Review of concentrating solar thermal power industry in China: Status quo, problems, trend and countermeasures

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Abstract. Concentrating solar thermal power (CSP) industry is a strategic emerging industry in China. Its further development is of great significance for promoting the energy revolution, achieving energy saving and emission reduction. In this paper, China’s CSP industry is systematically analysed. First of all, the status quo is elaborated from the perspectives of relevant policies and regulations, market and generation technology development. Secondly, the problems and the underlying reasons of China's CSP industry are deeply studied. On this basis, the future trends of CSP are expounded on the three levels of policy, market and power generation technology. Finally, a series of feasible countermeasures are put forward, designed to promote the development of CSP industry and the transformation of energy structure.

Keywords. CSP, Industrial policy, Power market, Power generation technology, Power supply structure transformation.

1. Introduction

Currently, due to the drastic fluctuations in the world energy market, along with the increasingly serious environmental problems, the concentrating solar thermal power (CSP) has been confronted with great opportunity for further development. As a strategic emerging industry in China, the CSP meets the appeals of the Belt and Road strategy from manufacturing to practical applications [1, 2]. Therefore, to development the CSP in depth is of vital significance to promote power supply structure transformation, energy saving and emission reduction, as well as energy security in China. However, at the present phase, the development of China’s CSP industry is still at the initial stage, with a few problems seriously hindering the large-scale and sustainable development of the industry [3]. In view of this, how to analyze and solve the encountered problems in the process of industry development becomes the main subject of current industrial research.

Some scholars have done some researches on CSP. Literature [4] and [5] focused on the development status of CSP technology, including the generation principles and technical characteristics of four technical routes, namely the trough type, tower type, dish type and Fresnel type. Literature [6] described the generation principles, development status and development prospects of trough-type, tower-type and dish-type technologies. Literature [7] used the patent analysis theory and method to study the development status of international CSP technologies, and then analyzed the overall trend and hotspot technology of patent application, which helped provide a reference for China’s CSP industry. Literature [8] analyzed the resource potential of solar energy in Hebei Province,
and then put forward the related suggestions and countermeasures. In summary, the existing researches on China's CSP industry are mostly limited to micro technical level. Moreover, they are normally single cases, lacking the systematic analysis on the whole industry.

In view of this, this paper conducts a systematic research on China's CSP development from the perspectives of policies and regulations, market and technology. First, it analyzes the industry development status, and the market analysis is with the emphasis on installed capacity, project layout and generation technology. Secondly, it deeply explores the existing issues and development trend of the CSP industry in China. Finally, the corresponding suggestions and countermeasures are proposed to promote the industry development, and then to lay a solid foundation for the transformation of energy structure.

2. Status Quo of China's CSP Industry

2.1. Regulations and Policies of CSP

Since the 1980s, China has promulgated many policies and regulations related to CSP to promote it rapidly develop [9]. Over the past two years, the Chinese government has attached particular importance to the development of CSP industry, and has not only actively introduced relevant policies and regulations, but also developed and improved the relevant policies from the aspects of demonstration project implementation, expansion in the industrial scale, the fiscal subsidy implementation and so on. And then, policy support is provided to develop solar thermal industry. The subsequent policies will be introduced continuously in expectation. CSP is expected to become the national vigorously supporting industry in the thirteenth Five-Year Plan.

2.2. Market Development Status of CSP

In recent years, with the great improvement of technology, repaid development of industry and increasing demand for clean energy, concentrating solar power (referred to as CSP) has gradually become an investing hotspot in the field of renewable energy in many countries and regions. Due to China's abundant concentrating solar resources, continuous improvement of CSP industrial chain, the clarity and development of the first CSP demonstration projects in 2016, and the support of national policies, CSP ushers in a rapid development period in China. Both large-scale centralized and small-scale distributed CSP stations will have a broad market prospect.

By the end of 2015, the cumulative installed capacity of global CSP is 4940WM. Among them, the solar thermal installed capacities in China is only 14.1MW, accounting for less than 1%, and the growth rate is only 2.2% compared to the installed capacities in 2014. In view of this, China's National Energy Administration has already determined the development schedule of CSP industry. That is to complete a number of CSP commercial demonstration projects application work in 2016 by means of the demonstration power price policy and to enter the large-scale development and construction stage in 2017, and then CSP will usher in the outbreak period [10].

As of September 2016, CSP projects being planned or developed in China is summarized, as shown in Figure 1. The main layout of China’s CSP projects is in Qinghai, Tibet, and Inner Mongolia, Hebei. According to the statistics of Provincial Energy Administrations, by the end of 2014, the total capacity of CSP projects approved and kept on record is 700MW in Qinghai Province, accounting for about 48% of the whole country and ranking first. The total capacity of CSP projects approved and kept on record in Tibet, Gansu and Inner Mongolia provinces are 251MW, 161MW, 160MW, accounting for 17%, 11.1% and 11% of the country, respectively. The number of China's first CSP demonstration projects explicit by National Energy Administration in September, 2016 is 20. And all the projects layout in Gansu, Qinghai, Inner Mongolia and Hebei four provinces. Among them, there are 9 projects located in Gansu, and the total capacity is 650MW. The numbers of the CSP demonstration projects layout in Tibet, Gansu and Inner Mongolia province are 4, 4, 3, respectively, with the capacity of 285MW, 214MW, 200MW.
The number of CSP projects being planned or developed by the end of 2014

The number of China's first CSP demonstration projects explicit by National Energy Administration in September, 2016

Figure 1. The overview of CSP projects being planned or developed in China.

2.3. Technology Development Status of CSP

According to the different types of receivers and condensation, CSP generation technologies can be divided into four classes, which are tower-type, trough-type, dish-type and Fresnel type [11]. The main difference is concentration ratio, which has significant positive correlation with the conversion efficiency of solar to electricity.

Because of the significant cost-benefit of trough-type technology, the installed capacity of trough-type power plants account about 50% of total installed capacity built and under construction in China, as shown in Figure 2. Tower-type power plants account for 38%, and with the continuous development and improvement of technology, the future cost has potential to reduce greatly, and the ratio will continue to increase. Fresnel type and disc-type power stations currently account relatively small, respectively 8% and 4%. The ratio will have a certain degree of growth in the future with the technology maturing. But in the next few years, tower-type and trough-type will still be the mainstream technologies of CSP.
3. Problems Existing in China's CSP Industry
For Regulations and policies, the policies relevant to CSP industry are mostly indirect and temporary, and the strength of policy support appearing is small, short of specific implementation details. Besides, CSP industry policy system in China is not perfect and the system and coordination of the policy planning is still lacking. Such as the disconnection among CSP planning, electric power planning and whole new energy planning, or the lack of overall planning among CSP, power grid and economic and social needs.

For CSP market, there are four main problems. First, compared with photovoltaic power generation, the cost of per kilowatt is relatively high, which to a large extent, restricts the scale development of China's CSP industry and is not conducive to the scale expansion of CSP’s installed capacity. Besides, China’s CSP projects are lack of financing means and the availability and convenience of financing for CSP projects are poor, which to some extent makes CSP to be lack of commercialization. Moreover, there are still weak links in CSP industrial chain. Last but not least, the on-grid power price of CSP has not yet been clear making the real progress of CSP to be very slow.

For CSP technology, there are three main problems. First of all, as a key technology to improve the efficiency of CSP system and to achieve the differentiated competition with photovoltaic power technology, energy storage technologies, such as oil, molten salt, are limited by cost, and the actual development has not reached the expected level. Secondly, although China has made some breakthroughs in CSP technology but the overall equipment technology and engineering development technology is still not perfect. Finally, CSP technology is lack of long term operation of commercial optical thermal power station and has great risk in the feasibility and long-term operational reliability.

4. Development Trend of China's CSP Industry
4.1. Development Directions of Policies and Regulations
At present, the government has issued a series of preferential tax policies to support solar energy industry. For example, for the income from investment and operation of public infrastructure projects supported by the state, including new solar power projects, the enterprises are allowed to enjoy three years' tax free and three years’ tax half pay on corporate income tax. In the future, related electricity price policies, credit policies, investment subsidy policies and preferential land policies, will be gradually introduced, better promoting the development of CSP industry.
4.2. Development Direction of CSP Market

According to the International Energy Agency's data, global solar thermal power market will show a rapid growth trend in the next 35 years and the proportion of the CSP will reach 11% in the global energy supply. At the same time, China's solar thermal power market will show explosive growth and the size of installed capacity continues to grow. The proportion of the CSP will reach 8% in the global energy supply [12]. Specific is shown as follows:

![CSP Generation Proportion](image)

**Figure 3.** The development of CSP market in the next 35 years.

For the future development of CSP market, two major markets can be focused on. On one hand, the government should encourage multiple methods of constructing CSP plants, including large-scale CSP stations equipped with energy storage devices, solar thermal-natural gas combined power plants, solar thermal-coal combined power plants, and transformation from coal-fired power units of 200 thousand kW and below to CSP plants. On the other hand, distributed applications of CSP are supposed to gain sufficient attention, including power supply, heat supply and water desalination through CSP in the islands and remote areas, promoting the construction of the solar thermal cogeneration plants and industrial steam in the areas with demand for industrial heat.

4.3. Development Direction of CSP Technology

In the future development and application, the development direction of CSP technology consists of three parts, which are high parameter, large capacity and continuous power generation. Among them, high parameter refers to high concentration ratio, operating temperature and thermoelectric conversion efficiency [13]. For this purpose, it is necessary to strengthen the research and development of core technologies and key equipment, such as high-reflectivity mirrors, high-precision tracking control system and solar thermoelectric conversion equipment. Large capacity mainly refers to large scale power generation. Continuous power generation is designed to improve the heat-storage efficiency. Currently, the heat storage medium includes steam, heat transfer oil and molten salt. In the future, the CSP industry will increase the heat-storage efficiency of the media through technical innovation.

5. Countermeasures and Suggestions for China's CSP Industry

5.1. Regulation and Policy Suggestions

China’s CSP industry has a weak foundation, so to achieve extraordinary development cannot rely solely on market forces. Instead, the Chinese government is supposed to perfect relevant industrial policies to stimulate the scale development and technology commercialization process, as well as encouraging the production and consumption of CSP. Meanwhile, policies and measures related to CSP industry should be stable, predictable and sustainable, and the corresponding incentive power should be gradually weakened with the technical progress and rising market competitiveness of solar energy application.
Besides, the coordinated development between power generation and power grid should be taken seriously. And then gradually cultivating a stable CSP market according to the principle of government guidance, policy support and market promotion.

5.2. Market Development Suggestions

(1) Effectively launch and expand the CSP market through cost optimization

According to the development experience of wind power, photovoltaic power and other renewable energy industry in China, CSP has been mature enough both in the technology and industry to enter the threshold of commercial applications [14]. For further development, the application of new CSP technology need to be further popularized, designed to improve the efficiency of CSP generation, optimize the power generation cost to promote the growth of installed capacity, and then accelerate the optimization and upgrading process of CSP industry.

(2) Promote project commercialization and broaden financing channels

At the present stage, the following three steps are supposed to be taken to improve the commercialization level of CSP projects. First of all, more efforts should be devoted to the construction of demonstration projects, aiming to lay a solid foundation for the industry chain. Secondly, it is of vital importance to vigorously develop large-scale power plants, so as to reduce the generation cost. Finally, commercial power plants need to be constructed and then realize the competitive development with no subsidies.

In order to solve the problem of financing means lack of CSP project, the diversified investment and financing system should be established and improved. Then enhancing the industry competitiveness through the integration of industrial capital and financial capital is needed. In addition, relevant government departments need to set up a credit guarantee fund for CSP enterprises, designed to provide security for the enterprises. With the joint efforts of industry and the government, the CSP industry will have a better development prospect.

(3) Clearly put forward the on-grid power price

On-grid power price is a key parameter to determine the profitability and solvency of CSP projects, which needs to be made clear by relevant departments. Hence, it is necessary to establish a scientific and reasonable pricing mechanism based on domestic power market and beneficial foreign experience. According to relevant researches [15], if CSP can achieve the development of hundreds of thousands to millions of newly installed capacity annually after three to five years, it will be able to adopt benchmark pricing mechanism or fixed price subsidy mechanism to promote the industry development.

(4) Cultivate a complete industrial chain system

The industrial chain of CSP industry is relatively long, so the in-depth development will be helpful to promote the transformation and upgrading of related industries. At the early stages, to cut into the CSP industry from a specific link will make it faster to enter the vertical integration phase, therefore contributing to the establishment of a complete and vertical-distributed industrial chain. To this end, it is indispensable to cultivate and build a relatively complete, coordinated and healthy CSP industry chain. What’s more, upstream and downstream enterprises are in need of necessary guidance to achieve moderate capacity expansion and reasonable resource allocation, leading to the improvement of international competitiveness.

5.3. Technology Suggestions and Countermeasures

(1) Strengthen research and development to promote technical progress

The development of CSP industry is closely related to the support from high technology and high-end equipment. The current focus is to conduct technical researches centering on the core technology of CSP. Meanwhile, with the purpose of pushing up the improvement of mobile energy technology conversion efficiency, enterprises and research institutions are encouraged to actively establish the national CSP technology laboratory, or to research and develop related technology based on the existing state key laboratory. During the development process, the government and power enterprises not only need to adapt related researches to the special conditions in China, but also to avoid the
simple and repetitive practices of massively introducing technologies and production lines, therefore establishing a truly independent CSP industry.

(2) Enforce the validation of technical feasibility and reliability
Although various types of CSP technologies have made some progress at the present stage, they are still short of the verification of technical feasibility and reliability due to the lack of long-running commercial CSP stations. To deal with the issue, relevant departments are suggested to continuously drive the development and improvement of technical standards based on the demonstration power plants. In the process of exploration, it is meaningful to pay attention to experience accumulation and speed up technological innovation to seek the development path with technical feasibility and reliability.

6. Conclusion
The 13th five-year is an important period in the scale development of new energy in China, so the government spares no efforts in promoting energy production and consumption revolution. As a national strategically emerging industry, the CSP industry plays an important role in pushing up the overall development of new energy and the transformation of power supply structure.

Based on the above analysis, this paper conducts researches on the development status of China’s CSP industry from the perspectives of related policies, market situation and technical development. Next, it further explores the main problems existing in China's CSP industry and the development trend. Finally, staring with laws and regulations, market development, and CSP technology three aspects, and then putting forward a series of countermeasures and suggestions to promote the development of CSP industry, mainly including: 1) Enhancing policy support, introducing the rules for the implementation and improving systematicness and coordination of related policy planning; 2) clearing the feed-in tariff and broadening project financing channels to increase the commercialization of CSP projects. Furthermore, by means of quantifying productivity and localization of equipment to reduce the cost and effectively expanding CSP market; 3) Strengthening research and development to promote CSP technical upgrading. The future of China's CSP industry will be showing a flourishing scene, and become a new economic development anchor.

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