Study on Gale Change and Grading for Power Grid Wind Zone in Guangdong Province

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Abstract. In the paper, a temporal and spatial variation characteristic of gale is analyzed based on the data of Guangdong gale stations in recent 54 years. Using Type I extreme value of distribution probability model, the statistical wind speed values of 86 meteorological stations in Guangdong Province are calculated, and the maximum wind speed statistics of 30-year and 50-year return period for Guangdong power grid are completed. According to grading standards of wind zone in Guangdong power grid, a wind-distribution map of power grid and its application principles and recommendations is presented. It play great role in technical supporting for wind disaster prevention of overhead transmission line of Guangdong power grid.

Introduction

In recent years, power grid construction in China has developed rapidly, and the number of overhead transmission line going through areas with complex terrains and adverse weather conditions has been increasing. Along with the frequent appearance of tropical cyclone, strong convection, cold wave and other extreme weathers, the threat of wind disaster fault to safe operation of power grid is increasing [1-3].

Guangdong Province is located in the subtropical zone, it belongs to subtropical monsoon climate[4-5], its terrain is higher in the north and lower in the south, its trend is mainly Northeast-Southwest, and its territory has mountains, valleys, basins, plains, urban agglomerations, coastal terraces and other terrains. The region is in the main path for tropical cyclone to land on mainland China, and gale disaster caused therefrom is one of the most serious natural disasters in the region [4-5]. Therefore, quantitative analysis of gale variation characteristics in Guangdong region and its relationship with wind disaster of power grid has important theoretical and practical significance for disaster prevention and mitigation of Guangdong power grid.

At present, wind resistance design of overhead transmission line mainly refers to wind speeds of various typical weather areas prescribed in Code for Designing of 110~750kV Overhead Transmission Line (GB50545-2010), its wind speed grading is general, and there may be a big difference between actual wind speed and designed wind speed for cross-regional overhead transmission lines. Therefore, it is necessary to carry out research on the distribution of wind speed in various regions of Guangdong, so as to provide scientific basis for the design and transformation of power grid wind disaster prevention project [6-9].

Many researches have been conducted on disaster prevention of overhead transmission lines in Guangdong power grid [10-12], which lays a solid foundation for the drawing of wind-distribution map in Guangdong power grid. This paper has made a statistical analysis to gale data of Guangdong region in recent 54 years, has completed the drawing of Guangdong power grid wind-distribution map based on meteorological data of Guangdong Province, and has given application suggestions of
wind-distribution map in Guangdong power grid. It has important guiding significance and engineering application value for guaranteeing the safe operation of power grid.

**Temporal and Spatial Variation Analysis of Gale in Guangdong Province**

Strong data used in this paper are taken from average daily wind speed, maximum wind speed and extreme wind speed data of ground meteorological stations arranged by Meteorological Information Center of China Meteorological Administration, and data from 86 stations of Guangdong Province during 1961-2014 have been collected.

![Figure 1. The spatial distribution of Maximum wind speed (a) and Super-wind speed (b) in Guangdong from 1961 to 2014 [m/s].](image)

During 1961-2014, spatial southern patterns for spatial distributions (Figure 1.a and Figure 1.b) of annual mean wind speed, maximum wind speed and extreme wind speed in Guangdong Province tend to be consistent, and wind speed presents the tendency of gradually decreasing from southern coast to northern mountain area. Large value centers are mainly concentrated in coastal areas: Jiangmen-Yangjiang-Maoming coastal area, Shanwei-Huizhou-Shenzhen coastal area, Leizhou Peninsula, and Chaoshou-Shantou coast in the eastern part of Guangdong Province. Among them, the central area with the maximum value is located near Shangchuan Island of Jiangmen, its annual mean wind speed is greater than 6m/s, its annual maximum wind speed is greater than 28m/s, and its extreme maximum wind speed is greater than 36m/s.

![Figure 2. The seasonal-interannual variation of gale days (a), mean wind speed (b), Max-wind speed (c) and Surp-wind speed (d) in Guangdong from 1961 to 2014[m/s].](image)

Figure 2 is an interannual-seasonal variation map of average gale days, average wind speed, maximum wind speed and extreme wind speed of Guangdong Province during 1961-2014. It can be seen from Figure 2.a that, the number of gale days in Guangdong Province before 1990s is large, it
had been decreasing from 1961 to around 2000, and gale days were concentrated in March-April and
July-October; since 2000 until now, gale days are mainly concentrated in June-September. It can be
seen from Figure 2.b that, average wind speed of winter half year is obviously higher than that of
summer half year in Guangdong Province, maximum values of general average wind speed are
concentrated in October-March of next year, and July is the month when average wind speed is high
in summer half year. It can be seen from interannual-seasonal variation of maximum wind speed
(Figure 2.c) and extreme wind speed (Figure 2.d) in Guangdong Province that, their
interannual-seasonal variation patterns are very consistent, and their large values are mainly
concentrated in June-October, which is the season when tropical cyclones frequently landing in
Guangdong.

**Wind-distribution Map and Its Grading in Guangdong Power Grid**

The wind-distribution map of power grid is based on ground meteorological data and original wind
speed database. Drawing process of the power grid wind-distribution map is as follows: establish a
standard wind speed database, obtain a basic wind speed database under different return periods
through simulation fitting calculation, formulate wind area grading standard of the region combined
with the actual situation, and comprehensive consider local micro topography, micro climate factors
and operation experience finally.

**Selection and Data Source Description of Reference Meteorological Station**

Basic data used for drawing wind area distribution map includes meteorological data and power
grid operation data, including (1) historical change of Guangdong meteorological station, change of
wind speed observation instrument etc; (2) annual maximum wind speed sequence of meteorological
station; (3) wind speed value and its basis when designing overhead transmission lines with 110 kV
and above of Guangdong power grid; (4) historical wind disaster fault records etc. of overhead
transmission lines with 110 kV and above of Guangdong power grid; (5) micro topography and micro
climate data etc. of Guangdong region.

At present, there are 86 national meteorological stations in Guangdong Province, they are
distributed in places where various municipalities and county administrative centers are located, and
these observation places are mainly distributed in town centers or nearby.

**Wind Speed Data Processing and Analysis**

In the paper, basic wind speed refers to the wind speed determined according to once-in-30-years
and once-in-50-years maximum values obtained through probability statistics, and the probability
statistics are conducted on the basis of average annual maximum wind speed observation data, which
are measured in 10-minute time interval at 10-meter height of 86 national meteorological stations in
Guangdong Province.

When determining the basic wind speed, this paper uses Type I extreme value probability
distribution model. This model has been widely used in power grid ice covered return period,
maximum daily rainfall return period, wind speed calculation of power grid survey and design and
other areas [13-20]. Type I extreme value probability distribution function used in the paper is as
below:

\[
F(x) = \exp\left[-\exp\left[-\alpha(x-u)\right]\right]
\]  

(1)

In which, \(\alpha\) and \(u\) respectively refer to scale parameter and position parameter. For finite samples,
\(\alpha\) and \(u\) can be calculated with the formula as below:

\[
z_i = \ln\left(-\ln\frac{i}{n+1}\right), \quad 1 \leq i \leq n
\]  

(2)
In which, \( \bar{x} \) and \( \sigma \) respectively refer to average value and standard deviation of wind speed data.

When average return period is \( T \) (30 years and 50 years), the maximum wind speed \( x_R \) can be calculated with the formula as below:

\[
x_R = \bar{x} - \frac{1}{\alpha}\ln \left[ \ln \left( \frac{T}{T-1} \right) \right]
\]

In the above formula: \( x_R \) refers to average annual maximum wind speed. Guangdong basic wind speed database is based on the maximum wind speed sequence meteorological data during 1985-2014 (30 years in total) in Guangdong Province, and \( n \) refers to \( C_1 \) and \( C_2 \) corresponding data of the 30 years, so as to calculate the maximum wind speed \( x_R \) when average return period is \( T \).

Table 1. \( C_1 \) and \( C_2 \) values corresponding to different return periods \( T \) of Type I extreme value.

<table>
<thead>
<tr>
<th>( T ) (Year)</th>
<th>( C_1 )</th>
<th>( C_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1.112374</td>
<td>0.536221</td>
</tr>
<tr>
<td>50</td>
<td>1.160661</td>
<td>0.548542</td>
</tr>
</tbody>
</table>

The Grading Standard of Wind Zone in Guangdong Power Grid

Wind zone grading standard of Guangdong power grid has followed the technical principles in Code for Designing of 110~750kV Overhead Transmission Line (GB50545-2010) and Technical Specification for Meteorological Survey of Electric Power Engineering (DL/T 5158-2012), has referred to wind pressure grading and distribution map drawing method of construction industry, and has combined with research findings and line operation experience in recent years. This paper has divided wind speed into 16 grades, which can improve the economy and safety of overhead transmission line design; for wind speed grading value, wind speed grade difference usually takes 2m/s, which can satisfy the use demands of overhead transmission line in design, operation and maintenance.

Based on the above factors and considering Guangdong coastal and inland gale characteristics, grading standard of wind area distribution map in Guangdong power grid can be divided into the 16 grades as follows: 12.0 m/s, 14.0 m/s, 16.0 m/s, 18.0 m/s, 20.0 m/s, 22.0 m/s, 24.0 m/s, 26.0 m/s, 28.0 m/s, 30.0 m/s, 32.0 m/s, 34.0 m/s, 36.0 m/s, 38.0 m/s, 40.0 m/s and >40.0 m/s. Considering the generality and practicability of the wind area map, if basic wind speed is less than 12.0 m/s, then it will be uniformly considered as 12.0 m/s.

When drawing a wind area distribution map, micro-climate and micro topographic effects on wind speed should be considered. For wind area grading of high mountain wind gap, gale zone affected by narrow tube effect and other micro topographies as well as mountain top, canyon, pass, watershed and other micro climate points, one more grade should be increased in principle. For example, for micro topography and micro-climate region with the basic wind speed as 20.0 m/s, wind area grade should be adjusted to 22.0 m/s when drawing a map, and so on.
**Drawing of Wind-Distribution Map for Guangdong Power Grid**

Based on the basic wind speed database established under different return periods in Section 2.2, and according to the grading standard of wind-distribution map in Guangdong power grid determined in Section 2.3, once-in-30-years and once-in-50-years wind area distribution maps of Guangdong power grid have been initially completed. Combined with the historical operation data of wind disaster fault in Guangdong power grid and considering the micro-climate and micro topography data of Guangdong, after local wind area grade is adjusted, the drawing of wind-distribution map is finally completed. As shown in Figure 3.

It can be seen from Figure 3.a that, wind area grade of once-in-30-years wind-distribution map for Guangdong power grid is mainly 16.0 m/s, coastal area is 28.0 m/s, and local area is 32.0 m/s. Among them, the areas with wind speed grading as 16.0 m/s, 24.0 m/s and 32.0 m/s are respectively accounted for 94.5%, 12.6% and 3.8% in total area of Guangdong. Seen from general distribution, Guangdong Province is basically under 16.0 m/s wind area, while 24.0 m/s wind areas are mainly concentrated in the western part of Guangdong Province; Jiangmen-Yangjiang coastal area; Shanwei-Huizhou-Shenzhen coastal area; the eastern part of Guangdong Province; and the central and northern parts of Guangdong Province etc. These areas are basically in the bottom of horseshoe shaped basin and estuary along the coast in Guangdong Province, and terrain is dominated by plain and terrace. Spatial distribution characteristics of Guangdong power grid once-in-50-years wind area distribution map grade (Figure 3.b) is similar to Figure 3.a, so here it will not be described any more.

It can be seen from overall wind zone distribution of Guangdong power grid that, distribution tendencies of once-in-30-years and once-in-50-years wind area maps are basically consistent, and high grade wind areas are mainly concentrated in coastal and surrounding areas, valley zone, plain region, mountain and hilly region of Guangdong Province. Therefore, wind speed distribution in wind-distribution map of Guangdong power grid has a significant correlation with topography and geomorphology of Guangdong.

![Figure 3](image_url)

Figure 3. Wind zone distribution for recurrence period of 30 years(a) and recurrence period of 50 years(a) [Unit:m/s].

**Application of Wind-Distribution Map for Guangdong Power Grid**

**The Distribution Rule of Design Wind Speed for Guangdong Lines in the Coastal Areas**

According to statistics, in the coastal areas of Guangdong, the total length of 500kV lines is about 5213.5km, the total length of 220kV lines is about 9916.5km, and the total length of 110kV lines is about 15019km.
The design wind speed at 35m/s in the case of 500kV line at the height of 20m in 30 years usually; the design wind speed at 35m/s is the most common in 50 years and 10m height; for 220kV and 110kV lines for 15 years The design wind speed at 30m/s and 35m/s is the most common at the height of 15m and 33m/s at 30m.

For the 500kV line, the design wind speed within 5km from the shoreline is more than 35m/s, the ratio is more than 90%, and more than 20% of the line design wind speed exceeds 37m/s; from the shoreline within 5 ~ 20km, the design wind speed is 33m/s ~ 37m/s, the proportion of nearly 80%, and no more than 37m/s design wind speed; when more than 20km from the coastline, the line design wind speed is not greater than 33m/s, the ratio is about 74%. As can be seen from the table, about 60% of the line design wind speed within 35 km from the coastline is 35.8 m/s. This is because the coastline design wind speed before 2008 is basically 40 m/s (20 m above ground) . Converted to 10m reference height of 35.8m/s.

For the 220kV line, the design wind speed within 5km from the shoreline is not less than 32.8m/s, the ratio is close to 100%, and 40% of the line design wind speed is over 32.8m/s; within 5-20km from shoreline, The design wind speed of the line is not more than 30m/s, the proportion is about 30m/s ~ 33m/s, the ratio is close to 90%, only the individual line design wind speed exceeds 33m/s; 70%. From the table, we can see that about 60% of the line design wind speed within 20km from the coastline is 32.8m/s. This is because the design wind speed of the coastal area in 2008 is 35m/s (15m above ground) Converted to 10m reference height of 32.8m/s.

The Application Suggestions of Wind-distribution Map for Guangdong Power Grid

The wind speed given in this paper is basic wind speed, and because the effect of micro-topography and micro-climate region on designed wind speed is large, the drawing of power grid wind area map cannot be accurate to all micro topography and micro climate regions. Therefore, in practical application, different micro topography and micro-climate regions along overhead transmission line can be revised according to the relevant standards.

Topography and geomorphology of Guangdong Province are complex and changeable, and their effects on wind speed are complicated. In recent years, meteorological department has set up many regional automatic meteorological stations, which are mostly located in urban area. However, corridors of overhead transmission lines with 110 kV mostly lies in wilderness, sparsely populated and coastal areas. It leads to their field representative is not very good, especially in inland areas, available stations are not many, coupled with very strong locality of wind, so in practical application, micro topography should be revised appropriately according to topographic features. For Guangdong power grid, use suggestions in the process of design and reconstruction (expansion) are as below:

1) Designed wind speed of 110kV and 220kV overhead transmission line for Guangdong power grid should take once in 30 years as the standard, and designed wind speed should not be less than 23.5 m/s; designed wind speed of 500kV overhead transmission line should take once in 50 years as the standard, and designed wind speed should not be less than 27.0 m/s.

2) When overhead transmission lines stretch across steep valley, if encountering dominant wind direction at the entry of valley and wind speed is relatively high, then designed wind speed value should be appropriately increased by 5%.

3) When air flow enters narrow area from open area, due to narrow tube effect, wind speed will increase, and wind speed value can be appropriately increased by 10%.

4) In prominent and open mountain top, gale speed at high altitude cannot be blocked by surrounding mountains, and wind speed is relatively high, then wind speed value can be appropriately increased by 10%.

Conclusion

Through the use of gale station observation data of Guangdong Province in recent 54 years, and based on the objective analysis to gale temporal-spatial variation characteristics of Guangdong region, this
paper has given the wind zone analysis method of Guangdong power grid, has completed the statistics of basic wind speed in different return periods, has determined wind area grading standard of Guangdong power grid, and has completed the drawing of Guangdong power grid wind area map.

(1) Annual gale spatial distribution in Guangdong Province presents obvious regional difference, in which, the number of gale weather in coastal areas is greater than that in inland areas. During 1961-2000, gale days and maximum wind speed in the five gale prone regions of Guangdong had the tendency of decreasing significantly, but it has changed to a significant increase again in recent 15 years.

(2) Area division is based on multi-year meteorological observation data, and extreme value model is used to conduct mathematical modeling, so that wind area grade division results of Guangdong power grid are formed. Wind area grade has prescribed the basic wind speed of return period in different regions, which can be used as a reference for design, planning, operation and maintenance of power grid overhead transmission line.

(3) It can be seen from wind area maps of 30-year and 50-year return periods in Guangdong Province that, the areas with the wind speed as 18-28 m/s are accounted for the largest proportion in Guangdong Province, which is about 70% or more, and they are mainly distributed in inland special topography and coastal areas.

(4) When using the wind area map of power grid, micro topography, micro meteorological environment and peripheral running line status should be fully considered.

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