Study on the Relationship between Acid-rain pH Value and Fog-water Conductivity

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Abstract. Active ions in acid rain may decrease the electrical performance of the insulation outside the electrical equipment. The relationship between acid-rain pH value and fog-water conductivity is studied in this paper. It is found that the acid rain ion component and pH value are very correlated with local air pollution. The pH value and conductivity of sediment water in different areas may be different. The conductivity $\gamma$ -value of acid precipitation decreases with the increase of pH value. The external insulation electrical test can be carried out by adjusting fog water conductivity equivalent simulation of acid wet sedimentation.

1. Introduction
The operating experience shows that the probability of insulator flashover in acidic wet settlement area is significantly higher than that of other areas. The reason is that there may be flashover caused directly by acid wet deposition, or flashover caused by the combination of acid wet deposition, corrosion products and original contamination layer. In order to study the insulator flash characteristics, researchers often need to carry out simulation tests in artificial climate chambers. Acid rain is not only corrosive, but also may cause harm to the human body of the test personnel. The pH value of acid rain using other equal value is of some significance to the simulation test. In this paper, the relationship between acid wet deposition and fog water conductivity is studied. The acidic deposition is equivalent to the fog water conductivity, which provides a reference for the AC flashover test of the polluted insulator in an artificial climate chamber simulated in an acid wet sedimentation environment.

2. Relationship between pH and Ion Content of Acid Deposition
Acid wet deposition refers to rain, fog, dew, snow, etc. in nature, which acidification degree is usually characterized by pH value. When pH is 7, it is neutral; when PH is greater than 7, it is basic; and when pH is less than 7, it is acidic. That is, the smaller the pH, the stronger the acidity. According to local atmospheric environmental monitoring data, with the gradual deterioration of atmospheric environmental quality, the frequency and acidity of acid wet deposition have gradually increased in recent years. There was a case where the pH value of acid wet sedimentation in some areas was less than 3, with a minimum of about 2.8.

As the atmospheric environment deteriorates further, the amount of dry sediments (contamination) in the atmosphere increases year by year. In the dry sediment, $\text{SO}_4^{2-}$ has exceeded 20 times of $\text{NO}_3^-$, which is equivalent to the amount of $\text{Ca}^{2+}$. At the same time, due to the increased application of
fertilizer in rural areas, the content of NH$_4^+$ in the dry sediment is only lower than that of Ca$^{2+}$, and higher than the content of K$^+$, Na$^+$ and Mg$^{2+}$. Because the wet deposition is formed near the ground and can directly absorb a large number of particles in the near-surface atmosphere, there is a strong correlation between the pH value and ion concentration of the wet deposition and the local atmospheric pollution. Domestic researchers have measured and studied the wet deposition in Beijing and Shanghai, as shown in Table 1. It can be seen from the table that the ion content in sediment water varies from region to region, and its pH and conductivity are also different. According to the statistical analysis of atmospheric environmental quality monitoring, it is shown that among rain, fog and dew, the rainwater has the highest acidity, followed by the fog water, and dew is the smallest. Although the acidity of fog water is low, the highest pollution component (ion concentration) can be dozens or even hundreds of times as high as Rain Water's. The variation of acidity of settling water in one year was the largest in winter, the second in spring and autumn, and the smallest in summer.

Table 1. Measured conductivity, pH and main ion composition of fog water in Beijing and Shanghai.

| γ     | pH | F$^-$ | Cl$^-$ | NO$_3^-$ | SO$_4^{2-}$ | NH$_4^+$ | K$^+$ | Na$^+$ | Ca$^{2+}$ | Mg$^{2+}$ | Cu$^{2+}$ |
|-------|----|-------|--------|----------|------------|----------|-------|--------|-----------|-----------|-----------|
| 1280  | 6.22| 20.96 | 30.15  | 640      | 135.7      | 6.0      | 14.4  | 12.6   | 31.0      | 5.6       | 0.1       |
| 1166  | 6.63| 21.82 | 27.36  | 86.3     | 308.8      | 46.15    | 6.8   | 5.3    | 36.2      | 3.3       | 0.09      |
| 1031  | 5.68| 1.40  | 3.95   | 75.0     | 222.0      | 77.0     | 6.6   | 1.7    | 22.2      | 1.0       |           |
| 2310  | 5.4 | 7.91  | 39.56  | 136.8    | 933.1      | 331.7    | 15.5  | 6.5    | 86.0      | 14.4      | 0.02      |
| 798.0 | 6.5 | 8.38  | 14.75  | 68.8     | 228.4      | 30.6     | 6.0   | 2.2    | 25.6      | 2.4       |           |
| 943.0 | 6.6 | 4.64  | 5.31   | 56.3     | 354.8      | 44.5     | 6.6   | 4.4    | 52.6      | 2.5       |           |

Although the acidity of precipitation in urban area is generally higher than that in suburbs, due to the action of wind direction and air flow, the pH value of far-suburb is lower than that of urban and suburb. There is even a case where the acidity of the ocean spot in far-suburb is higher than the highest monthly acidity in urban. Therefore, in the rural and hilly areas of the far-suburb, although it belongs to the clean area or slightly polluted area from the viewpoint of equivalent salt density, it does not take into account the factors that increase the surface conductivity of insulators caused by acid fog, dew and drizzle. In winter and spring, the probability of flashover may increase due to the large content of salt deposited on the surface of insulators and the high acidity of settling water.

In summary, the ion components and pH values in wet settling water are closely related to local air pollution. The pH value and conductivity of settling water in different areas may be different. The pH value of settling water is mainly the result of the comprehensive equilibrium of NO$_3^-$, SO$_4^{2-}$, NH$_4^+$, Ca$^{2+}$ and other ions.

3. Relationship between pH Value and Conductivity of Acidic Deposition

In order to find out the relationship between the pH value and the conductivity of the acid wet settling water, a certain amount of H$_2$SO$_4$ is added into a beaker filled with tap water to make it fully mixed. The acid water with different pH value is prepared. The pH value and the conductivity γ-value of the acid water are respectively measured by an acid meter and a conductivity meter. The relation curve is shown in Figure 1. It can be seen from Figure 1 that the conductivity γ-value of acid precipitation decreases with the increase of pH value, and finally tends to the γ-value of neutral precipitation. The curve in Figure 1 is fitted to obtain the equation:

$$\gamma = 13423.01 \exp(-1.225\text{pH}) + 349.6$$

That is to say, the pH value is exponentially related to the conductivity γ-value. The inflection point appears at pH≈4, the γ-value increases sharply when pH<4, and the change in γ-value is very small while pH>4. It is shown that when the pH value of wet precipitation is close to 4 or less, the sharp increase of conductivity will have a significant effect on the flashover characteristics of insulators.
According to the definition of pH: \( \text{pH} = -\log [\text{H}^+] \)

The relationship between pH value of acid solution and hydrogen ion concentration was obtained. When the pH value is between 4 and 7, there is little change in the hydrogen ion concentration, and there is little change in the conductivity in the corresponding case. When the pH value is between 3 and 4, the change of ion concentration and conductivity begins to intensify, with the further decrease of pH value, the ion concentration and conductivity increase more significantly. It can be seen that the inflection point of conductivity increases sharply, which is closely related to the change of ion concentration in solution. The conductivity of acid precipitates increases with the increase of acidity. When pH<4 or so, the conductivity increases sharply with the decrease of pH value.

4. Relationship between pH value, Conductivity and Salt Density of Acid deposition

In order to study the effect of acidity on the conductivity of pollution, the surface pollution of insulators with a certain salt density value was washed with 300ml distilled water. Hold the soiling solution in a container. And then add H\(_2\)SO\(_4\) to it to achieve a certain amount of acidity. In this way, the relation curve between the conductivity and acidity of the soiling solution under different salt densities (or acidity) can be measured as shown in Figure 3.

It can be seen from Figure 3 that when the equivalent salt density of the wet sewage layer of the insulator is constant, the conductivity of the soiling solution increases with the decrease of pH value, and there is an exponential relationship between them. When the pH \( \leq 4 \) or so, the larger the equivalent salt density is, the faster the \( \gamma \)-value of acid wet deposition increases. Compared with the conductivity of acid rain, the higher the equivalent salt density is, the greater the \( \gamma \)-value of acid wet deposition is. When ESDD is 0.12mg/cm\(^2\), the \( \gamma \)-value of acid wet deposition can reach more than 4 times of that of acid rain. The above analysis shows that the pH value is inversely proportional to the conductivity of fog water, and there is a corresponding relationship. The acidic wet deposition can be equivalent simulated by adjusting the conductivity of fog water.
5. Conclusion

1) The ion composition and pH value in acid precipitation are closely related to the local air pollution. The pH value and conductivity of settling water in different areas may be different.

2) The conductivity $\gamma$-value of acid precipitation decreases with the increase of pH value, and finally tends to the $\gamma$-value of neutral precipitation. The relationship between pH value and conductivity $\gamma$-value is exponential.

3) The pH value is inversely proportional to the conductivity of fog water, and there is a corresponding relationship. The acidic wet deposition can be equivalent simulated by adjusting the conductivity of fog water.

References

[1] Liu Zhang, Yafeng Chao, Fuyong Huang, Cheng Wang, Feng Wang. (2016) A Review of Researches on the Influence of Insulator Configuration on Pollution Flashover Voltage of Polluted Insulator. Electric Power, 49(6): 95-100.

[2] Lichun Shu, Qipeng Ran, Xingliang Jiang, Zhijin Zhang, Jianlin Hu. (2007) Comparison of AC Artificial Pollution Flashover Performance Between Porcelain and Glass Insulators. High Voltage Engineering, 33(3): 9-13.

[3] Mei Jiang, Peng Zhang, Tao Li, Jie Yang, Shaoqian Ma. (2014) Influence and control countermeasure of atmospheric pollution to power transmission and transformation equipment. Electric Power Environmental Protection, 30(4): 1-4.

[4] Committee on Corrosion Loss in Japan. (2001) Survey of corrosion cost in Japan. Zairyo to Kankyo (Corrosion Engineering) 50: 490-512.

[5] Hou Baorong, Li Xiaogang, Ma Xiumin, Du Cuiwei, Zhang Dawei, Zheng Meng, Xu Weichen, Lu Dongzhu, Ma Fubin. (2017) The cost of corrosion in China, 1(1).

[6] Koch, G., J. Varney, N., Thompson, O., Moghissi, et al. (2016) International measures of Prevention, Application, and Economics of Corrosion Technologies Study. NACE International.

[7] International Electrotechnical Commission. (2013) Artificial Pollution Tests on High-Voltage Insulators to Be Used on a.c. Systems. IEC 60507-2013.