Analysis on adaptability of eastern and central China with wind power integration

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Abstract. Renewable energy like wind power has developed rapidly in recent years, however, cognition to wind power development in eastern and central China still has a lot of controversy. This paper focuses on issues of wind power resource potential in eastern and central China, and its influence to power planning and power system operation. Then, typical day operation of Shandong power grid and Hunan power grid has been simulated, and possibilities of wind power curtailment in some period of time are analysed. Through identifying tough power system operation period to different areas, guidance for power planning of these areas would be brought forward, in order to make better accommodation situation.

1. Introduction
Recently, with China's energy system turning into low-polluting and low-carbon, renewable energy like wind power and solar power has developed rapidly. Particularly, wind power in eastern and central China, also known as power receiving regions, has developed boomingly in the past two years. In the future, wind power development in eastern and central China is about to usher in a new round of growth, influenced by a number of factors. These concludes technological progress of low wind speed turbines, good accommodation status of wind power integration, high public acceptance of renewable energy development, policy guidance like financial subsidies and electricity prices, as shown in literature [1] and [2].

At present, cognition to wind power development in eastern and central China still have a lot of controversy, such as, will the wind power resources potential of eastern and central china support local power demand, what the distribution of national wind power development should be, will there be wind power curtailment in eastern and central China in the future. In view of the above disagreements, this paper has focused on issues of wind power resource potential in eastern and central China, national distribution adjustment of wind power and its influence to power grid.

2. Resource potential and development status of wind power in east and central China
Now, profit-making and no curtailment are the main advantages of wind power development in east and central China recently. In the future, wind power resource, construction cost, exploitation mode and accommodation ability will be the central region to determine the development of wind power important factors.
2.1. Resource potential
Wind power resource in east and central China is limited, and onshore wind power theoretically technical development potential is about 3~3.3 billion kilowatts. According to Wind Resource Survey of Chinese National Weather Bureau and wind energy resources evaluation system of State Grid Energy Research Institute in literature [3], onshore wind power theoretically technical development potential of 80 meters and 100 meters high in eastern and central China is about 300 million and 330 million kilowatts respectively, only accounting for national wind energy development potential of 9%. As shown in fig.1, wind energy resources development potential is 120 million kilowatts in wind speed 5.5m/s and below, and share of total wind energy development potential in eastern and central China is 36.6%.

Offshore wind power theoretically technical development potential in eastern and central regions is about 120 million kilowatts. China's coastal areas (including Zhejiang, Hebei, Shandong, Jiangsu, etc.) are rich in wind energy resources, and conditions for offshore wind energy resources are favorable.

2.2. Development scale
In eastern and central China, wind power has accelerated development trend in recent years, with more than 43 million kilowatts installed capacity at the end of 2017. Wind power in eastern and central regions has been accelerating since 2011, with an average annual growth rate of 28% during 2011-2017. At present, wind power capacity in eastern and central regions was 43.17 million kilowatts, accounting for national wind power total capacity of 27%. In 2017, ratio of new installed wind power capacity in eastern and central regions in national new installed wind power capacity increased from 39% in 2016 to 45%, as a comparison, new installed wind power capacity in northwest China accounted for 22% in 2016 down to 16%.
2.3. Economy
Due to the higher feed-in tariffs and better accommodation situation, economy of wind power projects in eastern and central China is superior to that in north regions, as shown in fig.2. The internal rate of return for new built wind power projects in eastern and central regions in 2017 is estimated to be 8.5% to 13.6%, due to differential adjustment of feed-in tariffs for wind power projects.

3. Adaptability Analysis on China’s receiving power grid with wind power integration
Under the influence of many favorable factors, recent wind power development in China will continue slant to eastern and central regions, and it is expected that wind power capacity in eastern and central regions will be 80 million and 250 million kilowatts in 2020 and 2035 respectively.

3.1. Power planning
By using model given by literature [4], in a national view, wind power development in eastern and central regions will be limited by its resources, and wind power development will mainly be in north China in the future. As shown in fig.3, before 2025, wind power capacity share of eastern and central China in whole nation continues rising, and will be 34% and 38% in 2020 and 2025 respectively. After 2025, wind power development in eastern and central regions will slow down and account for 33% in 2035.

3.2. Power system operation
It is recognized that wind power has the characteristic of reverse output, which is, statistically, always generating less during peak load period and generating more after midnight when power load in valley. Therefore, with large-scale wind power development, there will be much more challenges when power system operating.

Apart from satisfying power demand, especially in peak load time, enough regulating capacity which related to power structure is also needed. Generally, regulating capacity needs to be larger than load valley-to-peak difference with a period of a day, and considering the reverse output characteristic of wind power, load valley-to-peak difference needs to add the wind power valley-to-peak difference. Thus, the concept of regulating capacity surplus can be defined as formula (1).

$$\Delta P_r = P_{r,max} - \Delta L - \alpha \cdot P_{Wind&PV}$$  \hspace{1cm} (1)

In which, $\Delta P_r$ is regulating capacity surplus, $P_{r,max}$ is regulating capacity that can be calculated as formula (2), $\Delta L$ is daily load valley-to-peak difference, $P_{Wind&PV}$ is total capacity of wind power and PV power, and $\alpha$ is a reverse regulating factor, which can be calculated based on statistics of historical power load and wind and PV output data.

$$P_{r,max} = 50\% \cdot P_{coa} + P_{gas} + \beta \cdot P_{hyo} + 200\% \cdot P_{PSH} + 50\% \cdot P_{bio} + 50\% \cdot P_{reciving}$$  \hspace{1cm} (2)
In which, $P_{\text{coal}}$ is capacity of coal power, $P_{\text{gas}}$ is capacity of gas power, $P_{\text{bio}}$ is capacity of hydro power and $\beta$ is regulating factor of local hydro power that can be calculated based on statistics of historical hydro power output data, $P_{\text{bio}}$ is capacity of biomass power, $P_{\text{reciving}}$ is capacity of feed in power transmission lines.

As shown in fig.4, regulating capacity surplus in 2020 and 2035 of each eastern and central China provinces was calculated. In 2020, because annual peak load is in summer, regulating problem always happen in summer, like in Fujian and Hubei. In 2035, with large-scale wind power development, both winter and summer will be hard to regulate, especially in Hebei, Fujian, Hunan and Hubei.

![Figure 4. National wind power development prediction](image)

4. Case study

With large-scale development of wind power and solar power, there will be accommodation problem during certain period of time, like heating period in north regions and high flow period in some south regions. The following analysis are based on power system operation simulation given be literature [5].

4.1. Shandong power grid

Shandong power Grid has the characteristics of increasing nuclear power scale, high share of self-possessed thermal power, limited regulation capacity in heating period and dense HVDC (High Voltage Direct Current Transmission) receiving, which bring big challenge of wind power and solar power accommodation. In 2017, wind power capacity and solar power capacity in Shandong power grid both exceeded 10 million kilowatts, and distributed PV developed rapidly. In 2035, capacity of wind power in Shandong power grid is expected to reach 40 million kilowatts, in the typical day simulation of heating period as shown in fig.5, daily wind curtailment rate will be 8%.

![Figure 5. Shandong power grid operation on typical day during heating period in 2035](image)
4.2. Hunan power grid

Hunan power grid is mainly characterized by largely hydropower which mostly runoff-based hydropower, especially often full of hydropower during high flow period, which lead to the lack of start-up thermal plants and weak grid regulation capacity, also trigger wind power accommodation problem. In 2035, wind power development scale of Hunan power grid is expected to reach 14 million kilowatts, in high flow period (including April, May and June) typical day simulation as shown in fig.6, if give the priority to PV generating, daily wind curtailment rate will be 35%.

![Figure 6. Hunan power grid operation on typical day during high flow period in 2035](image)

5. Conclusion

Generally, recent wind power development in China will continue to slant to eastern and central regions, however, due to limited by wind power resources, north China will be largely wind power developed in a long term. It is expected wind power capacity in eastern and central China to be 80 million and 250 million kilowatts in 2020 and 2035 respectively, accounted for 34% and 33% of national wind power capacity. In power system operation level, there will be wind power curtailment during certain period of time, like heating period in north regions and high flow period in some south regions.

Therefore, developing wind power in the light of local conditions is necessary, especially in eastern and central China. Specifically, an early deployment is needed of areas with weak accommodation capacity, on the other way, positive support should be set for some certain areas which have good resource conditions, strong power distribution grid and already booked market.

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