Analysis about the Influence of Terrain on the Fair-weather Atmospheric Electric Field Measurements

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Abstract: When the field mill is located in complex terrain, such as depression and mountain, the measuring error caused by terrain is always difficult to correct, which will lead the deficiency of observation data about comparability and consistency. Aiming at this problem, this paper conducts a simulation with Maxwell 3D software, thereby discusses the distribution of ground atmospheric electric field on the depression and mountain, as well as the influence area of both terrains. The results have a good reference value to the installation and error correction of the field mill.

I INTRODUCTION

As the common equipment for atmospheric electric field detection, field mill can be used in short-term thunderstorm warning by measuring intensity and polarity of the electric field, and the measured date also has great significance in the study of fair weather electricity, thunderstorm electricity and flashing lightning [1, 2]. During the observation, distinct differences always exist in the measuring results of different observation sites and field mills, owing to the influence of instrument and installation environment [3]. If the field mill is located close to tall objects (i.e., buildings, big trees, towers), the field mill reading will be lower due to the shadowing effect of these objects .On the other hand, If the field mill is mounted above the ground or installed at elevated objects, it will suffer from field enhancement [4, 5]. Nowadays, parallel plate calibration [6] and improved field mill component's performance are the preferred methods to improve the veracity of the detective data, but there are no effective correction methods for the error correcting caused by the installation environment, especially when the field mill located in depression and mountain.

Former researchers have thought that, an enhancement factor of 2.75 due to mountain itself with reference to the mountains surrounding terrain [7]. And the influence can be ignored if the distance between observation point and depression (mountain) was 5 times more than the vertical scale of depression (mountain) [8]. However, influenced by various factors, the above conditions are difficult to meet during actual installation [9]. Therefore, in order to provide the reference for the installation and error correction, this paper would analyze the distribution of ground electric field, and the influence area of both terrains with Maxwell 3D software.

II CALCULATION MODEL

As the theory of parallel plate electric field calibration, during the simulation calculation, we have firstly used two pieces of parallel-plate to produce the vertical downward uniform electric field E_0, and the upper plate is set with high potential, the bottom plate and model are set the potential of 0 V. Then, simplified the depression (mountain) into symmetrical ideal model, which is located in the center of the bottom plate. Half length of the plate is 10 times as long as the radius of model, in order to reduce the error caused by the plate's edge, seen as figure 1, the two plates space are 10 times as the height of depression (mountain). The model and the bottom plate are both taken the soil, and relative dielectric constant of soil is set at 10, conductivity at 0.05 S/m, medium between the plates and upper plate are both set as air [10, 11]. Finally, the value of background electric field is set at 200 V/m, considering the influence of aerosols on the atmospheric electric field. Dirichlet boundary condition is adopted and the iteration process would stop while the energy error comes to

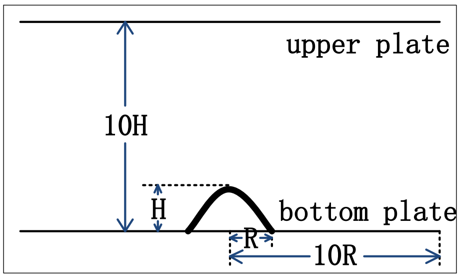


Figure 1.Simplified model for the mountain

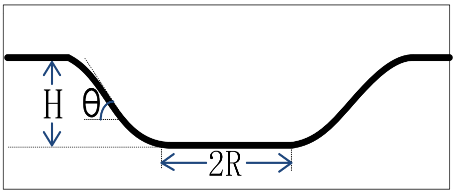


Figure 2.The vertical section of the depression's Simplified model

0.2%. Finally we choose the electric field above the ground at 1m to analysis and discuss.

In addition, we have assumed that the depression is made up of two parts: the circular flat bottom and the surrounding slope. Its structure is shown in *figure 2*. The radius of the bottom is *R*, the vertical distance between bottom and level ground is H, and the gradient of slope is θ.

III SIMULATION RESULT ANALYSIS

A. Distribution of ground atmospheric electric field on the mountain

Nowadays, the widely used field mill generally detect only on the vertical direction of the atmospheric electric field [10]. However, the fine atmosphere electric field has not only the vertical component and also the horizontal one, due to the uneven isopotential surface causing by the fluctuation with the terrain. So we would decompose the simulation field data into vertical component (E_v) and horizontal component (E_h).

As shown in the figure 3, Electric field intensity (E) at the foot of the mountain is smaller than E_0. Along with the mountainside to a certain height, E begins to be greater than E_0, and the maximum value is located at the top, about 2.5 times of E_0. That would give an illustration that, due to the existence of mountain, shadowing effect of electric field obviously existed at the foot of the mountain, while the top has been significantly enhanced. In addition, influence is relatively smaller in the middle to lower part.

In order to make a contrastive analysis , the paper sets up three mountain models with the same height and gradient of 14°(H:R=2:8)、21.8°(H:R=2:5)、33.7°(H:R=2:3). It can be found from *figure 4* that, the distribution of electric field corresponding to the mountains with different gradient are also different, and the horizontal component continues to increase with the augment of the gradient. But the vertical electric field component at the foot of the mountain showed a trend of decrease with the augment of the gradient. Demonstrates that the greater the gradient, the stronger the shadowing effect on the foot electric field. However, the vertical component on the top has no obvious rule. The increase of the gradient may do not necessarily contribute to the increase of vertical component, while the distortion of atmospheric electric field becoming more serious. The increase of electric field on the top may be mainly caused by the horizontal component. As a matter of fact, the distribution of the ground electric field is more complex, due to the uneven mountain's surface.

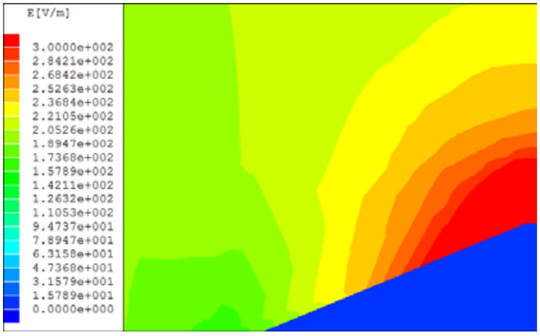
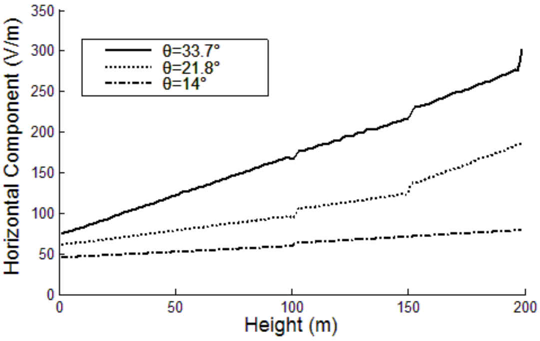
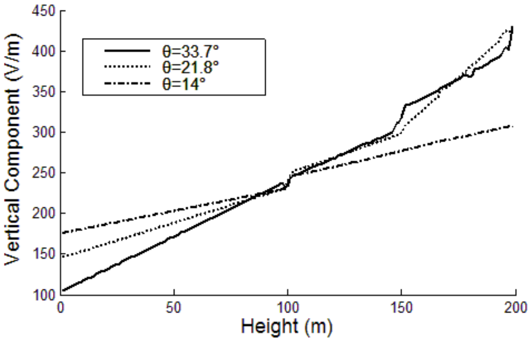


Figure 3.Atmospheric electric field on the mountain and around the mountain



(a) horizontal component



(b) vertical component

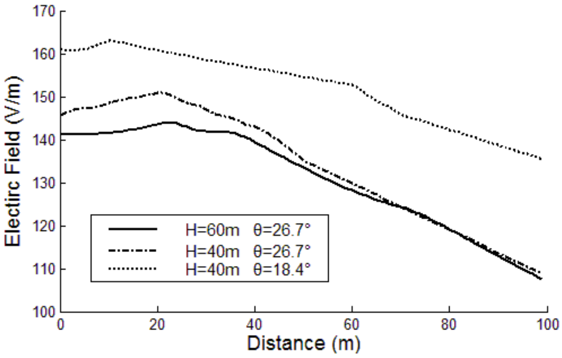
Figure 4.Atmospheric electric field on the mountain with different gradient

B. Distribution of ground atmospheric electric field in the depression

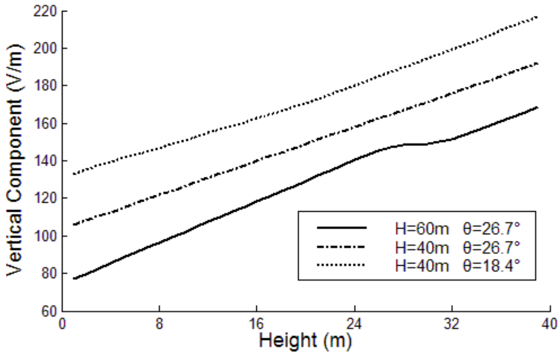
In order to study the distribution of ground atmospheric electric field in the depression, three models of depression have been established , as the slope height H=60m with the slope gradient θ=26.7° (depression A), H=40m with θ=26.7° (depression B), and H=40m with θ=18.4° (depression C) , all the models` bottom radius R=100m.

As shown in *figure 5*, abscissa stands for the distance to the center of bottom, and the bottom is mainly composed of E_v, approximately thinking that E is equal to E_v. However, E is always smaller than E_0. Along the center to the slope, E firstly increases, and then decreases, the minimum is at the junction between the bottom and the slope, after that, the E_v and E_h of the slope are both increasing. Directly reflect that, the existence of depression has weakened the surface electric field of the bottom and some areas lower on the slope.

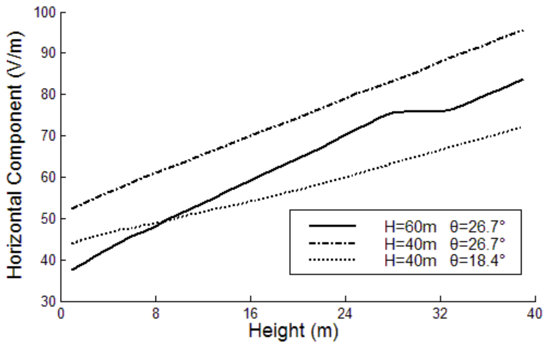
At the same time, through the comparison of electric field distribution curves between depression A and B we have found that, the horizontal and vertical component of A are both smaller than that of B, and the bottom also appears the similar phenomenon, except for the part near the junction area, whose electric field is basically the same. Thus we can conclude that, the higher the height, the stronger the shadowing effect for the slopes with the same gradient.



（a） the circular flat bottom



（b）vertical component on the slope



（c）horizontal component on the slope

Figure 5.Atmospheric electric field in the depression

The same method is used to analyze the differences between depression B and C, which are with the same height and different gradients, the distributions of electric field on them do exist difference, too. The electric field at the bottom of B is obvious smaller than that of C. As for the electric field on the slope , B is generally smaller than C, as the responding vertical component is smaller than C , while the horizontal is bigger than C. As a result, the increase of slope’s gradient can also enhance the shadowing effect, and mainly cause the decrease of the vertical component.

Moreover, with the increase of R, some unaffected areas begin to appear in the center of the bottom, under the condition of keeping the H and θ invariable. If E is equal to95% E_0, we could assume that the atmospheric electric field would not be affected by terrain. Therefore, as shown in *Figure 6*, unaffected areas began to appear when the R increases to 300 m, and with the further increase of R, the unaffected area is also enlarging. The electric field in bottom may obtain the most influence, in case that R equals 0 m, and other conditions keep unchanged.

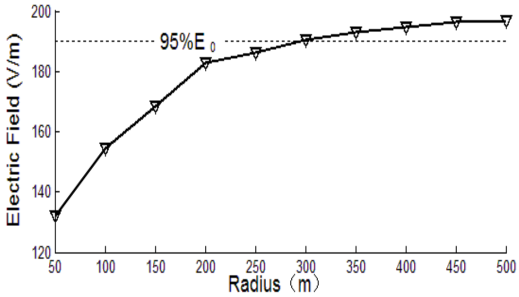


Figure 6.Atmospheric electric field in the center of the bottom along with the change of radius

IV INFLUENCE DISTANCE

The measuring accuracy of field mill generally depends on several factors, such as: instrument measurement precision, influence of terrain environment, influence of heavy weather and so on. Combined with the electric field instrument accuracy and the error of the simulation process itself, we could assume that the atmospheric electric field is not affected by terrain when E is equal to95% E_0. Thus, we can define the influence distance (D) as the distance between the level edge of the mountain (depression) and unaffected point (E=95% E_0), and the corresponding influence coefficient is λ (λ=D/H).

Table 1 shows that λ is almost smaller than 3 with the increase of gradient and the same height of the mountain. Thus, when the distance between observation point and level edge of mountain is more than 3 times compared the vertical height of mountain, the influence on the atmosphere electric field measure of the mountain can be ignored, that was different with the previous conclusion. Compared with the distortion of the electric field of depression, the effect of depression on the field around is not obvious. As it shown in table 2, with L being the distance between the observation point and level edge of depression, the effect on the electric field around the depression has not obvious deviated from E_0, besides a small area near the edge , and it is the same by changing the height of the depression's slope.

Table 1.Influence distance of the mountains with different gradient

θ （°）	14	16	18	22	17	30	34	39	45	53	63
λ	2.2	2.9	2.0	2.3	2.6	3.1	2.9	2.1	2.3	2.5	2.9

Table 2.Atmospheric electric field around the depression (H=100m、θ=45°)

L（**m**）	0	0.5H	1.0H	1.5H	2.0H	2.5H	3.0H	3.5H	4.0H	4.5H
E (V/m)	250.1	205.6	204.7	204.2	203.6	203.2	202.7	202.2	201.7	201.2

V CONCLUSION

In summary, the existence of mountain has an obvious shadowing effect on the electric field at the foot of the mountain, and the increase of the gradient of mountain can enhance the shadowing effect. And the existence of depression has weakened the surface electric field of the bottom and some areas lower on the slope; as for the slopes with the same gradient, the increase of the height would lead to the enhance of the shadowing effect; when comes to the slopes with the same height, the increase of the gradient would also lead to the enhance of the shadowing effect, while mainly cause the decrease of the vertical component.

When the distance between observation point and mountain's level edge is more than 3 times compared the vertical height of mountain, the influence on the atmosphere electric field measurements of mountain terrain can be ignored; as for the installation of field mill around the depression, getting away from the area adjacent to it is the only advice.

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