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Power Generation Efficiency and Prospects of Floating Photovoltaic Systems

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Abstract

At present, China's economic and social development is restricted by many factors, such as environmental pollution and the supply of energy, land resources and water resources. Compared with traditional terrestrial photovoltaic（PV）systems, floating PV systems can save a lot of land and water resources and obtain higher power generation efficiency. Although the academics have reached a general consensus about the advantages of floating systems, very few in-depth studies focus on the specifications of floating PV systems. Therefore, this study first discusses the development of PV technology, then studies the power generation efficiency of floating PV systems, and finally comprehensively analyzes the advantages and potential of floating PV systems in China.

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Keywords: floating PV system; power generation efficiency; conservation of water resources; land saving

1. Introduction

According to China's first national water census bulletin (2013) [1], the total number of natural lakes with a surface area of 1km^2 or larger is 2,865 and the total surface area is about 78,000km^2. However, water resource is unevenly distributed over the country and the volume per capita is very limited. China has constructed 46,758 hydropower stations. However, many of the hydropower stations in recent years could

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not operate at its full capacity due to insufficient water storage. In addition, the competition for water resource between electricity generation and agricultural production has become increasingly intensive in many areas in China. Therefore, it has been very crucial and urgent for China to conserve water resource, while promoting sustainable development of renewable energy at the same time.

According to China's Intended Nationally Determined Contribution (INDC), China aims to increase the consumption of non-fossil fuels to 20 % of the total consumption of primary energy by 2030. By 2015, the total installed capacity of photovoltaic (PV) plants had reached 43.18 GW [2]. Given that traditional terrestrial PV systems requires a large area of land surface (about 8 m^2 for 1 kW), the development of PV in China is facing enormous challenges about land resource, especially in eastern China.

Based on the above background, floating PV systems may offer a synthetic solution for energy production, without a significant demand on water and land resource. A floating PV system is a new form of solar electricity generation technology, i.e. to install PV cells on a floating system on water surface. The first study on floating PV cells was performed in 2007 to compare the performance of floating PV cells with traditional terrestrial PV systems. Since the first pilot floating PV plant was built in California in 2008, a total of 22 photovoltaic power plants had been built in the world by the end of 2014, with the installed capacity from 0.5kW to 1157 kW. In addition, Korea Water Resources Corporation has started to build a 500 kW floating PV system and planned to extend the system to a total capacity of 1800 kW by 2022 [3].

In contrast to the practical development of floating PV systems, most existing literatures only reported the operation of a certain system or calculated the payback period. For example, Trapani, Millar and Smith (2013) [4] proposed the design idea of the offshore PV power plant and first studied the feasibility of the floating PV systems. Ferrer-Gisbert et al. (2013) [5] introduced the water photovoltaic project in Agost, Spain, and analyzed its economic feasibility. Teixeira (2015) [6] studied the feasibility of a floating PV system installed on water storage reservoir for a hydropower station in south Brazil. However, there have been very few studies looking into the efficiency of floating PV systems under the cooling effects of water. In addition, to the authors' knowledge, no study so far has systematically discussed the potential of floating PV systems in saving water and land resource.

Therefore, the paper aims to study the power generation efficiency of floating PV systems and to explore the potential of floating PV systems in China. To this aim, the paper firstly developed a finite element model to examine the temperature differences between a floating PV system and a normal terrestrial system in order to verify the cooling effects of water. Based on the cooling effects, this study then analyzed the influence of the cooling effects on the power generation efficiency of the floating PV system. This study also quantitatively studied the potential of floating PV systems on conservation of water and land resources.

2. Methodology

Operating temperature has a significant impact on the efficiency of PV modules and the decrease of operating temperature tends to increase of the module efficiency. Therefore, compared with terrestrial PV systems, a floating PV system may benefit from the cooling effect of water and operate with a higher efficiency, since it is installed close to the water surface. In order to examine the cooling effect of water on PV modules, a 3-D finite element analysis was employed to study the temperature of PV cells. The results were then used to calculate the changes in the power generation efficiency. This study also comprehensively studied the potential of floating PV systems in terms of conservation of water and land resources.

2.1 Finite element simulation for floating PV systems

The 3-D model of a polysilicon PV module consists of five layers: glass, EVA, polysilicon solar cells, EVA and TPT backsheet layer (Fig. 1). The PV cell has a dimension of 156 x 156 mm and the heat transfer form is shown in Fig. 1. The parameters in the model are given in Table 1.