Research on Performance of Anti-metal RFID in Field Test of Type and 500kV Substation

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Abstract. With the rapid increase of power equipment and increasing the size of the stock, the traditional means of maintenance of operation and maintenance can not meet the new needs of modern operation and maintenance, the urgent need to improve the level of power transmission equipment and power transmission equipment, intelligent perception of lean management level. RFID tags have been widely used in all parts of the state grid system, the performance difference showed against the anti-metal UHF RFID tags in different environment, this paper analyzes the different specifications of the anti-metal UHF RFID tag performance in the laboratory environment type test and the substation environment. Through laboratory environment simulation test and substation field environment test, research the frequency range and interference intensity of field electromagnetic interference in Substation, to get the main reasons that affect the performance of the anti-metal UHF RFID tags. It has certain value on research the interference mechanism of substation anti-metal UHF RFID tags and anti-metal UHF RFID tags application promotion.

1. Introduction
In recent years, domestic and foreign research scholars have done a lot of research on the application of RFID in power system. Zhang[1] et al. have verified the feasibility of applying RFID technology in power transmission and transformation environment, considered the factors such as tag type and effective communication distance, and put forward the overall framework based on RF tags with sensors for the status information collection system of electrical equipment, but failed to take into account the impact of electromagnetism environment in the substation on RFID communication system. Reference[2] analyzes the external factors affecting the performance of the monitoring system, but fails to carry out the comparative test and modeling. Reference[3] analyzes the relationship between backscattering modulation mode and tag capture energy in RFID system, and points out that the channel fading of RFID system is different from that of traditional Rayleigh distribution model. Reference[4] mainly discusses the impact of antenna transmission power on RFID system, and puts forward the optimal power allocation between different transmitting antennas. Reference[5] points out that the forward activation power and backscattering power of the RFID system obey L-S distribution. Reference[6] analyses the impact of metal channel multipath effect in the application of the RFID system, makes simulated analysis using monte carlo method and points out that the forward link and reverse link channels are cascaded channels. The above-mentioned references do not specifically consider the impact of metal application environment on the wireless transmission of the system in the
practical application environment, and many metal electrical devices in substation lead to the complex electromagnetic environment\cite{7}\cite{8}\cite{9}. Therefore, it is necessary to take into account the impact of metal materials on UHF RFID system.

By comparing the data of anti-metal UHF RFID tags in type test and field test, this paper analyzes the impact of the electromagnetic environment in substation on UHF RFID tags, which is of great significance to the promotion and application in RFID system of substation and the construction of intelligent substation.

2. Routine test of anti-metal UHF RFID tags
In view of many factors such as cost, reliability and management level, passive anti-metal UHF RFID tags are recommended in substation. For comprehensive test and comparison, the frequency band of the test is 800MHz~1,000MHz, and that mainly analyzed in this paper is 920MHz~925MHz. Based on encapsulation material and dimensions, four different types of anti-metal RFID tags are selected to test their specifications. The comparison of specifications of four anti-metal UHF RFID tags is shown in Table 1.

| S.N. | Material                              | Dimensions (Unit: mm) |
|------|--------------------------------------|------------------------|
| 1    | Industrial-grade nylon               | 51×36×8                |
| 2    | ABS rigid plastic                    | 100×25×9               |
| 3    | Engineering plastics with strong hardness | 135×20×18            |
| 4    | PCB                                  | 95×25×4                |

2.1 Sensitivity test of anti-metal UHF RFID tags
Tag sensitivity is the minimum power intensity to identify tags, that is, the power threshold of activating tags. As an important performance index of tags, it can intuitively reflect the reading performance of tags. The test frequency range of this study is 800-1,000MHz, the scanning step frequency is 5MHz, and the power scanning step is 0.5dBm. A 140mm×140mm cold-rolled steel plate is used to simulate the electromagnetic environment on the surface of the switch case in the laboratory, and ground the cold-rolled steel plate due to passive anti-metal UHF RFID tag is usually attached to the surface of electric switch case. The test results of four tags are shown in Figure 1.

![Fig 1. Sensitivity test of four anti-metal UHF RFID tags](image)

The average sensitivity of four tags in the frequency band of 920MHz~925MHz is shown in Table 2.

| S.N. | Average sensitivity (dBm) |
|------|--------------------------|
| 1    | -12.2                    |
| 2    | -17.4                    |
| 3    | -12.1                    |
| 4    | -14.5                    |

According to the above table, passive anti-metal UHF RFID tags have different sensitivity in the metal environment due to different materials and specifications.
2.2 Test of the reading distance of anti-metal UHF RFID tags

Reading distance is an important indicator to measure the identification ability of RFID tags. It is defined as the maximum communication distance between reader-writer and tags. On the one hand, the transmitting power of the reader-writer is strong enough to activate passive RFID tags to work for information transmission; on the other hand, the signal intensity of tag return information shall be within the detection range of the reader-writer to achieve two-way communication.

In the laboratory environment, the test system of tag reading distance test is set as the same as the tag sensitivity test system, but the scanning power step is set to 0.1dBm. Similarly, the test behind a 140mm×140mm steel plate tag is added. The test results of the four tags are shown in Figure 2.

![Fig 2. Four kinds of anti-metal UHF RFID tag reading distance test](image)

Within the frequency range of 920MHz~925MHz, the average reading distances of four anti-metal UHF RFID tags are shown in Table 3.

| S.N. | Tag | Table 3. Average reading distances of four anti-metal UHF RFID tags |
|------|-----|---------------------------------------------------------------------|
|      | 1   | 2                     | 3                        | 4                        |
| Average reading distance (Unit: m) | 6.124 | 10.743 | 5.8855 | 7.7985 |

Within the frequency range of 920MHz~925MHz, the sensitivity of Tag 2 is greater than that of Tag 4, and that of Tag 4 is greater than that of Tag 1 and Tag 3, while that of Tag 1 is close to that of Tag 3. Therefore, it can be concluded that the descending order of reading performance of four anti-metal UHF RFID tags is as follows: Tag 2>Tag 4>Tag 1>Tag 3.

3. Field test of anti-metal UHF RFID tags

Due to the reflection, refraction and diffraction of electromagnetic waves in the practical application environment, the electromagnetic environment of UHF RFID is very complex, and the field test of electromagnetic environment in substation is of great significance to measure the stability of RFID system. Therefore, it is necessary to carry out communication interference detection and real-time performance test of tags on the spot. Advantages of HPLC carrier technology.

3.1 Communication interference detection

According to the layout of substation, fourteen typical test points are selected to continuously monitor the intensity of electromagnetic interference. One of the typical test points is located 5 meters away from the 500 kV main transformer. The test result curve is shown in Figure 3.
3.2 Real-time performance test of anti-metal UHF RFID tags

In the process of substation operation, the electromagnetic environment is changing constantly. During field test, it shall be continuously tested for a period of time to obtain the performance curve of anti-metal UHF RFID tags. An anti-metal UHF RFID tag shall be installed on the metal case of the test equipment, and antenna shall be fixed at a distance 2 meters from the tag, so as to continuously monitor the activation power of the anti-metal UHF RFID tag at 922MHz. In this paper, the real-time active power curves of field test and type test are put in the same figure. The comparison of Tag 1, Tag 2, Tag 3 and Tag 4 is shown in Figures 4 (a)~4 (d).

From Figures 4 (a), 4 (b) and 4 (d), it can be seen that the ordinate value of Curve 1 is larger than that of Curve 2, which shows that the activation power of Tags 1, 2 and 4 in the field test increases and the performance of tags becomes worse as compared to the type test. In Figure 4 (c), the ordinate value of Curve 1 is smaller than that of Curve 2, which shows that the performance of Tag 3 becomes better in substation.

Figures 4(a)~4(d)

Fig 4. Real-time performance test results of anti-metal UHF RFID tags
4. Analysis and conclusion
From the above test data, it can be seen that the performance of anti-metal UHF RFID tags with better test results in laboratory and open environment will be attenuated in substation environment, and that of only a small number of tags will be improved. According to the field test data of substation, the electromagnetic interference frequency bands in the 500 kV substation mainly concentrate on 870MHz~880MHz and 935 MHz~960 MHz, and the interference intensity is less than -60dBm. This shows that the electromagnetic interference of substation may not have a major impact on the performance of most anti-metal UHF RFID tags. The main reason for the performance change of anti-metal UHF RFID tags is that there are many metal environments in substation. In the event of multiple echoes, the anti-metal UHF RFID tags with enhanced performance that enhance or attenuate the RF signals of tags are not suitable for the general use in any metal environment. Therefore, if the substation have a more complex metal environment or limited space, the practical application environment shall prevail. In addition, the performance of anti-metal UHF RFID tags with different specifications shall be screened and tested to meet the application requirements of different.

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