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Accommodation issue of nuclear power in China: Status quo, barriers and solutions

Pingkuo Liu*, Penghao Chu, Jianchao Hou

College of Economics and Management, Shanghai University of Electric Power, Shanghai, 200090, China

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ABSTRACT

With the slowdown in economic growth and the oversupply of electric power, the nuclear power accommodation issue in China has become more and more serious since 2015. One purpose of promoting the accommodation capacity of nuclear power in China is to enable the power system to absorb a higher proportion of clean energy. This paper introduces the current situation of the nuclear power industry development and its accommodation capacity, discusses the policy environment from the aspects of development planning, supporting mechanism and policy tools, and further analyzes the barriers of the nuclear accommodation by using PEST model. The countermeasures for China's nuclear power development are proposed accordingly with respect to the strengths, the weaknesses, the opportunities and the threats. Through this research, the conclusions and policy recommendations are put forward to strengthen the accommodation capacity of nuclear power.

1. Introduction

The development of nuclear science & technology and the peaceful utilization of nuclear energy are two greatest achievements of the mankind in the 20th century, which makes the nuclear power (NP) technology become a useful source of electricity. There are many characteristics that make the NP an available energy resource in the electricity generation, such as reliability, security, virtually zero greenhouse gas emission etc. [1]. By the end of 2016, the global generating capacity of nuclear energy has reached 391.386 GW [2], while the number of operational nuclear power reactors increased to 447 in 2016, with 6 new reactors connecting to the power grid [2].

Japan's 2011 Fukushima Daiichi nuclear accident prompted a re-examination of nuclear safety and nuclear energy policy in many countries. The very accident sparked controversy about the importance of the accident and its effect on nuclear's future [3–6]. However, the nuclear power application is still projected to continue expanding in the coming years. Many countries begin to make every endeavor to develop their nuclear power gradually to meet their energy needs. At the beginning of 2017, 60 nuclear reactors with a total capacity of 64.5 GW are under construction in the world (The number of the global planned reactors is 164 with a total capacity of 391.3 GW while the number of the global proposed ones is 347 with a total capacity of 170.844 GW).

Objectively speaking, Coal is the main energy source in China's energy consumption, accounting for more than 70% of China's total energy demand. Such an energy structure may lead to some severe environmental issues[1] and raise questions on China's energy security. China is seeking to diversify the energy mix, and regards the nuclear energy as a critical tool for its strategic goal of achieving sustainable economic development, especially for reducing the environmental pollution [7]. China used to be embarking on a rapid nuclear construction program that aims to raise total capacity to 58 GW by the end of 2020, and it also had ambitions to build its new reactor designs overseas. However, China has also reviewed its nuclear power programs after Japan's 2011 Fukushima Daiichi nuclear accident, and announced that all nuclear power plant approvals should be stopped. China has begun a nationwide safety inspection into all its existing nuclear facilities in the wake of an explosion, which is the so-called "Comprehensive Safety Checks". Correspondingly, the pace of China's nuclear power development was directly slowed down during the "Twelfth Five-Year" period (2011–2015). After that depression, China now finally restart the approvals of new coastal nuclear projects thanks to the gradually matured new generation nuclear reactor technology and the increasingly perfect supporting policies in 2015 [8]. The National Development and Reform Commission (NDRC) approved 16 projects of the new nuclear power units in between 2015 and 2016. Moreover, China is seeking to export native Nuclear Power Plants (NPPs) technologies with self-owned intellectual property rights to other countries, such as

* Corresponding author. College of Economics and Management, Shanghai University of Electric Power, Shanghai, 200090, China.
E-mail addresses: pingoforever@sina.com (P. Liu), www.cphde@qq.com (P. Chu), hdshuoyu@126.com (J. Hou).

[1] For example: Air pollution caused by fog and haze makes people's production and livelihood inconvenient.

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Pakistan, Unite Kingdom, Argentina, Romania, and raise the nuclear power "Going-Out" Scheme as a national strategy [9]. Completely having mastered the technology of nuclear power plant Generation III, China achieved the annual production capacity of 6–8 nuclear power plants. That is a new changing fortune of nuclear energy in China.

With the slowdown in economic growth and the decline in power demand, the curtailment issue of wind power, photovoltaic power and hydropower is the first trouble that appears in China's power industry. And then, the condition has worsened since 2015 because the nuclear power industry has also suffered such a trouble. The base-load power generation of nuclear power is faced with an unprecedented challenge. As a capital-intensive industrial sector, the large-scale nuclear power industry needs huge investments. The nuclear power curtailment in China leads to the lack of full use of resources, the huge losses of social resources, and the reduced economic efficiency. At the same time, China's nuclear power curtailment does reduce the enthusiasm of nuclear power investment, and thus become the constraints of nuclear power development. The curtailment will not only adversely affect China's energy-saving emission reduction, but also make the negative externalities to the upstream and downstream enterprises of nuclear power industrial chain. The questions are: What is the changing fortune of nuclear energy in China? How to address the contradiction between the deployment of nuclear power and the accommodation?

2. Status quo

2.1. Industrial situation

2.1.1. NP development

China has become the fourth largest nuclear generating country all over the world by 2016. Qinshan nuclear power plant is the China's first indigenously designed and built unit. Qinshan's 310 MWe pressurized water reactor (PWR) became operational on 15th December 1991, and put into commercial operation in April 1994. Since that, the development of China's nuclear power has been through four stages: the beginning phase (1970–1993), the moderate development phase (1994–2005), the rapid development phase (2006–2011), and the safe & efficient development phase (2012-present) [10]. The under-constructed and/or the operating nuclear power plants are located in the coastal areas where the economic growth boosts an effective demand for electricity and the cooling water is pretty enough (Fig. 1).

As of 31st December 2016, China has 35 nuclear power reactors in operation, with total installed capacity of over 33.6 GWe, accounting for about 2.04% of the total installed capacity. In 2016, China's nuclear power generation was 210.519 TWh (accounting for about 3.56% of the total electric power production), however, the on-grid nuclear power was just 196.568 TWh. Table 1 shows the Mainland China's nuclear power plants in operation by the end of 2016 [11]. There are 21 nuclear power reactors under-construction, with total capacity of over 24 GWe. These include the world's first four Westinghouse AP1000 units and a demonstration high-temperature gas-cooled reactor plant [12]. Table 2 illustrates the mainland China's nuclear power plants under construction.[2] Most of China's nuclear power plants in operation and under construction mainly adopts the technology of PWR (including CP series, AES-91, M310, CPR1000, AP1000, EPR, etc.), others adopts the Candu-6 reactor or the HTGR. At present, CPR1000, as known as the "improved China's PWR"[3] and designated Generation II +, is the most used reactor technology for newly constructed nuclear power in China [13].

2.1.2. NPP generation

By the end of 2016, China's nuclear power installed capacity reached 33.6 GWe, accounting for 2.04% of the total. Fig. 2 presents China's power generating capacity structure in 2009–2016 [14]. Although nuclear power installed capacity increased from 2009's 9.08GWe to 2015's 33.6 GWe, the share of nuclear power installed capacity is relatively small. Fig. 3 shows China's electric power production structure in 2009–2016 [14]. The nuclear power generation increased from 2009's 70.05 TWh to 2016's 213.2 TWh, while the share of nuclear power production increased from 1.9% to 3.56%. The share of nuclear power production is also relatively small.

2.1.3. NP accommodation

Due to the oversupply of China's electric power, the nuclear power is also faced with the curtailment issue (accommodation dilemma). Fig. 4 presents the annual average utilization hours of mainland China's nuclear power equipment during 2008–2016. Before 2015, the annual average utilization hours of China's nuclear power equipment remained at a high level. A sharp decline appeared in 2015 with only 7350 h, and even decreased to 7042 h in 2016. The poor accommodation of nuclear power capacity made a difference since then. As can be seen in Fig. 5, the provincial imbalance of China's nuclear power accommodation capacity is critical [15,16].

As illustrated in Table 3, the average utilization rates of nuclear power units in Liaoning, Fujian and Hainan had a downward trend in 2014–2016 [11,17,18]. In Liaoning province, the average utilization rate of nuclear power units is less than 70% in 2016. In Fujian province, the average utilization rates at Ningde's main generating units showed a varying decline in 2016, which represented the more serious accommodation trouble. In Zhejiang province, the average utilization rates at Fangjiashan's main generating units also went down in 2016.

2.2. Policy tool

2.2.1. Development plan

Currently, the national government has made ambitious plans, willing to promote the nuclear power development in a secure and efficient way. The "*Energy Development Strategy Action Plan, 2014–2020*" [19] released by the State Council in November 2014, aimed to promote the use of clean energy, confirmed the 2015 target of 58 GWe nuclear power in 2020 (with 30 GWe more plants under construction). The "13th *Five-Year Plan for Energy (2016–2020)*"[4] formalized in December 2016 also confirmed the 2020's target [20,21]. Furthermore, the *Plan* additionally includes some specific aims for the nuclear power development: (1) Completing four AP1000 units at Sanmen and Haiyang; (2) Building Hualong Reactors "Demonstration I" at Fuqing and Fangchenggang; (3) Constructing the Reactor Demonstration CAP1400 at Rongcheng (Shidaowan); (4) Accelerating the Construction of Tianwan "Phase III" nuclear Power project (units 5 ∧ 6); (5) Starting to build a number of coastal new nuclear power projects; (6) Actively carrying out the early-stage work on inland nuclear power plants; (7) Speeding up and promoting the construction of demonstration and large-scale commercial reprocessing plant; (8) Strengthening the construction of nuclear security system.

[2] Hong Kong gets much of its power from mainland China, in particular about 70% of the output from Daya Bay's 1888 MWe net nuclear capacity is sent there. A 2014 agreement increases this to 80%. The Hong Kong government plans to close down its coal-fired plants, and by 2020 to get 50% of its power from mainland nuclear (now 23%), 40% from gas locally (now 22%) and 3% from renewables. Another option, with less import dependence, is to increase domestic generation from gas to 60%, and maintain mainland nuclear at 20%.

[3] Such main equipment has been realized localization. Most domestic companies have the capability to manufacture the core equipment for nuclear island and conventional island.

[4] In the 13th Five-Year Plan for power production announced by the NEA in November 2016, by 2020 coal capacity will be limited to 1100 GWe by cancelling and postponing about 150 GWe of projects. Gas in 2020 is projected at 110 GWe, hydro 340 GWe, wind 210 GWe, and solar 110 GWe of which distributed PV is to be 60 GWe. Nuclear 58 GWe was reiterated for 2020. Non-fossil 770 GWe will then produce 15% of electricity.