A Strategy of Suppressing the Underground Impact Scattered Current in Power Grid by Using Insulation Baffle

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Abstract. In order to solve the accidents happened in the ponds or other special places around the tower which were caused by the diffusion current after lightning stroke the transmission tower, the protection measures for the problem tower in the area of Guangdong Province which occurred dead fish in the pond in thunderstorm weather were studied in this paper. The COMSOL multiphysics simulation software was used in order to calculate the electromagnetic environment of the diffusion situation by grounding device after lightning stroke the power transmission tower. Study concluded that the safe distance between the fish pond and grounding device of transmission tower is 14 meter. The effects of the length and depth or stayed a gap of the insulation baffle on the fish in the fish pond were discussed. The protection method of the insulation baffle has important practical significance to the protection of the grounding device for diffusion current, and can provide some engineering guidance and basis for the grounding arrangement and transformation of the high voltage transmission line tower.

1. Introduction

With the development of the power system, the construction of high voltage transmission line density increases, transmission lines gradually develop in the direction of long-distance, large-capacity. High voltage transmission lines are inevitable in densely populated areas. Due to the high voltage grade of transmission line, the fault current under the ground is larger, moving irregularly under the surface. Electrical safety issues are surrounding the increasingly tower. In recent years, the accidents human and animal casualties have occurred when lightning strikes high voltage transmission lines, to which should be payed more serious attention.

With further research and the statistical analysis of power system fault by domestic and foreign scholars in recent years, one of the main reasons of lightning trip is highly impulse grounding resistance [1-2]. Thus, domestic and foreign scholars start a large number of studies surround tower grounding impulse characteristics under the effect of the lightning current in recent years [3-8]. Wen Xi Shan, Wuhan University, and some scholar use numerical analysis methods and study formula for calculating the impulse grounding resistance of the grounding conductor, combining with newest
theory[3]; H. Motoyama, from Japan, accurately measures the axial current amplitude and waveform of each point grounding device by using PEASON coil, designed to study the law of impulse diffuse current[4]; SIMa Wenxia, Chongqing University, studied the dynamics of soil considering the ionization diffuser law under the tower grounding device and made a tower grounding influence of different structures on the surface impact of the step voltage and contact voltage shock[5]; He Jin-liang, Tsinghua university, studied tower impulse grounding performance calculation methods under consideration spark discharge conditions and propose corresponding method of reducing the resistance[6]. In engineering, in order to reduce the grounding resistance, the main measures often used are increasing the net area, increasing the size of grounding, adding depth grounding, external leading, the use of natural grounding, soil replacement, using the reduction agent etc[7-9].

In recent years, the Pearl River Delta region appears the threat of personal, equipment and biological safety many times, and even had made some damage. For example, after a lot of transmission towers happening lighting accident in some areas of Guangdong Province, a great many animals in the fish ponds died, directly impacting on the economic benefits of fish farming. Experts measured ground resistance in the scene and found that it is consistent with the grounding requirements in "over-voltage protection and insulation coordination DL_T620-1997 AC electrical installations". Conventional grounding protection measures can not effectively solve such incidents, so a set of effective protective measures to reduce the diffusion current is needed.

Based on the structure of the tower grounding device in a certain area of Guangdong Province, the electromagnetic environment in the multi-physics simulation software COMSOL is used to structure model and calculate when the current is diffused by grounding device. This paper probes into the regularity of the lightning current dispersion, and puts forward the protective scheme using the insulation baffle, and probes into the influence of the length and the depth on fish in the fish pond.

2. Introduction to Engineering

Figure 1 for a village in Guangdong Province 500kV for the first line of N111 tower where the location of the nearby 1.5m is fish pond. Thunderstorms, the great magnitude of the lightning current from the tower run into the ground through the grounding device, seriously affecting the survival of fish in the nearby fish ponds, resulting in a huge economic loss.

As shown in Figure 2 about transmission tower grounding device. The four tower bases of the transmission tower are connected with the ground connection line by connecting plate of which length is 2.5m, the grounding device buried depth of not less than 0.8m. There is a number of vertical grounding electrode welding in the horizontal grounding pole. Vertical grounding length is 2m, size of grounding conductors and other grounded parts specifications shown in Table 1.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Relative position of pond and transmission tower.  **Figure 2.** Illustration of transmission line tower grounding device.
Table 1. The specifications of Grounding component.

| Serial number | name                    | specification | length (mm) | unit | quantity | weight (kg) |
|---------------|-------------------------|---------------|-------------|------|----------|-------------|
| 1             | Ground conductor        | Φ12 L         | Meter       | 1    |          | 12.34       |
| 2             | Lead down line          | Φ16 2500 root | root        | 1    |          | 2.22        |
| 3             | Connection plate        | -4×40 160 Piece | Piece       | 1    |          | 0.20        |
| 4             | bolt                    | M16 35 Pieces | Pieces      | 1    |          | 1.746       |

According to minefield level, defined by GB / T 50064"AC electrical installations over-voltage protection and insulation coordination design specification", multi-zone, Guangdong Province, were strongly minefield. Reference Guangdong Province 2010-2016 lightning lightning current distribution in the number of cases, as shown in Table 2 below.

Table 2. The specifications of Grounding component.

| years | <76kA | 76-125 kA | >126 kA |
|-------|-------|-----------|---------|
| 2010  | 45002 | 2090      | 630     |
| 2011  | 33520 | 18022     | 721     |
| 2012  | 53897 | 547       | 274     |
| 2013  | 68308 | 2422      | 499     |
| 2014  | 103668| 3142      | 429     |
| 2015  | 60178 | 2221      | 358     |
| 2016 1-8 month | 42749 | 1922 | 328 |

This study selected lightning current, of which amplitude is 30kA, front time of the wave is 8μs and half the peak time is 20μs.

3. Simulation model

In this study, the Geometry module in COMSOL software was used to geometrically model the grounding device and the shape, size and location of the fish pond. The ground drop is calculated and calculated by the coupling of the Electric Currents and the magnetic field (mfh) of the software when the tower grounding device is subjected to 30kA lightning current. With the study module, the transient current and potential values at any time and position can be obtained.

In the model established in this paper, the size of the grounding device is determined according to Fig. 2, and its buried depth is 1m. The depth of the pond is 2.5m. The soil resistivity is 100Ω·m and the soil environment is a single layer uniform soil model.

3.1. The current threshold of fish deaths

The behavior of the organism is basically controlled by the nerve, which control function is a kind of electrical control effect. When the body has a current flow, biological behavior will be disorder, such as the emergence of uncontrolled dancing and other phenomena, when the uncontrolled behavior is too intense, it will occur the phenomena similar to muscle strained and even bone cracked [10-11]. The role of electricity and the current channel also has a great relationship, when the current, especially the biological sensitivity of a certain frequency range of the current through the heart of the body, causing
the body of heart disorders, in a very short period of time can make biological death. Literature [12] pointed out, to make the fish in less than 1ms time electrocuted lightning current pulse, body by electrical stimulation of the maximum current density is 100 A/m². Thus, when the transmission line tower suffers the lightning, secure current density of fish in the ponds takes 100 A/m².

4. Simulation calculation

4.1. No protection measures, the safe distance of the fish pond

According to the electromagnetic simulation model of the grounding device lightning current scattered by the power tower in Chapter 2, in case of current amplitude 30kA, fish ponds at different distances are simulated. A 40cm fish is set in the fish pond at 0.5m (positive for grounding device). The fish safe current density determines a safe distance from the fish ponds.

Figure 3 shows the distance between transmission tower grounding devices and ponds at 15m, fish pond 0.5m, 1.5m, 3m, 6m, 10m, 13m, 16m, 20m, 23m arranged at a current density of fish distribution. With the distance getting farther, the current density of the fish gradually becomes smaller. So take follow-up study in the pond 0.5m at a current density of fish to be judged under the circumstances corresponding to all fish ponds security.

Figure 4 reflects current density value of fish when distance between pond and grounding device is 1m-22m. The overall trend is more secure farther away from ponds fish ponds. When the distance is 14m, the current density of the fish has reached the value of the security document (100A/m²) [12] above. Therefore, when a new transmission line tower is constructed, tower can be set up beyond 14m under the presence of nearby ponds, which can avoid the impact on fish ponds.

4.2. Baffle length

Need to know the impact of the baffle length on blocking the bulk. In the construction, the length of the baffle is obviously slightly larger than the size of the grounding pole; otherwise it can not be blocked into the bulk. Its length should be subject to geographical environment and economic benefits. Thereby setting a 10m-40m length of the insulating baffle into the depth of the pond depth (2.5m), to explore the impact of baffle length on fish during impulse current scattered.

Fish ponds current density increases with the length of the relationship between the baffle shown in Figure 5, the horizontal dimension of the grounding device is 15m, Figure 5 shows the length of the baffle at 10-20m, the protective effect is obvious, to continue to increase after reaching 20m block plate length, the protection to fish is not obvious. When the lightning current is scattered, some of the current will bypass the grounding device and the fish pond in the middle of the insulation baffle flow to the fish pond. When the baffle length is less than the grounding device horizontal size, there is still a large part of the bulk flow into the fish pond, blocking effect is not obvious. This condition
corresponds to a length of 20m grounding devices require protective shutter effect is obvious.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure5}
\caption{Illustration of current density of fish.}
\end{figure}

4.3. Baffle depth
Choose a length of 20m insulating baffle inquiry into the impact of its depth on the lightning current flowing into the pond. Considering the difficulty of the actual construction of mining, setting a depth of 1m-5m is a suitable insulating plate into the depth of the simulation to calculate the edge of the pond 0.5m at a current density of 40cm fish, explore the lightning Diaspora baffle depth of ponds The impact of the fish.

When ponds depth 2m, into the depth of the baffle between 1m-2.5m, a current density of fish faster rate of decline, while the current density after 2.5m slow the rate of decline. Indicating the depth of the baffle into the depth of the fish pond. Figure 6 compares the current density on the depth of 2m and 2.5m depth on bezel different ponds fish ponds. Illustrates this condition, ponds require at least 2m deep bezel depth of 2.5m, 2.5m deep ponds require at least bezel depth 3m. When the shutter depth of 4m, depth 2m, 2.5m fish ponds current density decreased to 100 A/m^2, the protective effect is obvious.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure6}
\caption{Illustration of current density of fish.}
\end{figure}

4.4. Baffle gap effect
The 20m insulation baffle is determined from the 4.2 section, the actual construction for the 20m long baffle directly excavation, into the ground will be difficult. So consider it half of the deal, insulation baffle was buried underground with two pice of 10m, and then use high-strength bolts to its fixed connection, the junction will produce gaps. Figure 7 shows the effect of the gap of 1 mm-1 cm on the current density of the fish in the fish pond. Figure 8 shows the current flow chart for two fish flowing through the model.

As the width of the gap increases, the current density flowing through the fish increases and increases faster and faster. When there is no gap, 20m insulating baffle, into a depth of 3m, the current density is 136 A/m^2. Gap control in less than 5mm, the current density increment is less than 40 A/m^2, which has acceptable influence on the fish. By adjusting the current slot is on the side of the fish and
the same distance from the baffle a fish of a current chart at 5m know, slit main effect on the surface of the fish, the current of fish on the side mainly come from the current around the baffle.

![Figure 7. Illustration of current density of fish.](image1)

![Figure 8. Illustration of flowing manner of current.](image2)

5. Conclusion

1) As the distance from the fish ponds, fish current density becomes smaller. The case by the fish pond 0.5m at a current density of fish safety 40cm 100 A/m$^2$ to determine without any protective measures, security fishpond distance between transmission line tower grounding and the pond device is 14m.

2) When the lightning current is scattered, some of the current will bypass the grounding device and the insulation baffle in the middle of the fish pond and flow to the fish pond. The length of the baffle should be matched according to the size of the grounding device, slightly larger than the size of the grounding device, and the protective effect is better.

3) By comparing the depth of 2m and 2.5m on bezel different ponds fish ponds current density. Bezel depth should change with depth of fish ponds and should slightly larger than the depth of fish ponds, which has obvious protective effect.

4) Against the baffle piece construction, a method of mounting block in the actual construction may be considered, which should be connected to the control at the width of the slot, in order to reduce the current density of the fish around the gap.

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