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Policies and economic efficiency of China's distributed photovoltaic and energy storage industry

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ABSTRACT

Storage energy is an effective means and key technology for overcoming the intermittency and instability of photovoltaic (PV) power. In the early stages of the PV and energy storage (ES) industries, economic efficiency is highly dependent on industrial policies. This study analyzes the key points of policies on technical support, management drive, and financial support. Focusing on the efficiency of PV power and the power load of users, including households and enterprises, in Shanghai City over 24 h in 2016, this study analyzes the costs, benefits, internal rates of return, and investment recovery periods of distributed PV (DPV) and ES systems in the current policy context. This study also discusses the influences of various policy variables, including the ES battery capacity, the peak-valley price ratio, feed-in tariffs for DPV, and the ratio of grid-connected surplus PV power, on economic efficiency. The results show that in China's current policy context, both household and enterprise users of PV power would gain some economic benefits if PV systems were fitted with aqueous sodium-ion batteries of an appropriate capacity. Finally, this study offers some additional government policy suggestions.

1. Introduction[1]

In recent years, distributed photovoltaic (DPV) power, an important step in the development of China's photovoltaic (PV) industry, has entered a rapid development stage. In 2016, the newly installed DPV capacity was 4,240,000 kW, corresponding to an annual increase of 200% [1]. However, due to the inherent issues with DPV power (e.g., an intermittent and unstable power supply), its rapidly increasing installed capacity poses a severe challenge to the stability and reliability of the power supply. In order to accelerate the development of the DPV industry and overcome this instability, it is imperative to properly configure the energy storage (ES) devices in DPV power stations [2]. By changing the charge–discharge state and magnitude of power, a PV and ES system can alleviate and even eliminate the fluctuation of DPV power and increase its stability [3,4]. To date, the Chinese government has promulgated quite a few policies to support the development of PV and ES systems. The distributed power generation and microgrid markets have become the largest markets for ES applications in China [5]. However, economic efficiency remains the primary constraint on the development of this industry, for two reasons. First, the configuration of ES devices incurs extra costs, and PV power is already expensive. Moreover, ES requires a very high level of investment per unit capacity. Thus, the DPV and ES industries are less cost effective. Second, the DPV industry is in a fledgling stage, and its development mainly relies on policy support [6]. Furthermore, the electricity price for renewable energy still follows the fixed price mode, which is dominated by the government, and a price mechanism suited to the DPV and ES industry has not yet been established. Therefore, exploring the intrinsic relationship between industrial policies and economic benefits is the basis for an efficiency evaluation under the existing government policies and the next adjustments to these policies, and this analysis is essential for improving the initiative of the developing DPV and ES industries.

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[1] Definition of abbreviations: PV: Distributed photovoltaic: PV: Photovoltaic: ES: Energy storage: PVP: Peak-valley price: FIT: Feed-in tariff; RPS: Renewable portfolio standard; IRR: Internal rate of return: IRP: Investment recovery period: ASIB: Aqueous sodium-ion battery NEA: National Energy Administration: NDRC: National Development and Reform Commission.

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Several previous studies have considered China's policies with respect to the PV and ES industries. In 2013, Zhang [7] summarized the current status of the application of ES technology in China and the related policies. Based on international ES policy, China's current ES policy, and the development of a new ES industry, the research team of the Planning & Statistics Information Department of the China Electricity Council [8] offered some suggestions for the development of the ES industry. Kang [9] offered some policy suggestions for ES applications in Gansu Province based on the status quo at the time.

Previous studies have also considered economic efficiency in the context of the PV and ES industries. Liu [10] comparatively analyzed the economic efficiency of grid-connected PV power systems with and without ES devices. Lyu [11] evaluated and compared the economic efficiencies of two types of users with different load characteristics under two application modes (including PV system, and PV and ES system). Sun [12] analyzed the economic efficiencies of six types of ES batteries in DPV and ES systems. Bortolini [13] developed a grid-connected PV power system based on ES, and found that it reduced the costs of power supply by nearly 24.5% compared with the power grid of Canada. Chen [14] analyzed a smart microgrid system comprised of DPV power, a wind power generation system, and an ES device and concluded that such a system was not necessarily economically optimal in Taiwan. Bracco [15] studied a smart microgrid system based on distributed power generation and determined that synergistic microgrid devices had advantages in terms of reducing of operating costs, conserving energy conservation, and reducing emissions. Based on a study of household solar ES systems in Germany, Kaschub [16] argued that PV power and ES battery systems were expected to be profitable in 2018 even if no electricity prices or subsidies were warranted. Kantamneni [17] pointed out that some households in the Upper Peninsula of Michigan reduced their electricity expenses by using a solar hybrid system comprising PV power, batteries, and small-scale combined heat and power generation.

The abovementioned studies on the DPV and ES industries focus on putting forward policy recommendations based on applications and development. Most studies on economic benefits analyse the influences of individual factors on economic benefits or evaluate the overall economic performance. Only a few studies address the internal mechanism of mutual influence between China's policies and economic benefits. Thus, this study thoroughly analyzes both the policies and the economic efficiency of China's DPV and ES industries.

The rest of this paper is organized as follows: Section 2 summarizes the key points and objectives of related policies, and Section 3 evaluates economic efficiency within the current policy framework. On this basis, Section 4 analyzes the influence of each policy variable on economic efficiency, and analyzes the internal relationships between the policies and economic efficiency. Finally, Section 5 concludes, offering some policy suggestions to improve economic efficiency.

2. Policies

Between 2011 and 2017, China's central government promulgated a series of policies to support the development of the DPV and ES industries, as shown in Fig. 1. Sections 2.1, 2.2, 2.3, and 2.4 summarize the policies with respect to technology support, management drive, environment protection, and financial support respectively. Section 2.5 compares China's policies with those of other countries to explain the specific nature of China's policies.

2.1. Technical support

As a technical support to and a key element of smart power grids, ES technology was first incorporated into the *Twelfth Five-Year Plan for National Economic and Social Development of the People's Republic of China* in 2011. Thereafter, China's central government has emphasized the need for continuous technical innovation, and has extended significant support to the development of ES technologies, as described in Table 1.

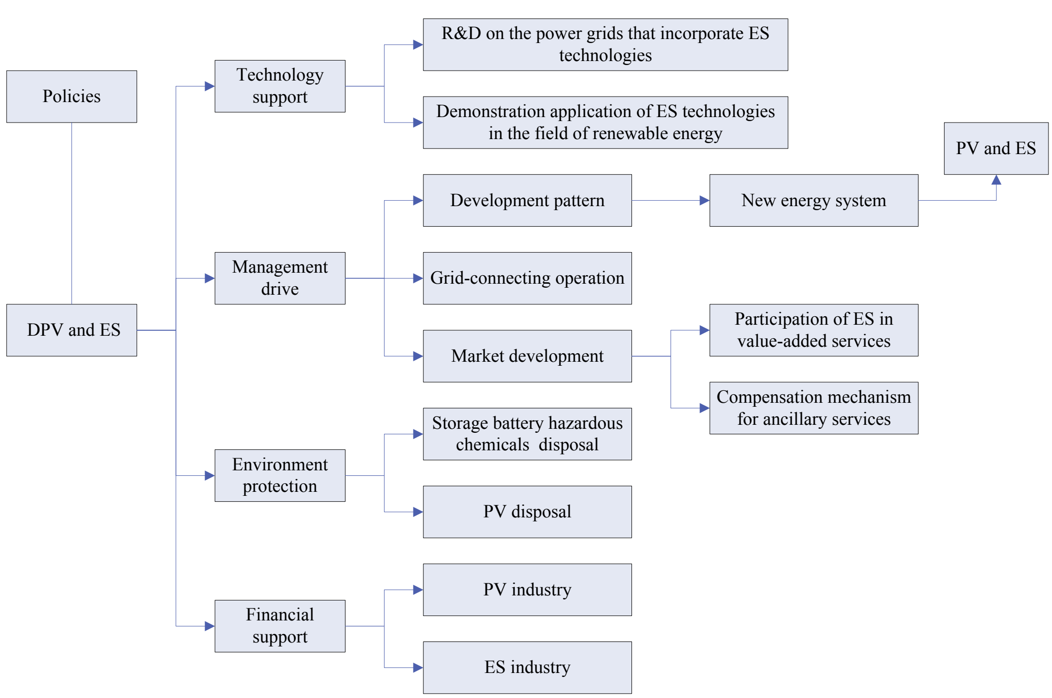

Fig. 1. Policy system for China's DPV and ES industry. Source: Author.