, compared with coal-fired power generation, nuclear power is equivalent to a reduction of 88.25 million tons of standard coal and a reduction of 231 million tons of carbon dioxide emissions [2].

In the near-term, although the wind power and solar energy industries should develop rapidly at a speed of more than 10%, it is still difficult to meet the growth of power demand. Under the condition that hydropower has been basically capped and thermal power is suddenly braked, nuclear power is an ideal clean energy source. Studies have shown that when the proportion of intermittent energy in the power structure exceeds 30%, it will bring security risks to the grid and increase the cost of electricity supply. Because nuclear power has a high energy density and is a base-load energy source, it is suitable for large-scale rapid development to rapidly increase the proportion of clean energy, which will have a greater impact on the total amount in terms of quantity and proportion [3]. The flexible arrangement of nuclear power bases in the load center can reduce the large cost of power transportation and have a positive impact on the overall social economy, that is, to achieve the combination of energy use in the eastern region from “by side” and “far from the distance”. To improve the power structure and overcome the challenge of large-scale access to renewable energy to the grid, especially in reducing carbon emissions.

Before the Fukushima accident, according to the China Academy of Engineering's “China Energy Medium- and Long-Term Development Strategy Research”, the carbon emission requirements were reversed. By 2035, nuclear power needs to reach 200 million kW, which is basically consistent with the previous analysis in this paper.

3.3 The Basis of China's Nuclear Power Development

Since the beginning of the 1980s, China's nuclear power development has adopted the principle of “taking me as the mainstay and Sino-foreign cooperation” to build nuclear power bases such as Qinshan, Daya Bay and Tianwan. After entering this century, under the guidance of the principle of “actively developing nuclear power”, China has introduced three generations of nuclear power technology through international bidding. It is also the Fukushima nuclear accident that occurred at this stage. China’s nuclear power development has entered a new stage of safe and efficient development. The stage of transformation and upgrading from the second generation to the third generation [4].

After years of development, China's nuclear power is under construction in the world, opening up a complete industrial chain; through continuous innovation and development, mastering the main core technologies, successfully developed the independent three-generation nuclear power technology CAP1400 and Hualong No. 1 and began to go global; He has accumulated a large amount of engineering practice experience and cultivated a talent team of various professions; the level of equipment manufacturing has been greatly improved [5]. All of these have prompted China to become the industrial center for the development of the world's three generations of nuclear power, and are moving from a “nuclear power country” to a “nuclear power powerhouse”.

By the end of 2018, the number of nuclear power units that did not operate in Taiwan Province was 44, with an installed capacity of 44.66 million kW, and 13 nuclear power units under construction, with a total of 57 units, with an installed capacity of 58.678 million kW.

3.4 Thoughts on the Cluster Development of Nuclear Power in China

According to the previous analysis, it is conservatively estimated that there will still be an increase of 100 million kW in nuclear power by 2030, that is, in addition to the current 57 units operating and under construction, 70 to 80 units will be newly started. Focusing on the long-term or taking into account the economically exploitable total of wind and light and coal power restrictions, nuclear power installed capacity will reach 250 million kW, which means that about 140 to 160 units will be added.

At present, there are about 17 nuclear power plants that have been developed in China, which can meet the installed capacity of 100 million kW. If the installed capacity is 150 million kW according to the existing development model, it is necessary to newly develop 6 to 7 nuclear power plant sites, and consider the installation of 250 million kW. , it is necessary to newly develop about 20 nuclear power plant sites. After the Fukushima nuclear accident, the development of nuclear power was greatly affected. The most important issue was the neighboring avoidance effect. It is difficult to obtain support from local people for nuclear power site selection. It is also constrained by tight coastline resources, resulting in difficult site selection and difficulty in project promotion. Big. Therefore, the idea of developing nuclear power needs to be adjusted and the idea of cluster development should be taken.

The cluster development is to expand the existing site in the existing site area and the area where people are highly accepted, and adjust the existing mode of 4 to 6 units. In a relatively large area, where technical conditions are feasible, two or three small sites will be arranged, and in a relatively large area, the installed capacity of the nuclear power base will reach 20 million kW to 30 million kW or higher. To meet the overall capacity needs, this is an important choice to promote the rapid development of nuclear power, optimize energy structure, and quickly achieve emission reduction targets [6]. As shown in Figure 1, the schematic diagram of the cluster nuclear power development project layout, that is, the expansion site developed at a distance of 2.5 kilometers from the existing site.

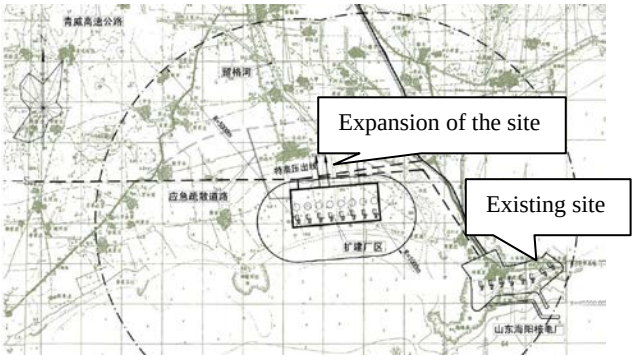

Fig.1 Schematic Diagram of Cluster Nuclear Power Planning

4. Advantages and Problems of Cluster Nuclear Power Development

4.1 Advantage

The advantages of cluster-based development of nuclear power are first of all to improve public acceptance and reduce development difficulty and public costs. The second is to save the site resources. According to the traditional development model, if there are still 20 sites in the coastal area, one is technically difficult, because the choice of nuclear power plant site has strict requirements for earthquake, geology, meteorology, transportation, etc. Second, about 15 kilometers around nuclear power is a planning restricted area, which will restrict the output of coastal economic and social development to a certain extent; the third is to have economies of scale. Mainly some disposable inputs can be allocated to the heap and reduce costs. According to the French construction experience, the unit price of the two units is 15% lower than that of the one unit. The unit price of the four units at the same site is 10% lower than the unit price of the four units at the two sites. If nuclear power clustering is carried out, the cost of a single unit will be greatly

reduced. As shown in Table 3, there are 60 nuclear power plant sites in the United States, including 24 single-unit sites and 36 multi-unit sites. As can be seen from the total cost, multi-units the power generation cost of the site is 70% of the single-unit site; the fourth is the advantage of industrial agglomeration.

Table 3 Summary of Nuclear Power Costs by Size and Operator of Usa in 2018 ($/MWh)

Category		Number of nuclear power plants/sites	Fuel cost	Capital cost	Operating cost	Total cost
National		60	$5.98	$6.21	$19.69	$31.88
Nuclear power plant scale	Single unit	24	$5.84	$8.34	$27.82	$42.00
	Multi-unit	36	$6.01	$5.62	$17.44	$29.07
Operator	Single-seat nuclear power plant	12	$6.47	$6.65	$20.40	$33.52
	Multiple nuclear power plants	48	$5.84	$6.08	$19.49	$31.41

4.2 Problem

The problems in cluster development are as follows: the existing laws and regulations need to be broken. The nuclear power construction standards being drafted in China stipulate that a coastal site should not exceed 6 units and 4 inlands. In accordance with the current national standards, such as the Nuclear Power Plant Environmental Radiation Protection Regulations GB6249-2011 and other environmental protection standards, more than 6 coastal nuclear power plants, part of the piled radioactive effluent emissions may exceed the standard limit, engineering measures are required Second, technical breakthroughs are required. A regional layout of 10-20 units requires strict demonstration of nuclear safety, especially in the case of common cause failures. It is also necessary to conduct special research on nuclear emergency aspects. Third, at site conditions. On the other hand, if it is arranged in the existing area, it is difficult to meet the natural foundation of all units, and special research on soft soil foundation is needed. Fourth, it is necessary to conduct research on accessing the power grid, for example, 20 million kW nuclear power is connected to the power grid. Considering the common mode failure, the impact on grid operation safety needs to be analyzed.

5. Conclusion

Based on the numerical basis, this paper predicts China's energy development and power development trends. It can be seen that the incremental growth of renewable energy sources is more than 10% per year. Even so, energy and especially power demand cannot be met. Moreover, the current large-scale access to wind power and solar power into the power grid has some obstacles in the absence of mature industries such as energy storage. From the perspective of economy, although the economics of wind power and solar energy projects have basically reached the conditions of affordable Internet access, if the whole system is considered to be equipped with energy storage, system additional backup, peaking unit cost, etc., the overall economic efficiency of the system. It is still too early to reach parity online. As for carbon emissions, China is under tremendous pressure. It is obvious that the development of nuclear power is an important strategic choice. Under the current circumstances, the development of nuclear power mode needs to be considered, and cluster development is a research direction.

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