Test and Analysis of Accelerated Corrosion of Electrical Equipment in Distribution Power System

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Abstract. With the construction of the Digital South Network advances, the requirements for power supply reliability will also increase. The requirements for distribution network automation are specifically manifested in the increasing requirements for the automation level, reliability, and environmental adaptability of equipment for distribution network automation. In the "three high" environment, the failure rate of distribution automation equipment has remained high, which shows that the current weather resistance test does not meet the actual working conditions of the southern coast. In order to better meet the actual situation, this paper studies the accelerated test of electrical equipment corrosion. Based on the experimental results, the author analyzes the inadequacy of the current test methods. At last, the author proposes improvement direction and suggestions.

**Keywords:** Distribution Automation Equipment, "Three High" Environment, Failure Rate, Accelerated Corrosion Test

1. Introduction

As the construction of the digital southern network accelerates, how to ensure the reliability of the power distribution equipment at the end of power consumption is particularly important, which is also a key point affecting the reliability of power supply. Distribution automation is an important part of the smart grid automation construction level, and it is also the key core of the digital southern network. The following table is Guangzhou Power Supply Bureau's 2008-2017 distribution terminal fault statistics. It analysis of the corrosion failure characteristics of distribution automation terminals in a hot and humid environment [1]. The environmental temperature and humidity, pollutant distribution and changes in the island microgrid is analyzed [2]. Natural environment accelerated test is experimented [3]. Targeted research on the environmental adaptability and durability of offshore wind power coatings in the humid and hot ocean area [4]. It analyze the atmospheric environment characteristics and study the atmospheric corrosivity of typical coastal areas [5]. The electrical corrosion behavior of connectors in a humid and hot marine environment is studied [6]. The principle and causes of atmospheric corrosion are studied [7].

**Table 1.** Distribution terminal fault statistics of Guangzhou power grid from 2008 to 2017

| number | year | proportion% | Failure rate% |
|--------|------|-------------|---------------|

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Due to the relatively short life of the distribution automation terminal, the actual distribution automation terminal is about 50% out of operation before 2011, so the failure rate is relatively low compared to 12-14 years. Relevant standards and grid specifications require that distribution equipment should meet the stable operation of 5-8 years, but in fact the failure rate is higher in 2012-2014. On the other hand verifies that the current product test system does not meet the southern coastal "High" climate requirements (high temperature, high humidity, high salt), especially a large number of electronic components in distribution automation equipment are prone to failure under high temperature, high humidity, and high salt fog. High temperature can easily cause downtime of electronic components, high temperature, high humidity, and high salt mist can also easily lead to device seal failure. After the failure, it is easy to cause internal electronic components corrosion, short circuit and other failures.

The core problem that needs to be solved at present is how to ensure the temperature operation of distribution automation equipment in harsh environment. After many years of experience in analysis and treatment of distribution network faults, the author summarizes the accelerated corrosion test of current distribution network automation products, which does not meet the coastal climate of high temperature, high humidity, and high salt. The service life of distribution automation equipment in most areas of Guangdong is significantly lower than the product design life.

2. Accelerated Corrosion Test of Distribution Network Automation Equipment

2.1 Brief Description of the Test
In accordance with the GB / T2423.18-2012 environmental test, the author conducted a complete accelerated corrosion test on different forms of FTU. The test was carried out in 4 test cycles according to severity level 5. One cycle consists of 4 salt spray cycles, each spray cycle is 2h (temperature 35 °C), each spray cycle is 20h high humidity heat retention cycle (temperature 40 °C, relative humidity (93 ± 3)%). After that, put it maintain 3d under the environment of relative humidity 80% and temperature 30 °C. As shown in Figure. 1 and Figure. 2 below.

![Figure 1. FTU accelerated corrosion test](image1)

![Figure 2. Schematic diagram of a test cycle](image2)

Before the test, testing the prototype according to the DL / T 721-2013 standard to ensure that the prototype meets the requirements. After each test cycle, test the no. 3 prototype’s three-remote, open, out, appearance, indicator lights, etc. as shown in Figure. 3.

|   | 2008-2011 | 36 | 16 |
|---|-----------|----|----|
| 2 | 2012-2014 | 44 | 39 |
| 3 | 2015-2017 | 20 | 20 |
2.2 Brief Description of Test Results
After 4 cycles of testing, in addition to the significant corrosion of the metal part of the body, the secondary components are in good condition, the surface of the PCB board is in good condition, and there is no obvious condensation or rust. The rest of the tests (including insulation) meet the standard requirements. There is no obvious deviation before the test. As shown in Fig. 4.

![Figure 3. Schematic diagram of detection after the test](image)

![Figure 4. Corrosion of the body](image)

The FTU was allowed to stand for 24 hours, then connecting the distribution switch test bench, its indicator lights, signal on and off, three-remote and other functions were working normally, and there was no malfunction or short circuit.

2.3 Analysis of Test Results
Through a 28-day test cycle, and test, it is found that after the accelerated corrosion test of the distribution network automation equipment is performed routinely, the test results cannot match the actual operating data. The main problem is that only the metal has a certain degree of corrosion, and the internal secondary components are in good condition.

The main corrosion of metal parts is welds, metal transitions (welds). There are many impurities at the welding seam, and there are many metals at the metal transition. The corrosion is that different metals are electrochemically corroded in a high concentration salt solution. The corrosion principle is as follows:

Anode metal dissolution:
Cathode hydrogen ion reduction reaction:

\[ M^{+n} + ne \rightarrow M^{+n} + ne \]  

(1)

\[ H^+ + e \rightarrow H \]  

(2)

\[ H + H \rightarrow H_2 \]  

(3)

The products after corrosion are mainly iron oxide:

\[ 2Fe^{+n} + 2NO^{-2} \rightarrow Fe_2O_n \]  

(4)

After studying the climate of domestic islands and typical industrial cities, we can find that the concentrations of NO₂ is 0.036, sulfate’s concentrations is 0.033) and the concentrations of ammonias is 0.029 in Guangzhou area. They were much greater than the concentration of salt, which is 0.0055, the unit of concentration is mass/mg 100 cm² d⁻¹: only at the island will the salt concentration rise to 0.556 (Wanshan Island). When acidic substances such as NO₂, sulfate and ammonia are dissolved in water, their corrosion is greatly accelerated, which leads to a large gap between the accelerated corrosion aging test and the actual. The acidity and alkalinity of the salt solution this time are close to neutral, resulting in a relatively slow corrosion.

Corrosion failure of electronic devices is mainly due to their metal corrosion, resulting in failures such as short circuits, poor contact, and short circuits between electronic components. Electronic device materials are mainly gold, copper, aluminum and alloys. Generally. When temperature increase in 10 °C, the chemical reaction will accelerate by 2 ~ 3 times. When the temperature is lower than 40 °C, the corrosion rate of electronic components is slow, it also shows that the temperature of this test is low, which leads to the insignificant corrosion of electronic components. Since the distribution network automation device was not charged during this test, the electronic device had no weak potential difference, which was also detrimental to the corrosion rate. Distribution automation equipment is generally close to the primary equipment and it is energized internally, so there is generally a certain amount of electrostatic induction and electromagnetic induction inside it. It is easy to form a certain amount of voltage difference at the electrical non-connection. Under the influence of this voltage difference, the metal components in the acid solution are prone to corrosion, which directly leads to the general life of the charged equipment is much lower than the charged equipment.

3. Suggestions for Improving the Accelerated Corrosion Test of Distribution Network Automation Equipment

Through this test and the analysis of the corrosion mechanism, it can be seen that the accelerated corrosion test of the distribution network automation equipment should be optimized and adjusted.

When configuring the salt spray solution, we should consider the atmospheric environment conditions of the place where the equipment is used, and NO₂, sulfate, and ammonia shadows under actual conditions. Acetic acid salt spray test is used to improve the severity of the test and reflect the true situation as much as possible. Increase the test temperature, speed up the corrosion rate, and improve the severity of the equipment evaluation. During the test of the distribution network automation equipment, connect the normal working voltage to simulate the real working conditions of the distribution network automation device. Considering the electrostatic induction, add a live induction coil at a certain distance from the distribution network automation equipment during the test. Study the contribution of different acidic substances, salt particles, etc. to corrosion, and formulate different proportions of the pollution, the accelerated corrosion test is easy to match the ratio and concentration.

4. Summary

In the current "three-high" environment, the reliability of distribution automation equipment is relatively low, and its rapid failure mainly due to insufficient protection. However, the current
corrosion acceleration test method cannot truly verify the protection and corrosion resistance of the equipment. In order to respond to the construction of Digital Southern Power Grid, and improve the reliability of distribution power supply, there is an urgent need to improve the existing weather resistance acceleration test methods and devices.

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