The influence of Urban Substation on Neighbouring Metal Grounding System

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Abstract. With the development of China's social and economic development, there are more high voltage substations in city and urban area. In order to better study the influence of fault current of urban substations on the neighbouring buildings, the paper studies the conduction interference between the urban substation with neighbouring merchants and civil buildings. Based on importance parameter, the surface potential, the conduction interference level of the civil substation system is quantitatively analyzed with different soil structure parameters, interval distance and the size change of the neighbouring grounding system. The research results show that, when the urban substation takes fault, even if there is no direct electrical connection, the surrounding commercial buildings and grounding system will be subjected to conduction interference. If do not considering the security of these grounding systems, it is easy to cause security risks. The soil structure is different, the influence of conduction interference is also different. The higher the soil resistivity in the bottom layer, more fault current will be scattered through the top soil, the more obvious the influence of conduction interference. With the increase of the size and distance between the neighbouring grounding system, the conduction interference effect will be reduced. In the design and safety analysis of the substation grounding system in the urban area, the safety of the surrounding buildings of the civil buildings should be considered. The research results provide theoretical basis and engineering guidance for the design of the grounding system in the urban substation and the safety protection of the commercial buildings surrounding the substation.

1. Introduction
The grounding system is an important part of the substation. When the short-circuit fault occurs in the substation, the fault current can quickly flow into the soil through the grounding system and carry out the flow, in order to protect the equipment and facilities of the substation and the safety of the personnel [1-3]. At present, with the rapid progress of China's industrialization and urbanization process, the load and demand of urban centralized users are increasing, and the high voltage substations in urban areas are appearing continuously.

At present, various design standards are concerned with the substation grounding system, and a variety of conventional effective methods and methods are proposed to ensure the substation grounding system to meet the security design requirements [4-9]. But, for Urban Substations, because of there are lots of commercial civil buildings and facilities around substations. For short circuit faults in Urban
Substations, the effect of fault current on the grounding system of other commercial buildings in the vicinity is less studied. How to ensure the surrounding public safety during short-circuit faults in urban substations is a new problem that needs to be considered during the research and analysis of grounding system in Urban Substations.

To better research the influence of short-circuit fault in Urban Substations, the influence of fault current dispersion on the surrounding buildings of commercial buildings and buildings is analyzed. The paper focuses on the conduction interference of the grounding system of the urban substation to the civil buildings and the grounding system of the surrounding merchants. The influence of the different soil structure parameters, distance and the size change of the neighboring grounding system is quantitatively analyzed. The results provide theoretical basis and engineering guidance for the grounding system analysis and the safety protection of the surrounding grounding system in the urban area.

2. Analysis Model

Theoretically, when the distance between the two grounding grids is infinite, there is no effect between them. In reality, especially for Urban Substations, it is difficult to do this. There are always various kinds of grounding systems and installations for commercial buildings and structures in the vicinity of Urban Substations. When the fault current flows into the soil through the grounding system of the substation, the potential of the surrounding soil will rise in addition to the potential of the grounding system. If there are other grounding devices around it, the grounding potential of the grounding devices will rise. That is, we call it as conduction interference.

Figure 1 shows the structure of the grounding system of a substation and its neighboring grounding system, which belongs to other building. Among them, (b) is the grounding system of Urban Substations; (a) the grounding system for neighboring buildings and structures. The grounding system of the urban substation is considered in accordance with the 100*100 square meter. The length of the grounding system of the commercial civil structure is M. The distance between the two grounding systems is D, the buried depth of the grounding system is 0.8 meters, the grounding conductor is 40*4 flat steel, and the equivalent radius is 0.02 meters.

![Figure 1 The diagram of substation grounding grid and neighboring grounding grid](image)

3. The influence of Soil Structure

Based on the uniform soil structure and horizontal two-layer soil structure, the paper analyzes the influence of soil structure on conduction inference. In the study, $\rho$ is the soil resistivity of the uniform soil structure; for the horizontal two-layer soil structure, $\rho_1$ is the top soil resistivity (ohm. m), $\rho_2$ is the bottom soil resistivity (ohm.m), the $h$ is the top layer soil thickness (m).

In case of the grounding network (b) takes failure, the fault currents will flow into the soil through the grounding system, and the current is conductive through the soil to the grounding grid (a) in the process of dispersion, so that the surface potential of grounding grid(a) is raised. Define, the ground surface potential of the substation grounding system(b) is 100%, and figure 2- 4 shows the surface potential of the substation grounding system of different soil structures.
potential ratio of the potential of grounding grid(a). Here, D=30 meters, M=70 meters. This ratio directly reflects the degree of conduction interference (b) to (a).

Fig. 2 Uniform Soil

Fig. 3 Two-Layer soil (\( \rho_1 > \rho_2 \))

Fig. 4 Two-Layer Soil (\( \rho_1 < \rho_2 \))

It can be seen from Fig. 2-4 that under different soil structures, the influence of conduction interference on the grounding grid (a) is also different. For two-layer soil structure, when \( \rho_1 < \rho_2 \), the conduction interference is more significant. The main reason is that more proportion of the fault current is scattered in the lower soil resistivity area of the top layer, so there is more current flow to the grounding grid (a), thus the conduction interference is more obvious in this soil structure.

Conversely, when \( \rho_1 > \rho_2 \), more fault current will flow into the deep soil area near the substation grounding system(b), so the current ratio on the grounding grid (a) is reduced. At the same time, the lower the soil resistivity of the bottom soil, the lower the conduction interference level. For uniform soil structure, under the same conditions, the degree of conduction interference is between them.

Based on the above two-layer soil structure parameters and grounding grids, the level and degree of conducted interference under different reflection coefficients K are given. The reflection coefficient \( K = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1} \) and \( V_1 \) is defined as the maximum surface potential of the substation grounding system (b); \( V_2 \) is the maximum surface potential of the disturbed grounding grid (a). \( R = \frac{V_2}{V_1} \times 100\% \). The top soil resistivity is 200 ohm.m , the thickness of top layer is 8 m.

Fig. 5 the influence of K change
It can be seen from fig.5 that for two-layer soil structure, the degree of conduction interference varies with the change of K value. The smaller the K value is, the lower the bottom soil resistivity is, the lower the degree of conduction interference is. Conversely, the higher the bottom soil resistivity is, the higher the conduction disturbance is.

At the same time, the following figure gives the extent of the conducted interference under the change of the thickness of the top soil.

![Fig.6 The influence of length of top soil](image)

From the above picture, we can see that for the K>0, that is, the soil structure of the bottom soil resistivity is greater than the soil resistivity in the top layer, and the degree of conduction interference increases with the increase the top soil thickness. Conversely, when the bottom soil resistivity is low, conduction interference degree decreases with the increase of top soil thickness.

4. The influence of Size and Distance of neighbouring grounding system

In practice, there will be a variety of commercial and civil buildings around the urban substation, and the size of the grounding system and the distance from the substation grounding system are different. The interference degree between the commercial civil grounding system and the substation grounding system is analyzed.

Fig. 7 shows the interference of substation grounding grid to the ground potential of surrounding substation with different distance D.

![Fig.7 The influence of Distance between substation and neighboring grounding grid](image)

As can be seen from the above picture, with the increase of the distance D between two grounding systems, the influence of the grounding system on the grounding system decreases. With the D increased, and the reduction trend tends to ease.

In addition, it can be seen from the diagram that when \( \rho_1 < \rho_2 \), the interference between the two is greater than \( \rho_1 > \rho_2 \), the main reason is as mentioned before. When the soil resistivity of bottom layer is low, the short-fault current of the substation mainly flows through the bottom layer soil, thus
reducing the current proportion to the neighboring grounding system, so the conduction interference is also lower.

Fig. 8 shows the extent of the transmission interference with the size change of the grounding system of commercial buildings. Here, D=50 meters, the soil structure is described in Figure 7.

![The influence of size of neighbouring grounding grid](image)

As can be seen from the above picture, as the size of the grounding system increases, the degree of conduction interference is reduced. The main reason is that with the increase of the size of the grounding system, the dispersion area increases, and the fault current can quickly flow into the soil, so its electric potential is also reduced.

At the same time, it can be seen that the soil structure is different, the increase of the area is not different for the reduction of conduction interference, the higher the soil resistivity in the bottom layer, the more significant the conduction is.

5. Conclusion

With the continuous emergence of substations in the city, new challenges and new problems are brought to the design and analysis of urban substation grounding systems. If there is a short circuit fault in an urban substation, even if there is no direct electrical connection between the two, the neighboring commercial buildings and the structure of the grounding system will be subjected to conduction interference.

The soil structure has a significant influence on the level of conduction interference. The higher the resistivity of the bottom soil, the more fault current will be scattered through the top soil, the more obvious the influence of the conduction interference.

The most effective way to reduce conducted interference is to increase the distance between substations and neighboring grounding systems as far as possible. In a certain distance, increasing the size of commercial civilian grounding system can reduce the degree of interference.

In the design and safety analysis of the substation grounding system in the urban substation, the traditional concept of the grounding system safety of the substation should be changed, and the safety of the surrounding commercial buildings should be considered simultaneously.

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