Key Technologies and Development Challenges of High-proportion Renewable Energy Power Systems

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Abstract. China promises to reach peak carbon dioxide emissions by 2030 and carbon neutrality by 2060. It will need to make every effort to achieve these objectives. Among all, the development of the renewable industry is the key way and roadmap. When high-proportion wind and solar energy are integrated into the power grid. The randomness and uncertainty of renewable energy reduced the safety margin and influenced the stability of the power grid. In this paper, the present situation of renewable energy in China is introduced. Total installed solar generation capacity was about 250 GW in China by the end of 2020, accounting for one-third of the world's total installed capacity. The capacity for wind energy generation was about 280GW. It has the highest generation capacity in the world. It also presents the potential challenges of integrating large-scale renewable energy into the power system and proposes mitigation techniques and is valuable for further research.

Keywords: Renewable energy, power quantity, energy storage, power system.

1. Introduction

In 2015, 196 countries signed the Paris Agreement, pledging to limit global warming to 1.5 degrees Celsius by reducing their greenhouse gas emissions. Climate change has a direct link to carbon dioxide concentrations. The quantity of carbon dioxide in the atmosphere has grown alongside the use of fossil fuels for energy, and the industrial revolution exacerbated this growth [1].

China shall attempt to reach peak carbon dioxide emissions by 2030 and carbon neutrality by 2060. This will need tremendous effort and China will make every effort to achieve these objectives [2]. According to the United Nations, tackling climate change, prioritizing renewables, and building sustainable and sustainable communities are key to sustainable development [1, 2].

The cost reduction of renewable electricity, the successful implementation of market reforms, and the scalability of wind and solar power make them vital to the energy supply. The proportion of renewable energy shall increase from 13.5% in 2020 to 87.6% under the baseline scenario and 92.2% in the carbon-neutral scenario by 2060[2]. Reducing the carbon footprint and consuming renewable energy is crucial to the world that is impacted by global warming. China has long been committed to developing the renewable energy industry in order to cope with energy shortages and environmental pollution. By the end of 2022, installed renewables capacity is expected to exceed 1,000 GW. It intends to have 80 percent of its overall energy mix come from non-fossil sources of energy by 2060 and to reach an installed total of at least 1200GW from solar and wind by 2030. With the rapid growth of renewable energy capacity, the randomness and volatility of power grid operation have increased severely, with the peak regulation resources tightened and the power system operation safety margin continuously reduced. This paper illustrates the present situation of renewable energy in China. It also presents the potential challenges of integrating large-scale renewable energy into the power system and proposes mitigation techniques.

2. Present Situation and Future Prospect of Renewable Energy in China

In 2021, China's total renewable energy capacity topped 1 GW, representing 43.5% of the country's total power-producing capacity, 10.2% more than in 2015. By 2060, 80 percent of the country's total electricity shall generate by non-fossil fuel sources, and solar and wind capacity will exceed 1,200GW by 2030. As shown in Figure1 and Figure 2, China is set to install a record 156 GW of wind turbines and solar panels in 2022, including 100 gig watts of solar, 50 onshore wind, and 6 offshore wind.

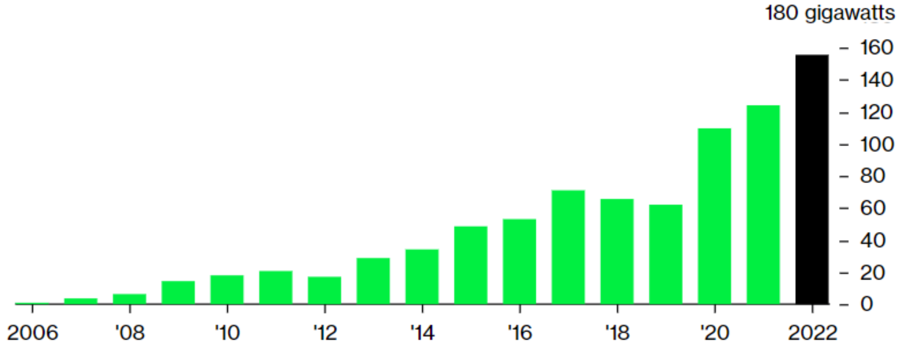

Fig.1 Chart of the increased renewable energy in China [3]

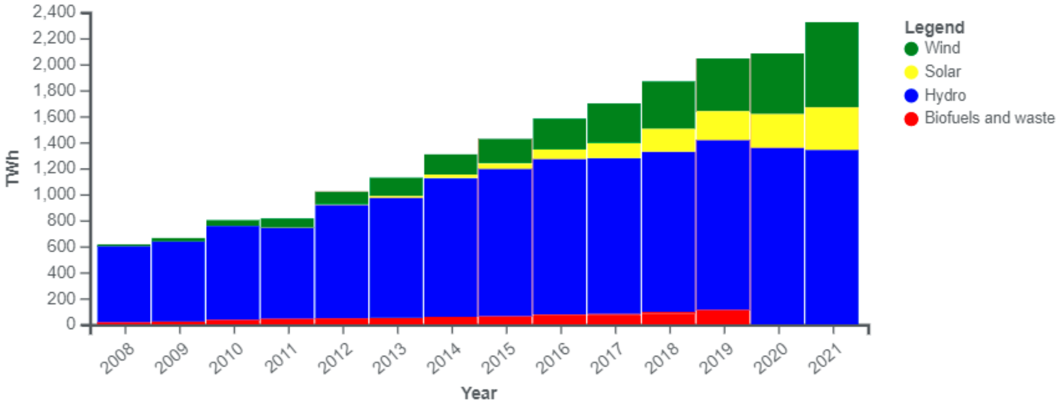

Fig. 2 renewable energy statistics of China

By the end of 2021, the power generation of hydroelectric power is 1340 TWh. It is the greatest source of renewable electricity production. Wind energy supplied the second-largest amount of energy with 655 TWh. Solar PV power began with a modest foundation of 152 GWh in 2008 and has expanded significantly to 327 TWh by 2021. According to the data in figure 2, the proportion of power generated from renewable sources climbed from over 17 percent in 2008 to more than 27 percent in 2021. renewable energy continues to increase rapidly.

The total renewable energy capacity is over 790GW, mostly from solar, hydropower, and wind sources. As of 2020, China's hydroelectric capacity had over 350 GW[3,4]. Solar and wind power capacity had over 250 GW and 280 GW respectively.

2.1. Solar Power Development in Recent Years

Solar energy is the most popular eco-friendly, secure and dependable power source. Only a little part of this huge source is utilized. Solar energy can be categorized into Active solar energy and passive solar energy. It is an important energy resource for making a green world.

By the end of 2020, Solar capacity has over 250 GW in China, representing almost a third of installed photovoltaic capacity in the world. The western provinces of China generate the majority of the country's solar energy, which is then transmitted to other parts of the country. The solar energy resource of China is illustrated in Figure 3 and Figure 4 depicts the photovoltaic capacity built in China.

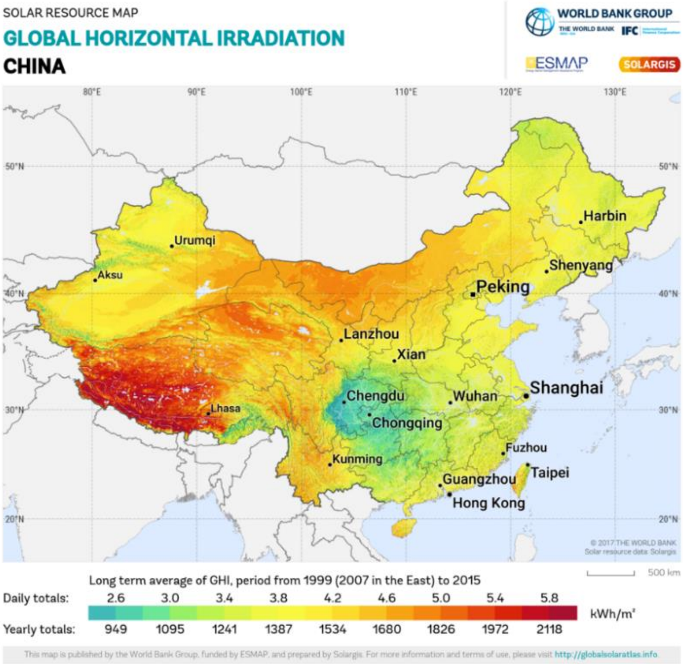

Fig.3 Global Horizontal Irradiation in China [5]

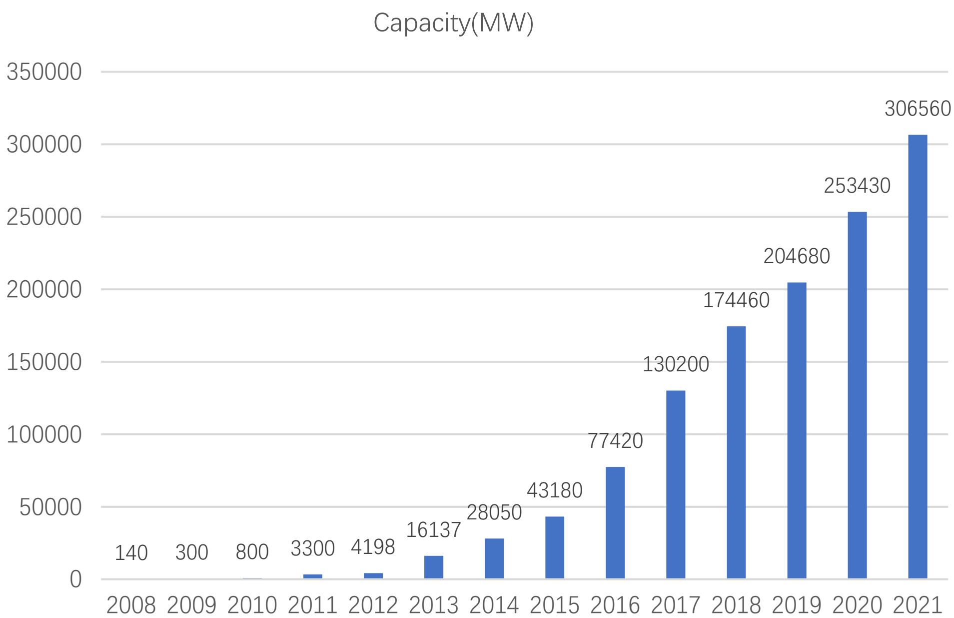

Fig.4 the Photovoltaic capacity installed in China

2.2. Wind Power Development in Recent Years

China is the leading country in wind energy production. It has the largest capacity and the fastest rate of developing new wind projects. It is over 2300 GW of usable capacity on land and 200 GW of exploitable capacity at sea in China.

The increased capacity of wind power is about 70GW in 2020, bringing its total capacity to 281GW in China. The wind resources in China are illustrated in Figure 5. The wind power capacity built in China is shown in Figure 6.

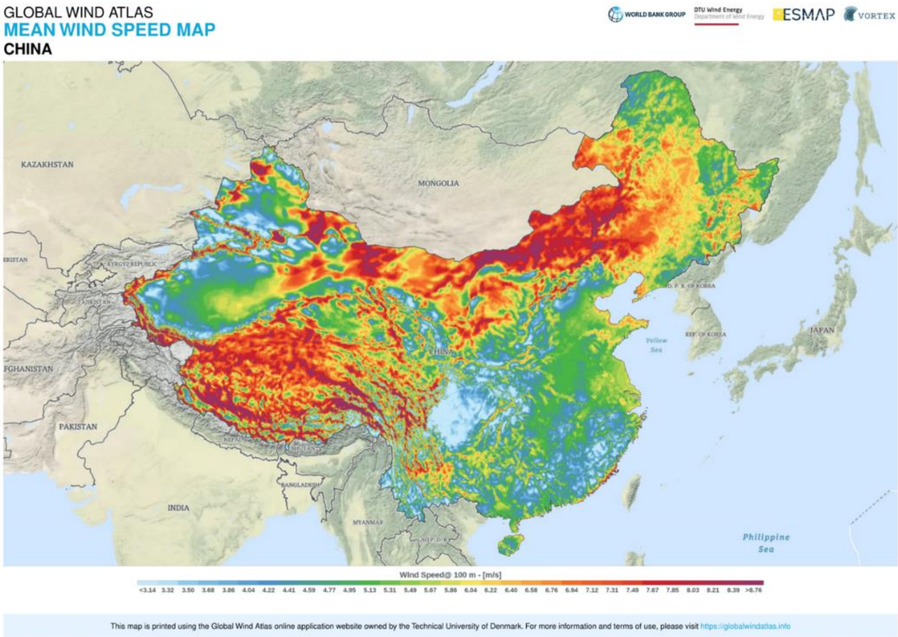

Fig. 5 distribution of wind resources in China [6]

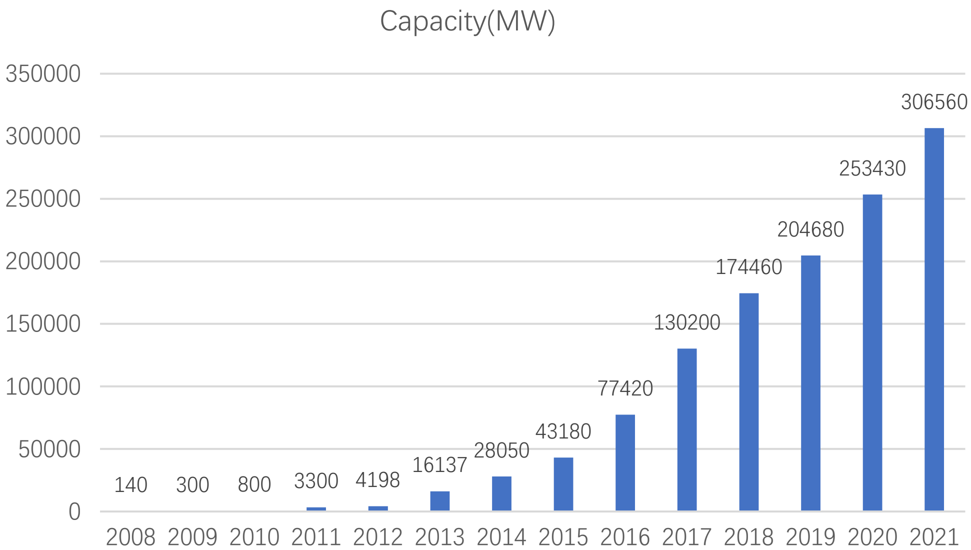

Fig.6 the wind power capacity installed in China

2.3. Other Renewable Power Development in Recent Years

China has become the third biggest producer of ethanol-based biofuels in the world. More than 20 million rural households were using bioenergy in 2005, with methane gas being the primary biofuel. Additionally, around 4000 bioenergy units annually create 8 billion cubic meters of methane gas. 20% of the gasoline consumed in 2006 was a 10% ethanol-gasoline mix. Bioenergy output of electricity is 5 GW in 2010 and 30 GW in 2020.

China is a largely agricultural nation with abundant biomass resources. The yearly amount of forest leftovers accessible across the nation are approximate 440 million metric tons [6]. The annual quantity of available forest leftovers is about 350 million tce, while the yearly quantity of manure is around 28 million tce. China's yearly availability of municipal solid garbage is 12 million metric tons equivalent. Moreover, the available biomass capacity had about 14 million kilowatts in 2014. China's biomass power generating business is growing fast due to the nation's plentiful biomass resources. Other renewable resources, such as tidal and wave energy are being studied but are rarely used for commercial power generation due to their high cost, low efficiency, and poor reliability [7-9]. China's total reserve of undeveloped marine energy resources is about one thousand GW, which has enormous exploitation potential [10]. China's geothermal resources are plentiful and widely dispersed. There are nearly 2,700 hot springs with temperatures exceeding 250 degrees Celsius on the surface. China's mainland had discovered 181 geothermal systems with an output capacity of over1700 MW by 2006. However, as of 2006, only 7 units with a combined capacity of 32 MW were operational.

3. Challenges of High-proportion Renewable Energy Integrated into the Power System

3.1. Variability and Uncertainty

The quantity of power that a renewable energy source can produce depends on the natural conditions of solar radiation and wind speed. Their varying output necessitates the balance of services over many time scales. Consequently, a large proportion of renewable energy in a power network may reduce the network's overall reliability. It is also uncertain and often unavailable at the time of demand. Their output depends on atmospheric and climatic conditions and is unpredictable

3.2. Concentration and Power Quality

The supply is concentrated during the hours when solar or wind resources are abundant. Solar systems rely on the steady absorption of sunlight. It lacks consistency and reliability. Power quality is a crucial aspect of a power system, especially since nowadays modern electrical equipment is sensitive to voltage variations [10]. Power quality influences voltage fluctuation, frequency, and oscillations. Voltage variations are a challenging issue, especially with considerable renewable energy integrated into the power grid. When integrating intermittent sources, this factor must be well considered. When s large-scale wind turbines are linked to a poor power network, voltage fluctuations are visible, particularly during the starting and stopping processes. These limitations make it challenging to design an energy system that is based largely on wind and solar energy.

4. Solutions for Renewable Energy Integration to the Power System

In order to solve the issues that renewable energy integrated into the power grid. Some potential solutions: are considered.

4.1. Enhanced Regional Coordination

In order to enhance the stability of the power system, strengthening the coordination with its neighbors is essential and important. This can make the region's power system more robust and contribute to addressing the region's flexibility issues. It also helps the region in finding solutions when renewable energy is surplus during certain hours.

4.2. Demand Response

During periods of grid stress, electric demands are lowered momentarily. Increased demand response can play an important role when a steep load ramp is necessary due to a decrease in solar production. Conventional demand response also acts as a proxy for measuring the efficacy of expanding the thermal fleet's ramping capabilities in the region’s area. Advanced demand response, wherein electric demand is decreased during certain hours and boosted during other hours to assimilate solar and wind energy during periods of excess output.

4.3. Energy Storage

When renewable energy is produced in surplus, t batteries or pumped hydro storage can absorb the excess electricity and release it to the power system if required. Energy Storage Systems are key components of smart grids that combine renewable energy sources. The fluctuation of such resources can be mitigated by the effective functioning of the ESSs. During off-peak periods, energy systems can store excess energy and release it to the grid during peak hours. In addition to their basic tasks, conventional storage technologies can provide diverse uses in power systems

4.4. Artificial Intelligence

The power system will undergo radical transformations as a result of artificial intelligence. As renewable energy is an important part of power systems, they need weather predictions to know how they will transmit electricity to the power system in order to decrease the fluctuation of solar and wind energy. Forecasts are essential for effective energy management. In the situation of renewable energy, when there is a variation in load, the present energy grid station was not designed to accommodate numerous energy source changes. It is now evolving as it integrates the RE systems with the most advanced AI systems for managing, transferring, and consuming renewable energy. The most recent systems use less time to calculate and get the greatest results

5. Conclusions

The current status of renewable energy in China is introduced in this paper. In 2020, the total solar capacity in China was about 250 GW, representing a third of the total solar capacity in the world. Wind power generating capacity was over 280 GW. China has the largest generation and growing capacity. It also presents the challenges of integrating renewable energy into the power system and proposes mitigation techniques. Several promising solutions are proposed to solve the issues, including regional coordination, demand response, energy storage, and the application of artificial intelligence. Among all the possible solutions, energy storage is the most promising technology. It will play an important role in the future power system. All these solutions will be critical to keeping the stable of the power system. It is beneficial for future research.

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