Overview and Analysis of Sandstorms in Gansu Province During the ± 1100 kV Ultra-High Voltage Direct Current Transmission Project from Zhundong to East China

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Abstract. In order to analyze the impact of sandstorms on EHV and take effective measures to weaken the impact of sandstorms on HVDC, SPSS and ArcGIS software are used to analyze sandstorms at 18 stations along the Zhundong-East China ± 1100 kV EHV DC transmission line through Gansu. The error bar chart and frequency distribution chart of the sandstorm are drawn, which provides a certain basis for the construction and design of Zhundong-East China ± 1100 kV EHV DC transmission line through Gansu.

Keywords: sandstorms;transmission;Voltage

1 Introduction

Dust storms mainly occur in deserts and adjacent arid areas. There are four major dust storm areas in the world: Central Asia, North America, Central Africa, and Australia. Northwest China is part of the Central Asian dust storm area. The arid areas in northwest China include Xinjiang, Gansu, some parts of Ningxia, and western Inner Mongolia. The arid areas with harsh natural environments are prone to sandstorms in China [1-3]. The ± 1100 kV ultra-high voltage direct current transmission line from Zhundong to East China passes through 7 urban areas in Gansu Province. When sandstorms occur, the friction between sand and dust particles will generate a strong electric field in space, which will affect the insulation performance of the transmission line and thus affect the safe operation of the transmission line. Due to the electrostatic dust effect of DC transmission, the pollution accumulation and flashover characteristics of insulators are significantly different from those of AC, resulting in more severe pollution discharge than AC. Therefore, it is necessary to analyze the sand and dust storm situation of the Zhundong-East China ± 1100 kV ultra-high voltage DC transmission line passing through Gansu regions.

The analysis of ± 1100 kV ultra-high voltage direct current transmission lines at home and abroad mainly focuses on literature [4] in which the conductor design of ± 1100 kV ultra-high voltage direct current transmission lines was studied according to electromagnetic environmental conditions, and only the conductors of transmission

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lines that meet electromagnetic environmental requirements were analyzed while minimizing costs. In [5], the conductor selection for the Gansu North section of the Zhundong-East China ± 1100 kV ultra-high voltage direct current transmission line project was analyzed. The aluminum cross-section of the conductors of the ± 1100 kV ultra-high voltage direct current transmission line was selected through electromagnetic environment and technical economic comparison. In [6], the ground-to-ground and crossing distance of the ± 1100 kV ultra-high voltage direct current transmission line was analyzed. The electric field effect was calculated for different conductor cross-sections, split numbers, and split spacing, and the ground-to-ground and cross-crossing distance and corridor width of the ± 1100 kV ultra-high voltage direct current transmission line was provided. The above literature has analyzed the electromagnetic environment, wire selection, and electric field effects of ± 1100 kV ultra-high voltage direct current transmission lines, without analyzing the factors that affect the performance of insulators at wire connections.

In [7-9], the spatial distribution characteristics of sandstorms and floating dust weather in Gansu Province over the past 30 years were analyzed, and frequency distribution maps of sandstorms in various regions of Gansu Province were not drawn.

As a catastrophic weather event [10-13], sandstorms not only cause great harm due to their strong winds and dense dust but also often lead to phenomena such as high-voltage ignition, power grid tripping, and communication interference when sandstorms pass through. This reflects the high potential generated at both ends of the wire during the passage of sandstorms. This high potential can affect communication quality in light cases and in severe cases, and lead to signal interruption and sometimes even breakdown of line equipment, endangering personal safety and causing major accidents.

As the strong wind above carries these gravels toward the destination [14-18], the wind drops to the point where it cannot continue to lift the gravel forward, causing outdoor power transmission lines to be buried. It can cause outdoor transmission lines to be compressed by a large number of foreign objects, and in severe cases, it can cause deformation and fracture of their supporting materials. Thus, it will weaken the heat dissipation effect of power equipment such as oil-immersed transformers installed outdoors.

The insulation is greatly affected by the concentration of impurities in the air. Due to strong wind and dust weather, the amount of pollutants in the air increases. This is not only harmful to human health but also leads to a decrease in air insulation performance, which also leads to a reduction in the creepage distance of insulators due to pollution [19-21].

When the gravel is carried by strong winds, the speed generated by the gravel is too fast after being subjected to strong enough winds. This can cause serious harm to transmission equipment that requires a smooth surface to improve insulation effectiveness, such as insulators, silicone, etc., ultimately leading to a decrease in insulation effectiveness and even causing surface discharge of insulators [21-25].

This article takes the data from 18 stations in Gansu Province over a decade (2014-2023) as the analysis object. After using the data exclusion method based on the Normanovsky criterion to remove the data from the decade, SPSS software and

ArcGIS software are used to analyze the data from 18 stations in Gansu Province, and error bar charts and frequency distribution maps of sandstorms are drawn. On this basis, the frequency distribution of sand and dust occurrence at 18 stations is analyzed, and the number of sand and dust days at each station is statistically analyzed.

The ± 1100 kV ultra-high voltage direct current transmission line project from Zhundong to East China starts from the Jiangjunmiao converter station in Zhundong, Xinjiang, and ends at the Wannan converter station in Anhui. The line passes through six provinces, including Xinjiang, Gansu, Ningxia, Shanxi, Henan, and Anhui, with a total length of about 3256.5 km, an aviation line length of 2963.8 km, and an altitude of 0-2300 m. The line has a tortuosity coefficient of 1.1, and the transmission end converter station is connected to the 750 kV AC power grid. The receiving converter station is layered and connected to the 500/1000 kV AC power grid. The longest span in this project is in Gansu Province, reaching 1276.9 km. The ultra-high voltage project passes through Jiuquan City, Zhangye City, Jinchang City, Wuwei City, Baiyin City, Qingyang City, and Pingliang City in Gansu Province.

2 Mathematical Comprehensive Analysis Method of Sand and Dust in Gansu Province Based on SPSS and ArcGIS Software

The ground station data comes from the dataset of the Gansu Provincial Meteorological Bureau, and its climate data consists of sand and dust data from 11 stations from 2014 to 2023. Firstly, the sand and dust data from 181stations from 2014 to 2023 are screened by using the Normanovsky criterion to eliminate invalid and incorrect data. Then, the meteorological data of 11 stations are analyzed by using SPSS software. Finally, the weather conditions of these 11 stations over the past ten years are examined, and ArcGIS software is used to draw frequency distribution maps of sand and dust at 11 stations along the Zhundong-East China ± 1100 kV ultra-high voltage direct current transmission project route. This article adopts the data exclusion method of the Normanovsky criterion, SPSS, and ArcGIS software analysis methods.

2.1 The Data Exclusion Method of the Normanovsky Criterion

During the data collection process, significant errors may occur due to operator errors, external conditions, and other factors. Measurement data containing gross errors is a serious distortion of measurement data and must be eliminated to ensure the accuracy of data processing.

When the sampling frequency is small ($n \leq 10$), applying the Romanovsky criterion to process data can obtain stable and reliable data processing results. This article uses the Normanovsky criterion to process and analyze the monthly dust data of 11 stations from 2014 to 2023 ($n=10$), removing erroneous data.

2.2 Analysis Method Based on SPSS Software

The SPSS (Statistical Product and Service Solutions) is a software for statistical product and service solutions. The initial full name of the software is Solutions Statistical Package for the Social Sciences.

On the basis of removing erroneous data by using the Normanovsky criterion, this article conducts a statistical analysis of dust and sand data from 11 stations over a decade by using SPSS software and obtains the changing trends of each station.

The ArcGIS product line provides users with a scalable and comprehensive GIS platform. ArcObjects contain a wide range of programmable components, ranging from fine-grained objects to coarse-grained objects, which integrate comprehensive GIS functionality for developers, such as map objects interacting with existing ArcMap documents.

This article analyzes the data of 11 stations over a decade based on desktop ArcGIS and draws the overall distribution map of sand and dust at 11 stations. The distribution map can intuitively show the changing trends of sand and dust at each station.

3 Results and Discussion

To analyze the trend of sand and dust changes in the Gansu region along the Zhundong-East China ± 1100 kV ultra-high voltage direct current transmission project line, error bar charts and frequency distribution maps are drawn based on SPSS and ArcGIS software for sand and dust data from 11 stations. An analysis is conducted on the sand and dust error bar charts and frequency distribution charts of 11 stations.

3.1 The Analysis Results and Discussion Based on SPSS Software

Table 1. Statistics of sandstorms at 11 Stations.

Region Name	Number of Years	Month												Total Days
		1	2	3	4	5	6	7	8	9	10	11	12	
Dunhuang	2014-2023	1	2	5	13	12	0	3	0	2	1	0	1	39
Anxi	2014-2023	0	0	2	8	5	1	3	1	1	0	0	0	21
Yumeng	2014-2023	1	2	1	9	4	1	1	1	1	0	0	0	21
Jinta	2014-2023	1	6	9	17	6	2	2	3	2	0	0	0	48
Jiuquan	2014-2023	0	4	2	18	4	1	0	0	0	0	0	0	29
Gaotai	2014-2023	0	1	3	8	1	1	2	2	0	0	0	0	18
Gulang	2014-2023	0	0	0	0	0	0	0	0	0	0	0	0	0
Minqin	2014-2023	1	3	9	13	13	7	1	2	0	0	0	3	52
Jintai	2014-2023	0	0	3	6	1	2	0	0	1	0	0	1	14
Jinyuan	2014-2023	0	0	0	0	0	0	0	0	0	0	0	0	0
Jinchuan	2014-2023	0	0	0	0	0	0	0	0	0	0	0	0	0

Sandstorm refers to a weather phenomenon where strong winds blow up dust and sand on the ground, making the air very turbid and the horizontal visibility less than 1 km. The specific data is shown in Table 1.

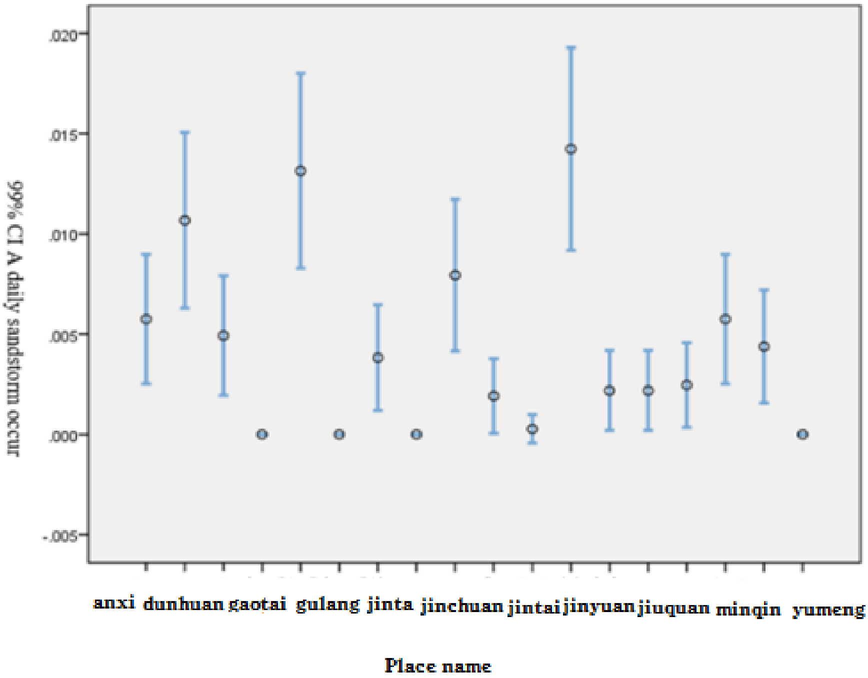

Fig. 1. Error bar chart of 11 stations in Gansu Province from 2014 to 2023.

The vertical axis in the above Figure 1 integrates ten years of data, with the average number of days of sandstorms occurring in each location. The horizontal axis represents 11 locations in Gansu Province. From the above chart, it can be concluded that the probability of sandstorms occurring in Minqin, Jinta, Dunhuang, and Jiuquan is relatively high, with a typical annual duration of 29 to 52 days. The probability of sandstorms occurring in Yumen Town, Anxi, Gaotai and Jingtai varies greatly, with a typical duration of 16 to 21 days throughout the year. The probability of sandstorms occurring in Jintai is relatively low, usually lasting for one day throughout the year. There have been no sandstorms in Gulang, Jingchuan, Jingyuan .

3.2 Analysis Results and Discussion Based on Arcgis Software

In order to further analyze the spatial distribution and frequency of sand and dust (sandstorms, floating dust, and blown sand) at various stations, this paper uses ArcGIS software to draw frequency distribution maps of sand and dust for ± 1100 kV ultra-high voltage direct current transmission line passing through 7 urban areas in Gansu.

The frequency distribution map of ± 1100 kV ultra-high voltage direct current transmission line passing through 7 urban areas in Gansu is as follows.

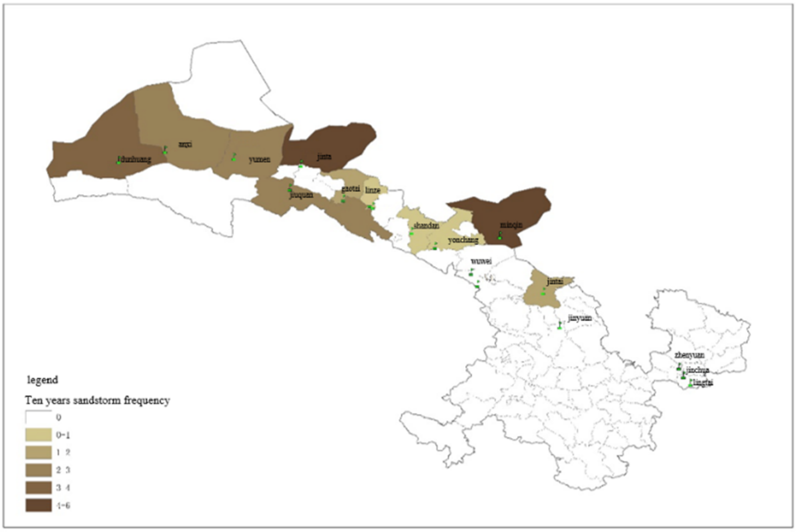

Fig. 2. Distribution of sandstorm frequency in the regions along the line.

From the frequency distribution map of sandstorms along the line in Figure 2 above, it can be seen that the frequency of sandstorms is very high in areas such as Dunhuang, Jinta, and Minqin, with more occurrences of sandstorms. Jingyuan, Jingchuan, and Lingtai hardly experience sandstorms.

4 Conclusion

This article is based on data from the Gansu Provincial Meteorological Bureau and comprehensively uses SPSS and ArcGIS software to analyze the sandstorms of the ± 1100 kV ultra-high voltage direct current transmission line passing through 7 urban areas in Gansu Province.

Based on the results and discussions presented above, the conclusions are obtained as below:

(1) The research results show that Dunhuang, Jinta, and Minqin are areas with a high incidence of sandstorms. When designing and constructing the ± 1100 kV ultra-high voltage transmission line passing through Gansu, special attention should be paid to areas with high incidences of sandstorms.

(2) The impact of sandstorms on the air gap of iron towers and the discharge characteristics of insulators should be fully considered.

(3) It is concluded that the sealed equipment and stainless steel outdoor shell should be used as much as possible.

(4) It is concluded that the equipment manufacturers should be required to thicken the glaze layer on insulators to improve their surface resistance to sand and dust and at the same time, strengthen the cleaning work of substations.

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