Research on Characteristics of Coastal Wind Power under Typhoon Environment in Fujian Province

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Abstract. The typhoons that landed or affected Fujian province from 2016 to 2018 are statistically analyzed. The results show that in recent four years, there are two typhoons affecting Fujian province every year on average, and seven typhoons landed and five are super typhoon. Typhoon landing in Taiwan island has a great impact on the coastal wind speed of Fujian province. The wind speed firstly increased and then decreased after entering the Taiwan Strait, and increased again before landing in Fujian province. When the typhoon directly landed, the wind speed continued to increase before landing and decreased after landing. The wind farm responded to the possible impact of the typhoon during the high wind speed, and selectively shut down. When the wind speed exceeded the rated wind speed, the wind turbine automatically cut out. When the wind turbine was not shut down or cut out, the consistency between wind power output and wind speed was relatively high. Before the typhoon landed, the output gradually increased to full power, with the intensity of the typhoon weakening, the output of wind power decreased.

1. Introduction
In recent years, the research on wind power has developed rapidly, but the situation of wind power consumption in the "Three Norths" region of China is still severe[1]. Eastern China is the power load center, with strong power grid structure and good new energy consumption conditions, so the development center of wind power is shifting to the southeast of China. Affected by wind energy resources and geographical conditions, coastal wind power is the main method of wind power development in the east of China[2-3].

The flow of air creates wind, and a typhoon is a spinning cyclone with a lot of energy. The whole typhoon can be divided into several areas and the wind speed in the middle of the cyclone is smaller than other areas, but the outward wind speed around the central area is generally very large and has a strong destructive power [4]. When the wind speed is within a certain range, the wind turbine can be driven to generate electricity with rated power. However, when the wind speed is very large, the wind farms along the way may be destroyed. Therefore, the impact of typhoons on coastal wind power is being paid more and more attention [5].

Hong[6] found that the offshore wind energy potential of China's exclusive economic zones will account for 46% and 42% of the total power demand in the coastal areas, in 2020 and 2030 respectively. Jiang[7] found that compared with other coastal areas in China, the coastal areas of Fujian province have more abundant wind resources, but they are also vulnerable to typhoon impacts,
especially in Fujian Province. Typhoon disasters often occur in summer and autumn, and are characterized by sudden and strong destructive forces, which bring huge risks to large-scale wind power access and the safe and reliable operation of the power grid[8-9].

At present, there are many wind power forecasting methods[10], but few wind power forecasting methods under typhoon environments, because the power characteristics of wind power are not clear and there are many sudden conditions in wind farms[11]. This study mainly focuses on analyzing the wind speed and power variation characteristics of wind farms under typhoon environments, and provides a technical reference for power prediction.

2. Data and methods

Table 1 shows the typhoons that landed or affected Fujian from 2016 to 2019. In the past four years, there are two typhoons affecting Fujian on average, the least in 2018 and the most in 2016. Among them, seven typhoons landed in Fujian and just one typhoon affected. There are five super typhoons, mainly concentrated in 2016.

Three wind farms in the city of Fuqing, Fujian Province are selected as the sample power stations to extract wind speed of 5min and wind power of 1min respectively for analysis. According to the typhoon occurrence time and the quality of wind power operation data, the following four typhoons are analyzed in depth. Among them, the wind farm of Baoying with 62MW (119.38°E,25.13°N) is selected to analyze typhoon "Nepartak". The wind farm of Qianxue with 77.4MW (119.45°E,25.39°N) is selected to analyze typhoon "Maria" and "Bailu". The wind farm of Dingyanshan with 50MW (119.28°E,25.18°N) is selected to analyze typhoon "Lekima".

Table 1. Typhoons that landed or affected Fujian from 2016 to 2019

| Name    | Intensity      | Landing Point | Time         |
|---------|----------------|---------------|--------------|
| Nepartak| Super Typhoon  | Fujian        | 2016 (7-8_11~7-9_15) |
| Meranti | Super Typhoon  | Fujian        | 2016 (9-14_22~9-15_07) |
| Megi    | Super Typhoon  | Fujian        | 2016 (9-27_12~9-28_05) |
| Nesat   | Typhoon        | Fujian        | 2017 (7-29_22~7-30_09) |
| Haitang | Tropical Storm | Fujian        | 2017 (7-31_01~7-31_07) |
| Maria   | Super Typhoon  | Fujian        | 2018 (7-11_01~7-11_10) |
| Lekima  | Super Typhoon  | Zhejiang      | 2019 (8-10_10~8-10_01) |
| Bailu   | Severe Tropical Storm | Fujian | 2019 (8-24_19~8-25_03) |

3. Characteristics of coastal wind power

3.1 Changes in wind speed

Figure 1 shows the time series of coastal wind speeds in the environment of four typhoons which affecting Fujian province.

(1) "Nepartak"

"Nepartak" landed in Taitung of Taiwan with a maximum wind of 60m/s, at 5:50 on July 8, 2016 and landed in the city of Shishi, Fujian with a maximum wind of 23m/s, at 13:45 on July 9, 2016. The wind speed of the Baoying wind farm is shown in Figure 1 (a) during the typhoon landing. The wind
speed of 10m/30m/50m gradually increased before the typhoon landed, and the wind speed consistency was very good. The maximum wind speed of 50m reached 27 m/s and the center point of the typhoon was in the south of Taiwan island at 7:55 on July 8, 2016. The wind speed decreased gradually when the typhoon passes through the Taiwan strait, and then increased about 3 hours before the typhoon landed. After landing, the wind speed decreased obviously with the typhoon weakening.

(2) “Maria”

The center of typhoon "Maria" landed on the Huangqi Peninsula of Lianjiang, Fujian at 09:10 on July 11, 2018. The maximum wind speed near the center was 14 magnitude (42 m/s) with a minimum pressure of 960 hPa. The wind speed of the Qianxue wind farm is shown in Figure 1(b) during the typhoon landing. The wind speed of 10m/30m/50m increased before the typhoon landed, and the wind speed consistency was very good. The maximum wind speed of 50m reached 27.5 m/s, at 10:30 on July 11, 2018, shortly after the typhoon had just landed. With the weakening of the typhoon, there was a clear decline in wind speed.

(3) “Lekima”

In the early morning of August 10, 2019, "Lekima" landed in Zhejiang province with a super typhoon. The maximum wind speed near the center was 16 magnitude (52 m/s), and the periphery wind of the typhoon affected Fujian province. The wind speed of the Dingyanshan wind farm is shown in Figure 1 (c) during the typhoon landing. The wind speed fluctuation of 10m/30m/50m increased and the wind speed consistency was good before landing. The maximum wind speed of 50m reached 9.6 m/s, with little influence on the wind speed fluctuation of the wind farm. As the typhoon landed in Zhejiang province, the intensity gradually weakened, but the wind speed of the wind farm increased.

(4) “Bailu”

"Bailu" landed on the coast of Manzhou Township, Pingtung, Taiwan, at 13:00 on August 24, 2019, with the maximum wind speed near the center was 11 magnitude (30 m/s). It landed again at the coast of Dongshan, Fujian Province at 7:25 on August 25, with the maximum wind speed near the center was 10 magnitude (25 m/s). The wind speed of the Qianxue wind farm is shown in Figure 1 (d) during the typhoon landing. The wind speed of 10m/30m/50m gradually increased before the typhoon landed, and the wind speed consistency was good. The maximum wind speed of 50m reached 22.6 m/s, at 18:00 on August 24, 2019 and then there was a gale period lasting about 7 hours. Before the typhoon landed, the intensity of the typhoon had begun to gradually weaken, and the typhoon wind speed then had a significant decline.

3.2 Changes in wind power

During the typhoon "Nepartak ", the wind power output of the Baoying wind farm is shown in Figure 2 (a). The output of the Baoying (62MW) wind farm is limited with the increasing of wind speed. During the period of high wind speed, the wind farm selectively shut down to deal with the possible impact of typhoon in the future.

During the typhoon of "Maria", the output of the Qianxue wind farm is shown in Figure 2 (b). The output of Qianxue (77MW) wind farm had a high consistency with the wind speed. When the wind speed exceeded 25m/s, the power value decreased significantly. Considering that the wind turbine automatically cut out, the wind turbine output during the typhoon wind was up to 50MW.

During the typhoon of "Lekima", the output of Dingyanshan wind farm is shown in Figure 2 (c). The output of Dingyanshan (50MW) wind farm had a high consistency with the wind speed. Since Fujian province was externally affected by the typhoon "Lekima", the wind speed was not exceed the cut-out wind speed. The wind turbine output during the strong wind was up to 45MW.

During the typhoon of "Bailu", the output of the Qianxue wind farm is shown in Figure 2 (d). Before the typhoon landed, the output of the Qianxue (77MW) wind farm increased with the increase of wind speed, and the maximum power was 68MW. When the typhoon was in the strong wind period for a long time, the electric field selectively stopped, with the wind power output reducing With the wind speed of typhoon decreasing, the consistency between wind power output and wind speed was higher.
Figure 1.  Wind speed changes in different typhoon environments

Figure 2.  Variation of 50m wind speed and wind power under different typhoon conditions

4. Conclusion
The wind speed and power data of typhoons that landed or affected Fujian province from 2016 to 2019 were calculated in this paper. It is found that:
(1) In the past four years, there have been an average of two typhoons affecting Fujian each year, of which seven typhoons landed in Fujian province, just one typhoon affected, and five typhoons directly landed were super typhoons.

(2) Affected by the island of Taiwan, the wind speed along the coast of Fujian province increased when the typhoon landed near Taiwan, and the wind speed decreased after entering the Taiwan Strait. The wind speed increased again before landing in Fujian province and decreased after landing.

(3) When the typhoon directly landed, the wind speed continued to increase before landing, the wind speed decreased or increased before landed. As the intensity weakened, the wind speed began to decrease before the landing, and the wind speed decreased rapidly after landing.

(4) The wind farm responded to the possible impact of the typhoon during the high wind speed, and selectively shut down. When the wind speed exceeded the rated wind speed, the power value was significantly reduced and the wind turbine automatically cut out.

(5) When the wind turbine was not shut down or cut out, the power output of the wind farm was consistent with the wind speed. Before the typhoon landed, the output gradually increased to full power. As the typhoon intensity weakened, the wind speed and power output decreased.

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