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Microgrid in China: A review in the perspective of application

Pengbang Wei, Weidong Chen*

College of Management and Economics, Tianjin University, No. 92 Weijin Road, Nankai District, Tianjin 300072, China

Abstract

The paper aims to explore key factors for the development of microgrid from the perspective of application and put forward some new proposals for promoting the microgrid projects in China through the review and extension researching combined approach. The main drivers of microgrid in China are promoting the local consumption of renewable energy, improving the ability to resist emergency, and saving power transmission loss. An overview of experiences with microgrids policies in China shows that optimal capacity planning for microgrid, energy storage technologies, and incentive market policy are key factors to promote the application of microgrid in China.

Keywords: microgrid; renewable energy generation; local consumption; review

1. Introduction

The electricity industry is the largest CO2 emission contributor to Chinese and global emissions. In the past decade, the CO2 emission growth from the electricity sector accounted for 32.1% of the world's and 49.1% of China's [1]. And if viewed China's electricity sector as a country, it could be the third largest CO2 emitter in the world [2]. In order to meet the increasing demand for electricity, emissions from China's electric power sector are likely to increase in the near future. Therefore, electricity sector's decarbonization pace in China is pivotal to achieving the emission goal of Paris Agreement [3].

In order to promote the decarbonization pace of China's electricity industry, it is necessary to transform the structure of the power supply and increase the power generation of renewable energy. But at present the

* Corresponding author.
E-mail address: weipb666@163.com(P. Wei), chenweidong@tju.edu.cn (W. Chen).

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development of renewable energy generation still faces a series of problems: I The un-coordination between power grid construction and the renewable energy power generation cannot meet the transmission demand for renewable energy power generation and consumption, which have resulted in the abandonment of wind and solar generation[4,5]. And Figure 1 illustrates the status of wind power abandoned in China. II Without matching large thermal power generator, the ultra-high voltage direct current project cannot fulfill renewable generation power transmission independently[6–10]. III Due to the lack of appropriate transmission and consumption patterns, the advantages of low marginal cost of renewable energy generation are not fully utilized[11,12].

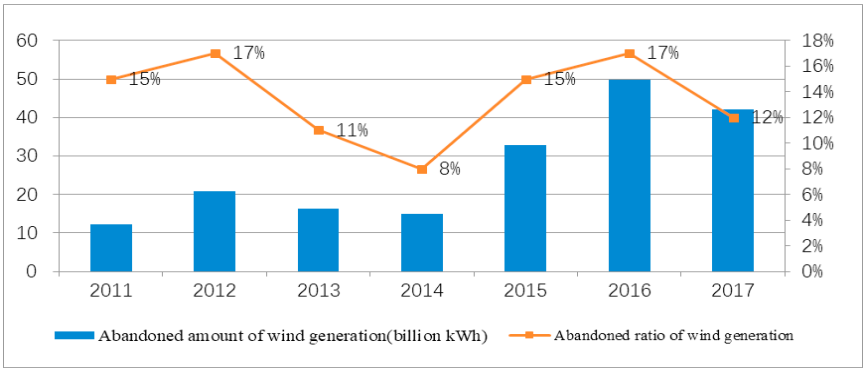

Fig. 1. The status of wind power abandoned in China. Source: China National Renewable Energy Center

Microgrid, at its minimal level of functionality, can enable locally distributed generator, energy storage and load (electricity consuming devices) to operate independently or connected to the main grid[13]. A typical microgrid is illustrated in Fig. 2[14], which can connect to the main power grid or not, and be including some local distributed solar power suppliers as well as responsive household demand. Within the microgrid, there are some corresponding energy storage systems utilized to charge and discharge power to smooth out the intermittency of renewable power generation[15].

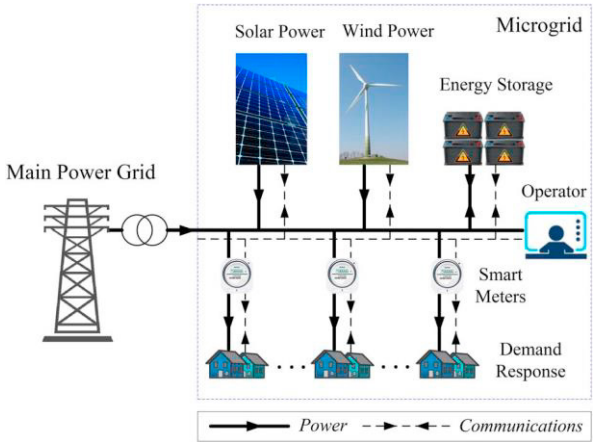

Fig. 2. A typical type of microgrid

This paper aims to explore key factors for the development of microgrid from the perspective of application and put forward some new proposals for promoting the microgrid projects in China through the review and extension researching combined approach. And the questions we aim to answer are: I What are the advantages of the microgrid compared with the existing large power grid? II What are the development status and obstacles of the microgrid in China? III Key factors for the development of microgrid in China. The remainder of this paper is organized as

follows: Section 2 introduces the advantages of the microgrid. Section 3 introduces the project mode of the microgrid and analyses the existing obstacles in China. Section 4 summarizes some key factors for the development of microgrid in China. Then, the conclusion of this article emerged in Section 5.

2. Advantages of microgrid

In order to solve the problem of the integration of distributed power generation and the main power grid, the concept of microgrid emerges with the requirement. The definition of microgrid was first given by the U.S. Consortium for Electric Reliability Technology Solutions (CERTS): A microgrid is a group of interconnected distributed energy resources devices and loads within clearly defined electrical boundaries that operates as a single controllable entity with respect to the main grid[16]. Typically, a microgrid can disconnect and connect from the grid to enable it to operate in both island or on-grid mode[17]. The following of subsection analyzes the specific advantages of the microgrid from the perspective of the application.

2.1. Promoting the local consumption of renewable energy

How to efficiently utilize the distributed renewable energy generation is facing great challenges, due to the strong increase in distributed renewable energy generation, often driven by the utilization of as much renewable energy as possible. The microgrid is considered to be the most powerful tool for promoting the local consumption of renewable energy. A microgrid can utilize local distributed energy sources to maintain essential power supply services.

Scholars have also done some research on how to maximize the microgrid's advantages in promoting the local consumption of renewable energy generation. Chen and Wei studied the solar photovoltaic microgrid in China and supposed that based on an understanding of the distributed solar radiation intensity in China, the microgrid can promote the local consumption of solar energy, and thus increase social welfare[18]. Pons and Repetto explored how to maximize local consumption of renewable energy generation in active distribution networks, and pointed a novel topological reconfiguration procedure in microgrid systems[19]. Sun et al. drawn the conclusion that microgrid should be focused on in China considering social cost as well as renewable energy electricity integration ratio (Note: *The renewable energy electricity integration ratio refers to the ratio of the annual renewable energy power supplied to end users in a society to the annual power consumption of the society*)[10]. Li and Xu proposed a system-wide optimal coordinated energy dispatch approach, which can absorb more distributed renewable energy generations and improve renewable energy electricity integration ratio[20].

2.2. Improving power supply reliability and resisting emergency

Including PV arrays, wind power, and other local distributed power generation, as well as energy storage systems, create advantages to microgrid in improving power supply reliability and resisting emergency[21]. The microgrid can be independent of the main power grid to achieve self-sufficiency in power supply, so as to achieve flexible power supply[21]. De Quevedo et al. studied power supply reliability in the smart grid context, and they found that the service restoration process could be aided by the formation of autonomous microgrids[22]. Adefarati et al. evaluated the reliability of a microgrid power system that consists of wind turbine generator, photovoltaic (PV) and electric storage system. They supposed that the power supply reliability could be highly improved if all the accessible renewable energy are fully utilized[23].

When extreme natural events cause severe power system blackouts in main grid, the microgrid can survive after such events and recover the power supply, especially for critical loads[24]. Farzin et al. focused on the value of microgrid in resisting emergency and proposed a new market mechanism to quantify the value of emergency energy transactions in multi-renewable energy generation microgrid system[25]. Shang supposed that microgrid can enable the use of distributed renewable energy generations to power critical loads as well as accelerate grid restoration [26]. Also, the main driver of microgrid development is to improve power supply reliability of “critical facilities” such as transportation, communications, healthcare, food, and emergency response infrastructure[27].

2.3. Saving power transmission loss and improving energy efficiency

China's energy resources reserves are mainly concentrated on the central and western regions, which are unbalanced with energy demand areas. So it is needed to implement large scale of cross-regional electricity transmission to match the power demand[28]. As for the microgrid, because of its direct distribution at the user side (see Figure 3), the transmission loss is almost 0[29]. So, compared to the main power grid, microgrid can save the transmission loss.

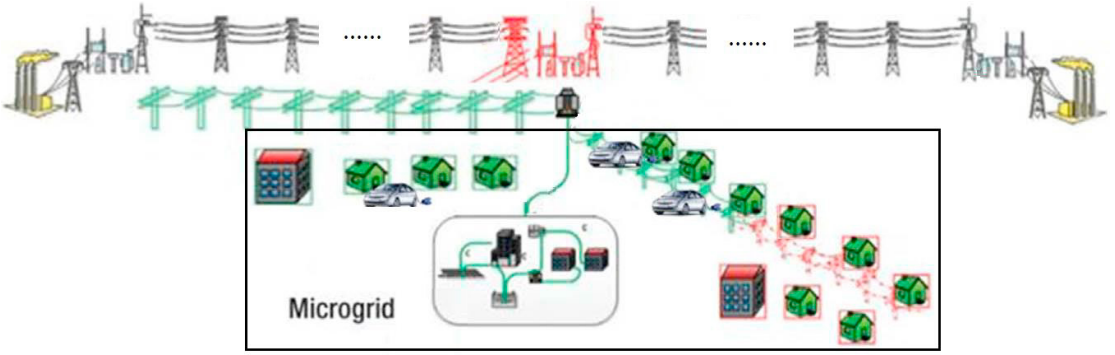

Fig. 3. The transmission comparison of microgrid and main grid

3. The project mode and barriers to the application of microgrid in China

3.1. China's microgrid projects

There were hundreds of microgrid projects put into operation since microgrid technology has been developing quickly in China. Table 1 shows some typical community microgrids in China. As illustrated in table 1[30], the installed microgrid projects' capacity ranges from several kilowatts to thousands of kilowatts including isolated and on-grid types. The typical application scenarios in China cover areas such as residential community, commercial buildings, commercial and industrial parks, and universities. All of these microgrid projects contain renewable energy generations, such as PV and wind units, which promote the near-end consumption of renewable energy.

Table 1. Some typical microgrids in China.

No.	Microgrid type	Capacity and corresponding storage capacity	Network voltage	Location	Application scenario
1	On-grid	PV 6.08-MW peak; lithium titanate battery 500 MWh	10 kV	Nanjing, Jiangsu Province	Commercial park
2	On-grid	PV 20-kW peak; wind power 15 kW; lithium iron phosphate battery 60 kWh; super capacitor 30 kW	380V	Shenyang , Liaoning Province	Resident community
3	Isolated	PV 2.06-MW peak; lithium iron phosphate battery 1 MWh; lead-acid battery 6 MWh	35kV	Gonghe, Qinghai Province	Town
4	Isolated	PV 3.35-MW peak; lead-acid battery 44.3 MWh	380 V/ 220 V	Yushu, Qinghai Province	Resident community/ school
5	Isolated	PV 3.087-MW peak; lithium iron phosphate battery 1.2 MWh; lead-acid battery 4 MWh	10 kV	Qilian, Qinghai Province	Town

3.2. Obstacles encountered in the development of microgrid

While existing great development prospect in China, the microgrid also meets a series of obstacles, including substantial up-front capital investments and high dependence on renewable energy resources. In China, electricity

supply sector is a deeply entrenched and heavily regulated industry, thus it doesn't naturally offer a fertile environment to new technologies and ideas. Additionally, renewable energies are most intermittent power sources, and its stochastic features would be highly location-dependent. Renewable energy generation also has the operation issue of intermittent and uncertain. While the ample energy storage system can improve the inertia and stabilize the system after disturbance, its cost is too high[31].

4. Key factors for the development of microgrid in China

The main driving force of microgrid development is to utilize more renewable energy resources and meet society's diverse demand for electricity. In order to promote the better application of microgrid in China, we need to pay attention to the following aspects. With the considering of short time renewable energy optimal allocation to design the optimal deployment of renewable generations capacity in the microgrid, which can reduce the abandoning rate of renewable energy. How to use the least energy storage battery to solve the issue of smooth power tie-line scheduling of microgrid. To formulate an efficient market to motivate the application of microgrids. In particular, policies should be made to internalize the positive external effects of microgrids and to increase the motivation of microgrid stakeholders.

5. Conclusions

An overview of experiences and researches with microgrids in China showed that optimal capacity planning for microgrid, energy storage technologies, and incentive market policy should be given more attention to promoting the application of microgrid in China.

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