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INTEGRATED MULTI-ENERGY SYSTEM: A SOLUTION TO REDUCE RENEWABLE ENERGY POWER CURTAILMENT IN WESTERN CHINA

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ABSTRACT

With the continually large-scale exploitation and utilization of renewable energy, China, especially in Western China, has faced serious hydropower, wind power and solar photovoltaic (PV) power curtailment difficulties since 2011. Especially in 2016, the amount of hydropower, wind power and solar PV power curtailment peaked. This paper summarizes the reasons for renewable energy power curtailment from four aspects of energy flow, and emphatically analyses the integrated multi-energy system (IMES) solution to reduce renewable energy curtailment. Statistical results show that these countermeasures achieved success in 2017 and 2018. Then, Longyangxia hydropower-PV integrated multi-energy project is used to prove the feasibility of IMES to reduce renewable energy power curtailment. And the successful case provides reference and guidance for the promotion of IMES in other areas of the nation.

Keywords: Western China, Renewable energy power curtailment, Integrated multi-energy system, Case study

NOMENCLATURE

Abbreviations	
PV	Photovoltaic
IMES	Integrated Multi-Energy System
UHV	Ultra High Voltage
NEA	National Energy Agency

1. INTRODUCTION

By the end of 2018, the total renewable energy installed capacity in China reached 728 GW: 352 GW from hydropower, 184 GW from wind power, 174 GW from solar PV power, and 18 GW from other sources, increased 12% year on year, accounting for 38.3% of the total capacity [1]. And non-fossil energy installed capacity continues to grow, it will account for 39% by 2020. Moreover, the installed capacity of renewable energy in Western China will account for more than 50% of the total renewable energy installed capacity [2].

However, China, especially in Western China, is facing the problem of renewable energy power insufficient consumption. As shown in table 1, the amount of renewable energy power consumption in Western China increased year by year, but the proportion of which decreased year by year from 2015 to 2017 [3]. Meanwhile, the phenomenon of serious renewable energy curtailment appeared in China, especially wind and solar PV power curtailment in Northwest China and hydropower curtailment in Southwest China. There are many and complex reasons for renewable energy power curtailment [4]. Of course, China government has been actively working to cope with renewable energy power curtailment.

Table 1 The situation of renewable energy power consumption in Western China from 2015 to 2017

	Renewable energy power consumption					
Western China: 12 provinces*	Amount (TWh)			Proportion (%)		
	2015	2016	2017	2015	2016	2017
	644.1	658.6	746.5	52.3	51.5	44.3

12 provinces*: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

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In this paper, renewable energy curtailment status is analyzed, including the current situation, reasons and countermeasures. Then, it is emphatically analyzed that the IMES on power supply side solution. Finally, Longyangxia hydropower-PV integrated multi-energy project is studied.

2. RENEWABLE ENERGY POWER CURTAILMENT IN WESTERN CHINA

2.1 The situation of renewable energy power curtailment in Western China

Although it boasts the majority of China's installed renewable capacity, the western region dominates the national curtailment of renewable energy, especially wind power and solar power curtailment in Northwest China and hydropower curtailment in Southwest China.

According to the statistics of the National Energy Agency (NEA), the amount of wind power curtailment and solar power curtailment in Northwest China reached the peak in 2016, which were 26.2 TWh and 7 TWh respectively. However, this phenomenon has been alleviated since 2017, and the amount significantly dropped to 16.8 TWh and 4.7 TWh respectively by the end of 2018 (figures 1 and 2).

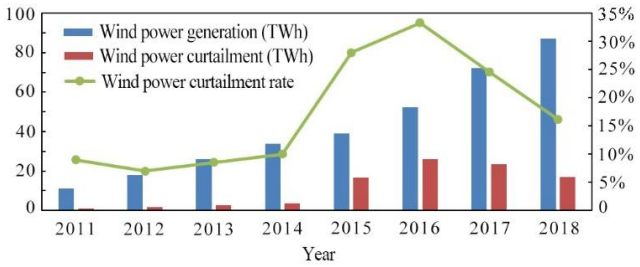

Fig 1 The situation of wind power curtailment in Northwest China from 2011 to 2018

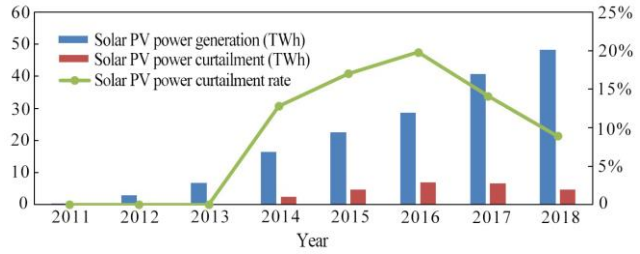

Fig 2 The situation of solar PV power curtailment in Northwest China from 2011 to 2018

Hydropower curtailment in Southwest China took place mainly in Yunnan and Sichuan Provinces. As shown in figure 3, the amount of hydropower curtailment in Yunnan and Sichuan increased rapidly from 2011 to 2016 and reached peak value of 31.4 TWh and 14.2 TWh respectively in 2016. However, the phenomenon of hydropower curtailment was relieved and the amount fell to 30 TWh and 14 TWh by the end of 2017.

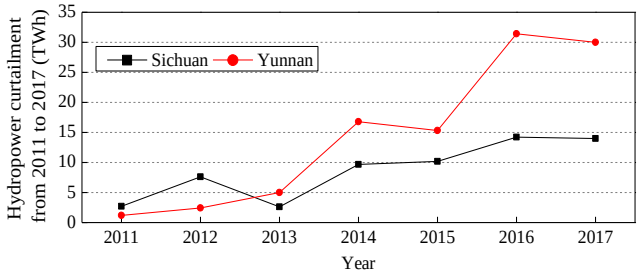

Fig 3 Hydropower curtailment in Sichuan and Yunnan provinces from 2011 to 2017

The alleviation of renewable energy power curtailment in 2017 is inseparable from a series of measures taken by China government. However, the western region will face enormous pressure from China government to basically solve the problem of renewable energy power curtailment by 2020. The following section will briefly discuss the reasons for renewable energy power curtailment in Western China and emphatically analyze IMES solution to reduce it.

2.2 Reasons for renewable energy power curtailment in Western China

There are many reasons for the renewable energy curtailment in Western China. From the perspective of energy flow, these reasons can be roughly summarized as four aspects: power supply side, end-user side, transmission network and energy storage.

Firstly, the installed capacity of renewable energy power accounts for a large proportion in all provinces of the western region, and it keeps rising year by year. The insufficient self-consumption of renewable energy power in provinces leads to oversupply of renewable power capacity [5]. Secondly, the incomplete transmission network between provinces in the western region, especially the less UHV transmission lines among regions, hinders the inter-provincial and inter-regional renewable energy power transmission and consumption. Thirdly, wind power and solar PV power are unstable, which require high peak shaving ability of power grid. The grid-connected operation is seriously affected. Last but not least, the slow development of large capacity energy storage equipment limits the further development and utilization of renewable energy power.

2.3 The IMES *solution to reduce renewable energy curtailment in Western China*

In order to solve the problem of renewable energy power curtailment in Western China, China government has put forward a series of solutions. This paper only analyses the IMES solution to reduce renewable energy curtailment in Western China.

In July 2016, “the implementation opinions on promoting the construction of IMES projects” was issued by NEA. IMES projects mainly include IMES on end-user side and IMES on power supply side (figure 4). The following section will emphatically analyze the IMES on power supply side solution.

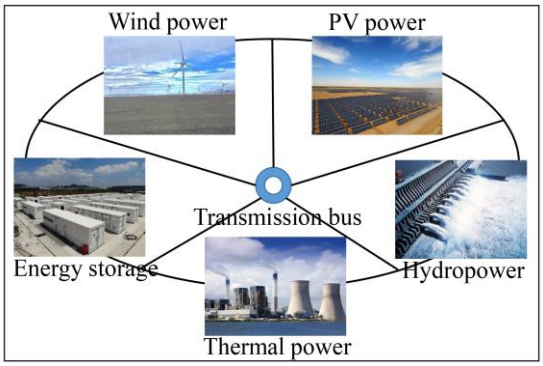

Fig 4 The IMES on power supply side diagram

In January 2017, the NEA announced the first batch of IMES projects, including two categories: 17 IMES on end-user side and 6 IMES on power supply side. Moreover, 5/6 projects of IMES on power supply side are in Western China (table 2).

Table 2 The first batch of IMES on power supply side projects

No.	Project location
1	Zhangbei County, Zhangjiakou, Hebei Province
2	Tumoteyouqi, Baotou, The Inner Mongolia Autonomous Region
3	Kala Town, Muli County, Liangshan, Sichuan Province
4	Longmen Economic & Technical Development Zone, Hanchen, Shanxi Province
5	Geermu county, Haixizhou, Qinghai Province
6	Hainanzhou, Qinghai Province

The 13th five-year plan of energy development points out that utilizing combination advantages of wind, solar, hydro, coal, natural gas and other resources and giving full play to the flexible peak shaving capabilities of hydropower and thermal power to carry out IMES projects in Qinghai, Gansu, Ningxia, Sichuan, Yunnan, Guizhou, Inner Mongolia and other key provinces and regions.

The IMES is one of the effective measures to solve the renewable energy power curtailment in Western China. Due to the different power generation characteristics of different energy sources in IMES, through close coupling, diversified cascade utilization and collaborative optimization, the system can adapt to the access of renewable energy with higher permeability. Thus the instability of power supply can be greatly reduced and the consumption of renewable energy power can be promoted effectively.

3. CASE STUDY: LONGYANGXIA HYDROPOWER-PV IMES PROJECT [6]

3.1 Project introduction

Longyangxia hydropower-PV IMES project is located in Qinghai Province, Western China, which includes a hydropower station with an installed capacity of 1280 MW and solar PV power station with an installed capacity of 850 MW. As shown in figure 5, solar PV power is transmitted to Longyangxia hydropower station by 330 kV transmission line, and then transferred to the power grid through hydropower regulation. The linear distance between hydropower station and solar PV power station is about 36 km. Longyangxia hydropower-PV IMES project is the first and largest grid-connected photovoltaic power station in the world to adopt the hydropower-PV complementary coordinated operation power generation control mode.

3.2 Project characteristics

Longyangxia hydropower-PV IMES project puts forward the concept of "virtual hydropower", which regards 850 MW solar PV power station as a "virtual hydropower unit" connected to hydropower station. Therefore the problem of power limitation and curtailment in an independent solar PV power station is avoided. And the project formulates the principle and strategy of hydro-optical complementary control, and compiles a large-scale hydro-optical complementary test scheme and program.

Longyangxia hydropower-PV IMES project uses a variety of the most advanced equipment and technologies at home and abroad, including 23 components, 21 inverters, 30 design concepts and 13 tracking technologies. The project also develops an on-line monitoring and data comparative analysis system to provide an empirical platform for PV industry design, equipment development, standard formulation, operation management, investment benefit analysis, etc.

3.3 Comprehensive benefits

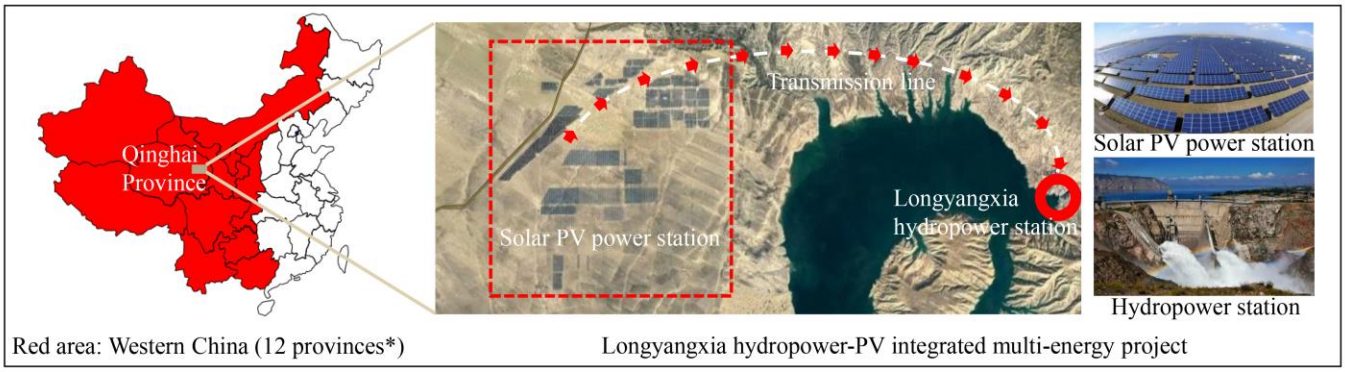

Fig 5 Longyangxia hydropower-PV integrated multi-energy project diagram

Longyangxia hydropower-PV IMES project can save 70% of spinning reserve capacity of the power system, about 400 MW to 600 MW. Moreover, the peak-shaving and frequency-modulation ability can be enhanced by 18% (sunny day), 9% (cloudy day) and 5% (rainy day), and transmission capacity can be increased by 22.4%. Through the complementary operation of hydropower and solar PV power, annual utilization hours of the transmission lines can be increased from 4621 hours to 5019 hours, which improves the economic benefits.

In addition, the Longyangxia hydropower-PV IMES project has also created good ecological and environmental benefits. Annual power generation can reach 1494 GWh and. Converted into thermal power, it is equivalent to saving 493 million kgce per year, reducing CO_2 emissions 1.232 million tons, SO_2 emissions 4.191 million tons and NO_X emissions 3.649 million tons.

4. CONCLUSIONS

In China, especially in Western China, the imbalance between the rapidly increasing production of renewable energy power and continually insufficient consumption leads to serious renewable energy power curtailment. From the perspective of energy flow, reasons for renewable energy curtailment in four aspects are summarized, including power supply side, end-user side, transmission network and energy storage. In response to renewable energy power curtailment, China government proposed and implemented IMES demonstration projects solution in 2016, and it achieved initial success in 2017.

The successful operation of Longyangxia hydropower-PV IMES project proves the feasibility of IMES. Through the complementary operation of hydropower and solar PV power, the peak-shaving and frequency-modulation ability can be enhanced by 18% (sunny day), 9% (cloudy day) and 5% (rainy day), and transmission capacity can be increased by 22.4%. Moreover, the Longyangxia hydropower-PV IMES project has achieved excellent comprehensive benefits, which shows that the IMES project can effectively solve the renewable energy power curtailment. Thus, it provides reference and guidance for the promotion of IMES in other regions of China.

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