Influence factor analysis of atmospheric electric field monitoring near ground under different weather conditions

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Abstract. Monitoring of atmospheric electric field near ground plays a critical role in atmospheric environment detecting and lightning warning. Different environmental conditions (e.g. buildings, plants, weather, etc.) have different influences on the data’s coherence in an atmospheric electric field detection network. In order to study the main influence factors of atmospheric electric field monitoring under different weather conditions, with the combination of theoretical analysis and experiments, the electric field monitoring data on the ground and on the top of a building are compared in fair weather and thunderstorm weather respectively in this paper. The results show that: In fair weather, the field distortion due to the buildings is the main influence factor on the electric field monitoring. In thunderstorm weather, the corona ions produced from the ground, besides the field distortion due to the buildings, can also influence the electric field monitoring results.

1. Introduction

The atmospheric electric field is generated by the earth and the charged particles in atmosphere above the earth surface. Monitoring of the atmospheric electric field close to the ground surface is an essential part of atmospheric environment detecting and lightning warning [1-4]. Especially under thunderstorm conditions, the atmospheric electric field, as a diagnostic tool, can reflect the evolution of the charged centers in the thundercloud [5]. Moreover, the atmospheric electric field is generally monitored by a detection network, and the data’s coherence among different detection positions is the key issue in the detection network. However, the electric field close to the ground surface is susceptible to the surface features, humidity, lightning, precipitation, etc. [6-7]. According to the instruction manual of the lightning warning system in the Cape Canaveral air force station, the installation location requirements of the field mill is too exacting to be fulfilled [7]. At present, in order to ensure the coherence of the monitoring data in the detection network, only a modification based on the surface features is performed [8]. The influence of different weather conditions on the modifying factor is usually ignored. In this paper, in order to study the main influence factors of atmospheric electric field monitoring under different weather conditions, the electric field monitoring data on the ground and on the top of a building are compared in fair weather and thunderstorm weather respectively. The research result can provide a basis and guidance for improving the accuracy and coherence of the electric field monitoring data from multiple sites.

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2. Atmospheric electric field monitoring instruments and experimental setting

At present, for low-frequency or slowly varying electric field monitoring, the electric field sensor based on charge induction is widely used [9-12]. This type of sensor, with high stability, is suitable for electric field monitoring in the harsh environment such as low temperature, moisture and mechanical oscillations. In this paper, two electric field mills with a resolution close to 5 V m⁻¹ in a range of ±50 kV m⁻¹ are adopted to monitor the atmospheric electric field. Furthermore, in order to eliminate the zero drift and linearity error of the sensors, the two field mills are both calibrated before the comparative experiments. The calibration curves of the two field mills are presented in figure 1. As follows from figure 1, the two field mills show good accordance in the electric field measurement and exhibit good linearity in the measuring range.

According to the existing experimental conditions, the experimental setting of the electric field mills under different weather conditions is depicted in figure 2. The field mill EM1, located on the top of the building with a height of 15 m, is used to monitor the electric field on the top of the building. The field mill EM2, located on the ground away from the building with a distance of 25 m, is used to monitor the electric field on the ground. The surrounding regions of the field mills are flat, open and clear, which can eliminate the influence of environmental factor on the experimental results to the maximum extent.

3. Comparative experiments of electric field monitoring under different weather conditions

3.1. Comparative experiment in fair weather

In normal conditions, the atmospheric electric field is down directed in fair weather and in the pure air. The charged particles, such as light ions, heavy ions in the atmosphere, and the negative charge in the earth are the main origins of the atmospheric electric field. In the urban areas, the atmospheric electric field is a quasi-static field with statistical intensity, close to the ground surface, of 130 V m⁻¹. Moreover, the atmosphere electric field in fair weather always varies with the time and space, because of the influence of meteorological phenomena, geographical conditions, solar activity, etc. In general, the atmospheric electric field has a negative correlation with the atmospheric conductivity in fair weather. As the light ions concentration, which is closely related to the atmospheric conductivity, has a negative correlation with the atmosphere aerosol concentration which is in accordance with the atmospheric temperature inversion, the comparative experiment of electric field monitoring in fair weather is performed at the time with slight temperature fluctuation on a clear day. The ambient temperature during the experimental period is presented in figure 3. It can be seen from figure 3 that
the average temperature during the experimental period is about 27.5 °C, and the fluctuation range is no more than 1 °C. Comparison of the electric field monitoring results between the two positions is shown in figure 4.

![Figure 3. Ambient temperature during the experimental period.](image1)

![Figure 4. Comparison of the monitoring results between the two positions on a clear day.](image2)

According to the statistical calculation on the atmospheric electric field in figure 4, the average atmospheric electric field on the ground in fair weather is about 637 V m⁻¹, with a standard deviation of 73 V m⁻¹. This statistical value is much larger than the present statistical intensity of 130 V m⁻¹ in the urban areas mainly for the following reasons: 1) there are obvious spatial-temporal differences for the atmospheric electric field distribution. 2) The statistical value of the atmospheric electric field in fair weather, with intensity of 130 V m⁻¹, is obtained in the case that the sensor surface of the field mill is located in the same surface with the ground surface. However, the electric field monitoring instrument EM2 in this experiment extends out from the ground, which will inevitably lead to the distortion of the electric field near the sensor.

By comparing the electric field on the top of the building with the electric field on the ground in figure 4, it can be seen that the electric field curve on the top of the building is similar to the electric field curve on the ground, only with a coefficient difference. The electric field on the top of the building is distinctly stronger than the electric field on the ground. The average atmospheric electric field on the top of the building during the experimental period is 1.306 kV m⁻¹, with a standard deviation of 0.145 kV m⁻¹, and the ratio of the electric field on the top of the building to the electric field on the ground is about 2. This is mainly due to the distortion effect of the metallic materials and steel mesh of the building on the atmospheric electric field. By employing the finite element analysis software ANSYS, the vertical electric field on the top of the building under a certain background electric field condition can be calculated. Relationship between the enhanced ratios of the electric field
on the top of the building and the horizontal distance between the observation point and the center of
the building at different heights $h$ are shown in figure 5. It can be found that in the position of the
electric field sensor with a height of about 1 m on the top of the building, the enhanced ratio is
approximately 1.9, which is in accordance with the measurement result.

![Enhanced ratio vs Distance](image)

**Figure 5.** Influence of the building to the E-field at different heights.

3.2. *Comparative experiment in thunderstorm weather*

Monitoring of the electric field in thunderstorm weather is especially important to lighting warning. Figure 6 shows the comparison of the electric field monitoring results between the two positions on a thunderstorm day.

![Electric field vs Time](image)

**Figure 6.** Comparison of the monitoring results between the two positions on a thunderstorm day.

As shown in figure 6, during the thunderstorm, the changing trends of the two electric field curves obtained from different monitoring positions are basically consistent. However, the degree of correlation between the two curves in thunderstorm weather is worse than that in fair weather. The fluctuation range of the electric field on the top of the building is significantly larger than that on the ground. By comparing the ratio of the electric field at the key feature points, it can be found that the ratio of the electric field on the top of the building to the electric field on the ground is not stable.
during the thunderstorm. Especially when the atmospheric electric field is strong enough, the ratio of the electric field in thunderstorm weather is much greater than the ratio in fair weather. Note that at the two time slices marked with the elliptical lines in figure 6, the electric fields on the top of the building are not directly proportional to the electric fields on the ground. There are obvious differences between each other not only in quantity, but also in the polarity of the electric fields. This is mainly due to that the corona ions produced from the ground, besides the field distortion due to the buildings, can also influence the electric field monitoring results in thunderstorm weather. When the absolute value of the electric field intensity close to the ground surface is stronger than 1.5 to 2 kV m\(^{-1}\), the point discharge from the ground points with a small curve radius will produce large numbers of positive ions or negative ions. These corona ions have a suppressing action on the atmospheric electric field to a certain extent [13]. And this action decreases rapidly with the increasing altitude.

Furthermore, the electric field close to the ground surface will change suddenly while lightning occurs. The ratios of the sudden electric field change at the two positions are also calculated in this paper, as shown in figure 7. It can be seen from figure 7, the amplitude of the sudden electric field change on the top of the building \(\Delta E_1\) is about the double of that on the ground \(\Delta E_2\). Thus, the distortion effect of the building is the major factor influencing the amplitude of the sudden electric field change. The influence of charged ions from point discharge on the sudden electric field change is slight and can be ignored.

![Figure 7. Ratios of the sudden electric field change at the two positions.](image)

4. Conclusions
At present, monitoring of the atmospheric electric field is influenced by many complex factors. Aiming at this, two electric field mills located at different positions are employed to monitor the atmospheric electric field under different weather conditions. By comparing the experimental result with the simulation result from ANSYS, the main influence factors on the electric field monitoring in fair weather and thunderstorm weather are obtained: In fair weather, the field distortion effect due to the buildings is the main influence factor on the electric field monitoring. In thunderstorm weather, the corona ions produced from the point discharge, besides the field distortion due to the buildings, can also influence the electric field monitoring results. Therefore, traditional modification approach, only modifies the monitoring results based on the surface features, can hardly guarantee the consistency of the monitoring data from multiple sites. Moreover, further research is required on the influence laws of the corona ions produced from the point discharge on the monitoring of the atmospheric electric field.

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