Research on wind load characteristics of conductors in transmission lines of Gansu power grids

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Abstract. The distribution characteristics of wind speed and the features of wind load of transmission lines in Gansu Province are studied on the basis of the statistical data observed by meteorological stations and the results of CFD simulation. Research shows that most areas of Gansu are in the gale region where the average wind speed is higher than 17.2 m/s, and the transmission lines are highly stressed; the wind load coefficients of smooth round conductors are 1.12 and 1.18 respectively when the average wind speed is 20 m/s and 30 m/s; under gale weather conditions, type conductors and smooth conductors mostly happen to large wind deflection, while round stranded conductors are in the state with random vibration and wind deflection coexisting.

1. Introduction

Typical wind-induced disasters to conductors include aeolian vibration, wind deflection, waving, sub-span oscillation, wind swing, etc. The phenomenon of wind-induced vibration happened to conductors has become a major form of disaster that jeopardizes the safe and stable operation of transmission lines in China [1]. Passing through the gale region in Northwest China, the phenomena of wind-induced disasters suffered by power grids in Gansu are particularly serious and severely threaten the safe and stable operation of the lines every year.

At present, the design values of wind loads borne by conductors are mostly based on the limited results of wind tunnel tests of smooth round conductors [2-3], which are limited to some extent when come to application and hardly apply to all types of wind fields and conductors. In this paper, the statistical characteristics of wind fields in the gale region in Northwest China represented by Gansu are firstly researched and then CFD simulation models are built accordingly for different types of conductors based on the ADINA platform to study flow features of wind loads around conductors and thus provide the basis for wind resistance design of transmission lines in this region.

2. Statistical Characteristics of Wind Fields in Gansu

2.1. Calculation Principle for Maximum Wind Speeds with Varying Reoccurrence Periods

The maximum wind speeds in 10min of every meteorological station with the reoccurrence periods of 30, 50 and 100 years are calculated with the type-I distribution function of extreme values...
recommended in the enterprise standard Classification Criteria for Wind Region and Drawing Rules for Wind Distribution Map (QGDW11005-2013) of State Grid Corporation of China[4].

The distribution function for type-I probability distribution of extreme values is:

\[ F(x) = \exp \left\{ -\exp \left[ -a \left( x - u \right) \right] \right\} \]

(1)

Wherein: \( u \) is the location parameter of distribution, i.e. the mode of the distribution; \( a \) is the scale parameter of distribution.

\[ v = \frac{\sum_{i=1}^{n} v_i}{n} \]

(2)

\[ \sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (v_i - \bar{v})^2} \]

(3)

\( U \) and \( a \) are decided with the average value and standard deviation obtained from the above formula, i.e. \( u = v - \frac{c_2}{a} \) and \( a = \frac{c_1}{\sigma} \); \( c_1 \) and \( c_2 \) are coefficients, of which the values can be found according to the maximum wind speed over \( n \) years. The maximum wind speed with the reoccurrence period of 100 years can be decided with the formula below:

\[ V_{100,\text{max}} = u - \frac{1}{a} \ln \left[ \ln \left( \frac{100}{100} - 1 \right) \right] \]

(4)

The maximum wind speed with the reoccurrence period of 50 years can be decided with the formula below:

\[ V_{50,\text{max}} = u - \frac{1}{a} \ln \left[ \ln \left( \frac{50}{50} - 1 \right) \right] \]

(5)

The maximum wind speed with the reoccurrence period of 30 years can be decided with the formula below:

\[ V_{30,\text{max}} = u - \frac{1}{a} \ln \left[ \ln \left( \frac{30}{30} - 1 \right) \right] \]

(6)

2.2. Statistics of Average Wind Speeds of Meteorological Stations

![Figure 1. Statistics of Annual Average Maximum Wind Speeds of Meteorological Stations in Gansu](image_url)
There are many gale days in Northwest China and the gale often lasts for a long time. More than 70% of the region has the annual gale days of not less than 10 days. The research team collected and sorted the maximum wind speed data observed by 80 meteorological stations of state level in Gansu Province for more than 30 years and calculated the distribution of average maximum wind speeds in 10 min of every meteorological station with the reoccurrence periods of 30 years, 50 years and 100 years based on the type-I distribution function of extreme values, as illustrated in Figure 1 and Figure 2 separately.

Figure 2. Distribution of Maximum Average Wind Speeds with the Reoccurrence Period of 50 Years.

It can be drawn from Figure 1 and Figure 2 that a total of 72 stations in Gansu Province have the annual average wind speed of 17.2m/s, accounting for 90%; among them, 5 stations have the annual average wind speed of more than 30m/s and 67 stations have the annual average wind speed from 17.2m/s to 30m/s, which shows that most areas of Gansu Province fall within the gale region with the annual maximum average wind speed not lower than 17.2m/s and transmission lines are highly stressed.

3. Wind Load Characteristics of Conductors under Gale Conditions

3.1. Wind Load Adjustment Coefficient

Due to the long-term suffering from a high level of wind speed, the vibration response characteristics of conductors in the gale region in Northwest China are different from other regions. On the one hand, standard values of basic wind pressure in some areas need to be increased according to the actual conditions in the design of transmission lines in the gale region in Northwest China, i.e. to be converted based on the new statistical maximum average wind speed; on the other hand, the change rule of pneumatic pressure of conductors under high wind speed needs to be further defined in accordance with the results of CFD simulation[5-6] so as to further specify load adjustment coefficients for conductors in this region.

Figure 3. Wind Load Adjustment Coefficient with V=20m/s.
Figure 4. Wind Load Adjustment Coefficient with $V=30\text{m/s}$.

It can be drawn from Figure 3 and Figure 4 that the pneumatic load adjustment coefficient of smooth round conductors increase from 1.12 to around 1.18 with increasing wind speed. Different from smooth round conductors in actual lines, type conductors and round stranded conductors require in-depth research with further simulations and tests.

3.2. Effect of Conductor Sections on Wind Load Distribution

In view of gale conditions in Gansu region, three typical forms of conductor sections, namely smooth round conductors, round stranded conductors and type conductors, are selected for CFD calculation. They are respectively exerted with the inlet speed with the average wind speed of 20m/s and 30m/s for 10 min and applied with 10% turbulence. The maximum instantaneous simulated wind speed is expected to be not lower than 50m/s. The distribution characteristics of their wind pressure are as illustrated in Figure 5 and Figure 6.

![Figure 5](image)

(a) Smooth Round Conductor

(b) Round Stranded Conductor

(c) Type Conductor

Figure 5. Instantaneous Wind Speed Distribution with $V=20\text{m/s}$ and $t=2\text{s (m/s)}$. 
Figure 6. Instantaneous Wind Speed Distribution with V=30m/s and t=2s (m/s).

It is drawn from the figures that vortex shedding effects of smooth round conductors, round stranded conductors and type conductors all begin to weaken once the average wind speed reaches 20m/s and above, especially evident for type conductors and smooth round conductors, followed by round stranded conductors. As the wind speed reaches 30m/s, the type conductors only have a trailing vortex near the conductors, and the downstream wind pressure is almost evenly distributed; the smooth round conductors are close to the type conductors, of which the downstream distribution gradient of wind pressure is also small; the round stranded conductors still have a small amount irregular trailing vortex. This shows that for type conductors or smooth round conductors, they mostly undergo substantial wind deflection and displacement at an average wind speed under gale conditions, but with significantly weakened vibration effect; while the round stranded conductors will be in a state with random vibration and substantial wind deviation coexisting, thus they are more likely to be damaged.

4. Conclusion

The distribution characteristics of wind speed in Gansu Province and the features of wind load borne by conductors there are researched in this paper based on the statistics of observation data and the results of CFD simulation, which shows that most areas in Gansu are in the gale region where the average wind speed is higher than 17.2m/s; taking the smooth round conductor as an instance, its wind load adjustment coefficients are 1.12 and 1.18 respectively corresponding to the average wind speeds of 20m/s and 30m/s; under gale weather conditions, type conductors and smooth round conductors mostly happen to wind deflection and displacement, while round stranded conductors are in the state with random vibration and wind deflection coexisting, which are more vulnerable to damage.
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