Analysis of Electromagnetic Interference in Shielded Cables by Ground Potential Difference in Substation

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Abstract. At this stage, with the continuous improvement of the substation voltage level and the use of related intelligent equipment, the electromagnetic environment is gradually complicated, which seriously threatens the safety and reliability of the operation of the high-voltage transmission system. In view of this, based on the analysis of the theory of substation ground potential difference, this paper studies the specific causes of electromagnetic interference of shielded cables in substation ground potential difference, and then proposes the main measures to prevent the rise of substation ground potential, and the anti-interference ability of shielded cables. It is of great practical significance to improve the anti-jamming ability of shielded cable.

1. Introduction
In the multi-conductor transmission angle, a numerical calculation method for detecting interference voltage and current on a shielded cable is proposed. Through the validity test of the calculation method, it is found that the calculation method can effectively reduce the voltage and current on the shielded cable. The numerical calculation method is used as a breakthrough to calculate the potential difference of a 500 kV substation grounding grid, the interference current and voltage generated under low voltage DC conditions, and finally find that the current and voltage have exceeded the reasonable range. In actual work, control of related currents and voltages cannot be ignored. (Wu and Cui, 2005). In the process of designing the substation ground network, the electromagnetic interference effect of communication equipment can often be terminated on the ground. However, this access method has a large security risk. If the substation is subjected to lightning strikes or out-of-line circuit fault conditions, a strong transfer potential difference will result. The resulting potential difference, on the one hand, causes a main insulation between the cable core and the shield, which directly breaks down some of the main medium. On the other hand, this potential difference will form a loop, generating a large transient current, which will have a large interference effect on surrounding related communication equipment[1-2].

Whether the grounding form of the cable shield is correct will directly affect the signal, service life and transmission quality of the cable, and even a large safety hazard for human body safety. Under normal circumstances, the choice of the grounding mode of the power cable mainly depends on the magnitude of the induced voltage or current. According to the Faraday cage effect principle, the access to the cable shielding is controlled to reduce the interference to the external communication equipment. However, in the choice of single-ended or double-ended access ground, it is found that the single-ended does not need to be grounded, mainly used to prevent static electricity generation; the
double-ended needs information grounding treatment, in order to reduce the voltage and avoid the potential difference generated by shielding at different positions[3].

Analyze the maintenance and operation data of the faulty cable and disassemble the faulty cable. It has been found that if the cable end is poorly sealed, it will cause a large potential difference between the cable and the shielding layer. Under the weakest environmental conditions, partial discharge will occur, and the surrounding related objects will be broken down. Therefore, in the future, the handling of cable potential differences should be strictly controlled to ensure the safety of equipment operation [4-5]. With the development of China's economy, under the support and guidance of macro-policies, relevant institutions are investing in power grid construction projects. Relevant institutions have invested a lot of manpower, material and financial resources in power grid construction projects, so far it has entered a high-speed development stage. However, in the specific implementation process of related power projects, the environmental problems generated are also becoming more and more prominent. The electromagnetic pollution generated around the power project has a great impact on the health of the surrounding residents. Under this circumstance, taking the sub-station in Binhu District, Wuxi City, China as the main investigation object, the surrounding pilot substation was selected for environmental layout detection research, and the impact of electromagnetic pollution on the surrounding environment was analyzed. The study found that the indoor substation with cable entry has little effect on the surrounding environment[6-8].

2. Research purposes

During the operation of the secondary cable, the electromagnetic interference generated by the substation will directly affect the operation effect. At present, there are two aspects to the control of the cable shielding layer at home and abroad. One view is that grounding from one end will reduce electromagnetic interference. Another point of view is that grounding at both ends is the main way to reduce electromagnetic interference. There is still much controversy about the specific research and practical effects of these two methods[3-4].

Moreover, using data calculation and theoretical analysis, the corresponding mathematical models are established to study the lightning shock accidents near the substation. The potential difference generated by the rise of the point is responsible for the safety of the control cable. The research results show that under the action of transient lightning current, in order to avoid the potential difference of substation, the soil resistivity should be considered, and the design and selection of related materials for ground access should be optimized[6-7].

In addition, people have once again studied the control measures of electromagnetic interference. Taking the intelligent substation as the main research site, a large number of surveys were conducted on the substation site to study the electromagnetic interference received by the electronic sensor, and then the influencing factors of electromagnetic interference were studied. After the relevant technology processing, a large number of interference surges are placed on the ground, and it is desirable to minimize the tolerance time of the potential difference. Filtering measures are taken to control the electromagnetic interference around the substation to avoid the influence of electromagnetic interference generated by the substation on surrounding equipment [4-5].

Through the above analysis, it is found that the current research on the ground potential difference of the substation and the research on the influence factors of the potential difference on the electromagnetic interference of the shielded cable still has great differences, and the inconsistent findings are not conducive to the effective control of electromagnetic interference by relevant institutions. Therefore, on the basis of combing relevant literatures, this paper deeply studies the causes of substation ground potential difference, and deeply analyzes the electromagnetic interference effect of potential difference on shielded cables, and then proposes corresponding solutions, which is of great significance.
3. Electromagnetic Interference on Shielded Cable In Ground Potential Difference in Substations

The generation of the ground potential difference in the substation causes the current to flow into the ground through the grounding drain. When current flows through the grounding body, it will contact the secondary cable of the guard to generate an interference voltage. In addition, the voltage is transmitted to the secondary device under the action of the surrounding current, this will cause greater harm to the secondary equipment. In order to reduce the overvoltage generated during the secondary conduction of current, the shielding layer is often used for grounding treatment in the substation circuit. In the access process, the grounding at both ends and one-point grounding are adopted. In order to compare the electromagnetic interference generated by the two grounding methods for the secondary cable, an experimental simulation loop is constructed, as shown in Fig. 1.

![Figure 1. Analog Loop](image)

As shown in Figure 1, the grounding grid is a grid of 4*7, the grounding point of the generator body is N22, and the grounding point is N24. There are four main ways for the substation to be grounded at both ends. First, the two ends are grounded. Second, it is only accessible at the point where the ground needs to be discharged. Third, double-ended floating access. Fourth, grounding is performed at the ground control point. According to the different ways of substation ground potential difference, it can be divided into full wave and chopping. Due to the large dispersion of electrical chopping, there are also large differences in the way they are produced. In order to deeply study the interference of the electromagnetic wave generated by the ground potential difference of the substation to the shielded cable, the same impulse voltage generator as the international standard was used for the simulation experiment.

After the measurement, the corresponding measurement data is imported into the computer for calculation. The settlement shows that for single-ended grounding near the shield, the maximum amplitude of the voltage on the cable is 400V, and the electromagnetic interference generated is relatively small. When measuring two grounding conditions, the voltage dividing circuit can be used to meet the scope of the oscilloscope. Finally, through the relevant method, the measured data is converted again to obtain the waveform of the interference voltage on the actual cable. By analyzing the measurement results, it can be found that the amplitude of the interference voltage on the substation cable core line is gradually reduced from the initial maximum value.

This is due to the single-pulse filtering generated by the substation ground potential difference. After being cut off by the relevant ball gap intercepting device, the voltage will drop rapidly and eventually gradually become zero. Under the single-ended grounding of the substation shield, the duration of the interference voltage on the cable is 20us, which is greater than the double-ended grounding. It can be found that when the substation adopts double-ended grounding of the shielding layer, the electromagnetic interference effect on the shielded cable is small. When single-ended grounding is used, the electromagnetic interference generated by the shielded cable is greatly affected.
by the influence of voltage and current. The frequency domain and time domain of different grounding methods are shown in Table 1.

### Table 1. Frequency and Time Domains of Different Grounding Methods

| Grounding method                                      | Frequency Domain | Time Domain |
|-------------------------------------------------------|------------------|-------------|
|                                                        | Main frequency   | Absolute value of voltage amplitude/V | Peak/V |
|                                                        | distribution/MHZ |                                         |        |
| Single-ended ground near the discharge point           | 2.21, 7.56       | 489         | 936    |
| Double-ended grounding                                 | 2.23, 7.48       | 36.2        | 36.5   |
| Double-ended suspension                                | 4.38, 5.56       | 496         | 934    |
| Single-ended grounding at the side of the control room | 4.08, 5.86       | 22.5        | 95.4   |

It can be seen from the results shown in Table 1 that the secondary cable shielding layer of the substation uses the double-ended grounding method, which can effectively control the electromagnetic interference amplitude and reduce the distribution range of the main frequency voltage, which is beneficial to improve the compatibility level between the secondary system and the equipment. However, in the case of double-ended grounding, the electromagnetic interference voltage on the cable may still affect the secondary equipment, and it is necessary to further reduce the ground potential difference in the substation or improve the anti-interference ability of the equipment.

### 4. Measures to Prevent the Rise of Substation Ground Potential

Various protection and control systems in substations face complex high electric field, high voltage and electromagnetic electromagnetic field environment in the specific operation process. There are not only a large amount of magnetic field interference, but also high voltage current or equipment, causing electric field interference. Through the above analysis, it is found that the rise of the ground potential of the substation will have a greater impact on the shielded cable. In the actual application process, the effective grounding of the substation plays an important role in reducing the potential difference. At the same time, the electrical devices and low-resistance systems used inside the substation can also reduce electromagnetic interference to a certain extent. In addition, based on the above analysis, the main measures for preventing the rise of the substation potential are further proposed.

First, make full use of natural grounding bodies to reduce resistance. In the substation grounding body, it can be mainly divided into two ways: artificial grounding body and natural grounding body. In the grounding design, the artificial grounding body is mostly used, which not only keeps the resistance within the specified range, but also avoids the influence of other factors in the natural world on the current and voltage. Manual grounding can be divided into vertical grounding and horizontal grounding. When the manual grounding method is adopted, the resistance value of the grounding mainly depends on the contact area between the earth and the grounding body and the nature of the soil. Under normal circumstances, the distance between the vertical grounding body and the ground is required to be kept at about 5 cm. And the grounding device requires that the parts buried in the soil should meet the standards, and the corresponding welded parts should be treated with anti-corrosion treatment.

Second, equipotential bonding. In the modern lightning protection theory, if it is necessary to ensure the voltage equalization, it is necessary to carry out equalizing equipotential bonding, and the relevant lightning protection and anti-electricity device can be regarded as a voltage equalizing and electric connection network. The purpose of the isoelectric connection within the substation is primarily to reduce the potential difference between the various metal components and the various systems. Therefore, in the specific prevention of electromagnetic interference, attention should be paid to the use of equipotential bonding devices, and the relevant equipment should be introduced into the grounding device to minimize the ground potential difference.
Third, the metal shield is grounded. In the substation, the buried shielded cable is the main source of interference that interferes with the power supply, that is, the generator of electromagnetic interference, and is also responsible for the reception of the relevant electromagnetic. Using a buried shielded cable as a generator, it can generate radiation into the space to form electromagnetic noise. When the buried shielded cable is used as an absorber, it can sensitively receive adjacent interference sources and receive electromagnetic noise emitted by the interference source. Therefore, when the substation performs related processing, the buried shielded cable should be applied to the relevant modules as much as possible to help suppress electromagnetic interference.

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