Effect of acid wet deposition on operation of power grid equipment in China

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Abstract. The distribution law of acid rain in China is counted, and the operation of power grid equipment in acid wet deposition area is investigated. It is found that southern China has the strongest acidity of precipitation in the country. The ratio of SO$_4^{2-}$, NO$_3^-$, NH$_4^+$, Ca$^{2+}$ concentration in acid rain is higher. Acid rain causes serious corrosion of transmission line and transformation equipment in Shandong, Sichuan, Shanxi and Henan provinces of China. The acid rain and corrosion products aggravate the dissolution and chemical reaction of the original dry deposition pollution on the external insulation surface of power grid, which may lead to corrosive flashover.

1. Introduction
China is a developing country with rapid industrialization, but its environmental protection is lagging behind. The increase of emissions of various types has a negative impact on the ecological environment. For power system, after air pollution caused by various kinds of emissions, on the one hand, when the polluted atmosphere encounters wet weather such as rain and fog, the dissolution of polluted components reduces the insulation strength of air, and the acid components in wet deposition erode the metal structure of power grid; on the other hand, the polluted particles settle to the surface of insulators to form a polluted layer, which forms a contaminated layer on the surface of insulators under wet conditions. Water film with high conductivity on the contaminated layer can dramatically reduce the electrical performance of insulators.

This paper summarizes the characteristics and distribution of acid wet deposition in China, and counts the current situation of corrosion and corrosive flashover in acid wet deposition area.

2. Characteristics and distribution of acid wet deposition in China
The main forms of acid wet deposition are acid rain, acid fog and acid snow. At present, acid rain is the main form of acid wet deposition in China. China's acid rain area is the world's three largest acid rain areas after Europe and North America, and among the three major acid rain areas in the world, China's strong acid rain area (pH < 4.5) is the largest, and the southern and southwestern regions have become the most acidic regions in the world. The range of strong acid rain areas in China has been expanded, and the acidity of precipitation in strong acid rain areas has weakened as a whole. the percentage of each ion in acid rain in China is shown in Figure1. The ratio of SO$_4^{2-}$, NO$_3^-$, NH$_4^+$, Ca$^{2+}$ is higher than other ions.
3. Corrosion status of power grid equipment in acid wet deposition zone in China

Corrosion is a common problem faced by all countries in the world. The annual loss caused by corrosion accounts for about 3-5% of the gross national product of each country, which is larger than the total loss caused by natural disasters and accidents[5-6]. The author investigates five substations with the most serious corrosion (corrosion) and five transmission lines with 110 kV and above in each municipal power company of 27 provincial power companies in China, China Southern Power Grid is not included in this statistic. According to the investigation and statistics, 6251 cases of corrosion of transmission and transformation equipment have been reported by various units, including 4478 cases of substation equipment and 1773 cases of transmission lines. The number of corrosion cases in 27 areas is shown in Figures 2 to 4. Among them, the uninterrupted islands and oceans are not included in the statistics, so they are not reflected in the statistical map. The grey part is the power supply scope of China Southern Power Grid and Taiwan Provincial Power Grid.

It can be seen that the corrosion of transmission and transformation equipment exists in different degrees in 27 provinces. Due to the difference of climate and environment and the different depth of anti-corrosion work, there are great differences in the corrosion situation of different places. Among them, there are many cases of transmission and transformation equipment corrosion in Shandong, Sichuan, Shanxi and Henan province in China.
According to DL/T374-2010 "Drawing method of pollution distribution map for electric power system", the pollution degree in different areas is divided into five grades a to e from very light to very heavy. The corrosion statistics under different atmospheric pollution levels is shown in Figure 5. From Figure 5, it can be seen that the corrosion cases occur most frequently in the area with pollution grade d, followed by grade c, and the number of cases in the area with most serious pollution grade e is less than that in grade d and c.

The author considers that the corrosion of transmission and transformation equipment during operation mainly includes the following reasons:

1) The material and anticorrosion technology of transmission and transformation equipment components are not up to standard, and the coating technology or thickness do not meet the requirements.

2) Corrosion-related research is not deep enough, the data of important corrosion parameters such as relative humidity, sulfide, chloride and nitrogen oxide are scarce, and the atmospheric corrosion degree cannot be accurately classified. The differential anti-corrosion design and material selection of transmission and transformation equipment are not carried out systematically, and the anti-corrosion work is not precise and pertinent.

3) The anti-corrosion standard system is weak, and the transmission and transformation equipment lack systematic standard guidance in anti-corrosion design, material selection, anti-corrosion coating and detection and evaluation, and some standards need to be strengthened.

4. Current status of corrosive flashover in acid wet deposition zone in China

Southern regions of China such as Chongqing, Hunan, Jiangxi and Zhejiang are typical acid rain and acid fog settling areas. For decades, little attention has been paid to the characteristics of this pollution and its impact on the safety of power grids. The pollution caused by corrosion of metal parts of power grid facilities in acid wet deposition area is both liquid and dust. It may be more serious than the traditional dry deposition pollution, and it may form a more serious type of power grid disaster when it is superimposed with the conventional dry deposition pollution. In wet settling environment, corrosive contamination not only has a high degree of natural contamination, but also aggravates the dissolution and chemical reaction of dry settling contamination. Therefore, even if the external insulation designed according to the dry deposition pollution meets the requirements, corrosive flashover may occur. There are many unexplained flashover in the power grid, which can not be excluded from the random pollution.
According to publicly reported data, overhead line corrosive flashover occurred in most provinces in China. Reference [1] reported that corrosive flashover was caused by metal rust caused by acid wet deposition many times in Henan Province. Reference [2] reported corrosive flashover caused by corrosion of insulator cap and steel foot of a 220 kV transmission line in Hulunbeir; Reference [3] reported corrosive flashover caused by acid wet deposition discharged by chemical plants in Lanzhou; Reference [4] reported corrosive flashover caused by acid wet deposition from a 500 kV transmission line in Guangdong Province. Hunan province is also one of the areas seriously polluted by acid rain. The PH value of precipitation is low and the frequency of acid rain is high. According to incomplete statistics, from 2001 to 2010, 371 corrosive flashovers occurred in 35 kV and above voltage level transmission and transformation equipment in Hunan power grid, and 158 trips were unknown.

Towers, conductors and various types of metal fittings of transmission line tower-line system are metal parts. They are running in acid wet deposition environment for a long time, and metal parts are corroded continuously. Rust and rust water can settle on the surface of insulators under various wind conditions, which greatly reduces the electrical performance of insulators and faces flashover risk at any time.

5. Conclusions
1) Acid rain is the main type of acid wet deposition in China, which mainly distributes in southwest, central, Eastern and southern China.
2) The main components of acid rain in China are \( \text{SO}_4^{2-} \), \( \text{NO}_3^- \), \( \text{NH}_4^+ \), \( \text{Ca}^{2+} \). The concentrations of \( \text{SO}_4^{2-} \), \( \text{NO}_3^- \) in the precipitation of coastal developed areas are approximately the same, while the concentrations of \( \text{SO}_4^{2-} \) in most inland cities are much higher than those of \( \text{NO}_3^- \) in China.
3) The metal parts of overhead lines in acid wet deposition area are seriously corroded, and the higher the pollution grade, the more corrosion cases occur.
4) Additional contamination such as acid rain can lead to corrosive flashover of insulation equipment outside power grid.

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