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China's energy storage industry: Develop status, existing problems and countermeasures

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ABSTRACT

With the global environmental pollution and fossil energy shortage problems getting increasingly serious, renewable energy sources (RES) are drawing more and more attention. In China, RES are experiencing rapid development. However, because of the randomness of RES and the volatility of power output, energy storage technology is needed to chip peak off and fill valley up, promoting RES utilization and economic performance. So to speak, energy storage is the precondition of large-scale integration and consumption of RES. However, China's energy storage industry is at the exploration stage and far from commercialization. This restricts the development of RES to certain extent. For this reason, this paper will concentrate on China's energy storage industry. First, it summarizes the developing status of energy storage industry in China. Then, this paper analyzes the existing problems of China's energy storage industry from the aspects of technical costs, standard system, benefit evaluation and related policies. Finally, solutions are proposed based on the above problems to promote the sound development of China's energy storage industry.

1. Introduction

With the worse environmental conditions and growing scarcity of fossil energy worldwide, RES draw more and more interests. Currently, RES have been indispensable for countries to safeguard energy security, protect environment and tackle climate change [1], and have been used for various purposes, such as UPS and EPS in communications, smart grid, micro-grid, power supply for remote areas, DG, energy storage device used in EV and the large back-up sources [2]. Therefore, storage problem for RES becomes a new research focus [3], and the energy storage technology thus attracts tremendous attention.

China has rich RES, however, due to the inconsistency between

Abbreviations: AC, alternating current; AGV, automatic guided vehicle; AQSIQ, General administration of quality supervision, inspection and quarantine (of China); BEV, battery electric vehicles; BMU, Bundes Ministry for Umwelt (of Germany); CAES, compressed air energy storage; CAGR, compound annual growth rate; CAS, Chinese Academy of Sciences; CBIA, China Battery Industry Association; CCHP, combined cooling heating and power; CCSA, China Communications Standards Association; CEC, California Energy Commission; CEPRI, China Electric Power Research Institute; CIAPS, China Industrial Association of Power Sources; CNESA, China Energy Storage Alliance; CPUC, California Public Utilities Commission; DICP, Dalian Institute of Chemical Physics; DG, distributed generation; DGPV, distributed generation of photovoltaic; DOE, Department of Energy (of America); EPRI, Electric Power Research Institute (of America); EPS, emergency power system; ESCT, energy storage calculating tool; ESEM, Energy Storage for Electric Mobility; ESVT, Energy Storage Valuation Tool; EU, European Union; EV, Electric Vehicles; FB, Flow batteries; FCEV, fuel cell electric vehicles; FM, frequency modulation; FWES, flywheel energy storage; IEC, International electrotechnical Commission; IEE, Institute of Electrical Engineering; IET, Institute of Engineering Thermophysics; IPP, Institute of Plasma Physics; KFW, Kreditanstalt Für Wiederaufbau (of Germany); LiB, lithium batteries; $LiFePO_4B$, lithium-iron-phosphate batteries; LiMnB, lithium-manganese batteries; METI, Ministry of Economy, Trade and Industry (of Japan); MF, Ministry of Finance (of China); MHD, magnetohydrodynamic; MIIT, Ministry of Industry and Information Technology (of China); MoHURD, Ministry of Housing and Urban-Rural Development (of China); MOST, Ministry of Science and Technology (of China); MSES, molten salt energy storage; NaSB, Sodium-sulfur batteries; NBS, National Bureau of Statistics (of China); NDRC, National Development and Reform Commission (of China); NEA, National Energy Administration (of China); NEDO, New Energy and Industrial Technology Development Organization (of Japan); NiCdB, Nickel-cadmium batteries; NiMHB, Nickel-metal hydride batteries; NREL, National Renewable Energy Laboratory (of America); PbAB, lead-acid batteries; PCS, power conversion systems; PHEV, plug-in hybrid electric vehicles; PLA, People's Liberation Army (of China); PSS, pumed storage stations; PV, photovoltaic; RES, renewable energy sources; SCES, super capacitor energy storages; SES, Stationary Energy Storage; SGCC, State Grid Corporation of China; SGCT, smart grid calculating tool; SHIC, Shanghai Institute of Ceramics; SHMEPC, Shanghai Municipal Electric Power Company; SMES, superconducting magnetic energy storage; TEPCO, Tokyo Electric Power Company; TIPC, Technical Institute of Physics and Chemistry; TOU, time-of-use; UPS, uninterruptible power supply; US, United States; VRFB, vanadium redox flow batteries; WSST, Wind-Solar-Storage-Transmission; ZnBrFB, zinc-bromine flow batteries

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power output period and consumption period, wind power abandoning is serious [4]. Energy storage can reduce the peak-valley difference and smooth the load to promote RES utilization. At present, China's power grid peak-shaving mainly depends on PSS [5]. But PSS is subject to geographical conditions. Small peak-shaving system, like high-capacity energy storage battery, can realize multiple-point peak load regulation on the micro level and is unconstrained by geographical condition. And it can also be a beneficial supplement to PSS with its flexible size. In addition, the demand for energy storage has been strengthened with the rapid power grid construction in nonelectric regions, the further dilatation of household DG, the fast promotion of EV and the upgrade of communication base station [6,7].

In November 2014, the State Council of China issued the *Strategic Action Plan for energy development* (2014–2020), confirming energy storage as one of the 9 key innovation fields and 20 key innovation directions. And then, NDRC issued *National Plan for tackling climate change (2014–2020)*, with large-scale RES storage technology included as a preferred low-carbon technology [8]. In February 2015, the research on *13th Five-year' Energy Storage Plan* launched by NEA [9], marking that the energy storage was first included in the national plan. In July 2015, NEA issued *Guidance for Promoting the New Energy Micro-grid Demonstration Project*, proposing that the new energy micro-grid should have enough capacity and reaction speed and providing the development scheme for energy storage system. In addition, it can be observed that China has given full attention to energy storage industry.

Currently, energy storage industry in China is extending from demonstration project stage to commercial operation stage, but series of development dilemmas exist. For example, cost of energy storage device is still high, the average cost of 1.5–1.8 yuan/kWh is far over the current electrovalence. And core technology have bottleneck, such as the mid and high load compressor technology of CAES, the high speed motor, bearings and high strength composite technology of FWES, and the key material processing and lot sizing technologies are behind the world advanced level. In addition, some new technologies not receive enough attention in research and intellectual property layout. Besides, incentive policy is not perfect, elaborate implementation outline is lack such as the subsidy mechanism, preferential policy, benefit sharing and accounting.

All in all, energy storage industry of China has many problems at present restricting its commercialization. Finding out the existing problems and propose effective solution are important for the economical operation of energy storage. Reviewing of the existing research, reviews of China's energy storage have been studies by some scholars. As the most mature and widely used large-scale energy storage technology, the PSS become the focus of most research [10–13]. There are also scholars [14,15] studying the technical and economic performance of thermal energy storage. In addition, the opportunity of building energy storage in China is also analyzed [16,17]. However, because of the late start of China's energy storage industry, the comprehensive study for the whole industry is very few. We found a review which provided a relatively comprehensive analysis of the technical and economic issue of it. Compared with other studies, its research has a good comprehensiveness. Nevertheless, the review elaborated the development status of various technical types of China in a general way, the demonstration projects and implementation cases were rarely cited, and the technical details and implementation effects were rarely mentioned. In the section of the issue analysis, this review didn't analyze the existing problems combined with the practical demonstration projects and implementation cases, thus the data supporting was insufficient. In the meantime, contrastive analysis between China and other countries were not conducted. At last, in the section of countermeasures, the suggestions proposed were not specific enough thus lack of operability. In conclusion, due to the space limit of this review, its analysis was relatively in general terms. Therefore, based on the existing reviews, this paper studies the develop status, existing problems and countermeasures of the energy storage industry in China from a deeper level to further boost the technical progress, accelerate the construction of micro-grid, guarantee the safe and stable operation of electric power system, and promote the large-scale utilization of RES. Firstly, the development status of energy storage industry in China is analyzed including various technical types and their practical applications. Then, the existing problems are discussed from four inspects including high technical costs, incomplete technical standards, lake of benefit evaluation system and imperfect policies. On this basis, the corresponding solutions are proposed to improve current situation thus promoting the sound and orderly development of China's energy storage industry.

2. Development status of China's energy storage industry

This chapter will firstly state the environment of global energy storage industry. Then, the general situation of China's energy storage industry will be analyzed. Furthermore, it will elaborate on a variety of energy storage technologies in China.

2.1. Overview of the world's energy storage industry

In recent years, global energy storage market maintains rapid growth. Driven by the Euramerican and Asia-Pacific market, worldwide energy storage industry experienced fast development in 2015. According to CNESA, global cumulative installed capacity of energy storage system was 946.8 MW (excluding PSS, CAES and heat storage) by the end of 2015 and the growth rate was 12.7% compared with year 2014. The global total installed energy storage capacity during 2000–2015 [18] is shown in Fig. 1.

From the national perspective, America and Japan were in the top two with their total capacity accounting for over 80%. Europe gained the fastest CAGR of 115% during 2013–2015 while China ranked the second with 35% [19,20]. From the perspective of technical classification, the

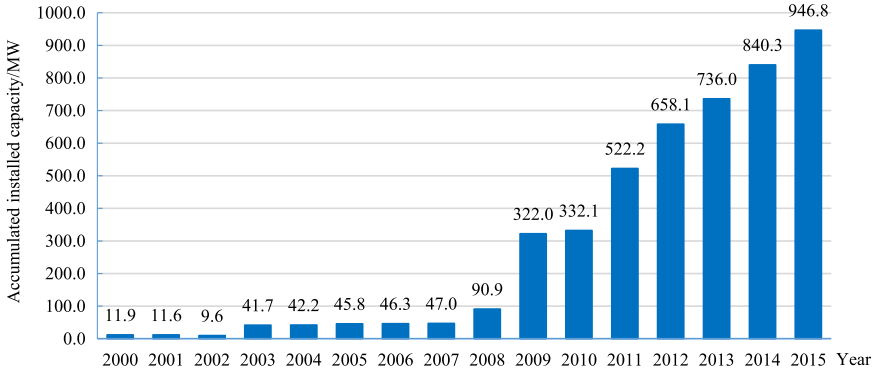

Fig. 1. Global total installed energy storage capacity during 2000– 2015.