Protection Method of Biological Lightning Safety around Power Grid Based on Grounding Electrode Structure

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Abstract. Aimed at the actual situation of fish death in fish ponds near the power transmission line towers after the thunderstorm happened in Guangdong Province in China, this paper studied the influence of the ground current on fish in the pond. Firstly, this paper studied the current density of the fish without protection. On this basis, paper studied the horizontal pole with full-shielded, the vertical pole with half-shielded, the horizontal pole with extension three kinds of protective measures and effects. Finally an effective protection scheme was put forward according to the engineering practice. The results can provide some engineering guidance and quantitative basis for the design and modification of grounding devices when the tower is adjacent to the fish ponds in southern China.

1. Introduction

It’s more possible that transmission line in Guangdong Province being struck by lightning due to climatic frequent lightning activity. For the accuracy of the lightning detection signal higher, we need to draw support lightning meteorological monitoring experience [1]. According to statistics in Guangdong, from 2004 to 2008, four years there’re 42 groups transmission line towers of 220 kV and above occurring lightning failure flashover [2]. Visible lightning accident is an important factor in Guangdong Power Grid security implications.

In recent years, the Pearl River Delta Guangdong Province, the problem that massive death of fish in ponds near transmission line tower frequently occur after the thunderstorm. Research shows that fish death is due to being struck by lightning [3]. Paper [4-6] studied the fish death problem caused by the electric. And paper [7-12] studied some impact characteristics of tower grounding. However, research on the impact on organisms of the current diffusion and current distribution is rarely usual.

This paper firstly studied current density on fish under grounding device unprotected. On this basis, paper studied the horizontal pole with full-shielded, the vertical pole with half-shielded, the horizontal pole with extension three kinds of protective measures and effects. Lastly the protection method is given in line with the actual practice that is of great significance for the safe under transmission line towers near pond.
2. Engineering situation
Figure 1 shows the typical relative positional relationship between fish pond and transmission line towers in Guangdong region. Figure 2 shows the grounding device structure of a 220kV transmission line tower used in Guangdong region. Meaning and Structural parameters represented by the symbol in figure are shown in Table 1, wherein the ground conductor relative resistance was chosen 17, relative permeability of conductor was chosen 300.

![Figure 1](image1.png)

**Figure 1.** Relative position of pond and transmission tower.

![Figure 2](image2.png)

**Figure 2.** Schematic diagram of tower grounding device.

| Symbol | Value | Description |
|--------|-------|-------------|
| r/mm   | 7     | Ground conductor radius |
| a/m    | 15    | Horizontal ground length |
| h/m    | 2     | Vertical ground length |
| s/m    | 5     | Vertical ground pole spacing |
| d/m    | 2.8   | Injection point lead line length |
| w/m    | 2.8   | The boundary distance |
| l/m    | 4     | Grounding lead line height |
| rh/m   | 0.8   | Grounding depth |

3. Model details
Fish pond is set to a cylinder with a radius of 40m, a depth of 2.5m in model. Water resistivity of pond is set to 52Ω·m by measuring. Soil resistivity is set to 100 Ωm. The line connecting ponds center and grounding centers locate in the y-axis direction, being perpendicular to the x-axis. The fish pond is at a distance of 1.5 m from the grounding device. This paper selected the lightning current wave with half the peak time of 8/20μs and amplitude of 30kA [13]. According to the existing research and related articles, article selected fish tolerance threshold with 100A/m². Taking into account the shape of fish is similar to ellipsoid, model used ellipsoid instead of fish, setted three directions axle length respectively to 0.2m, 0.03m, 0.05m, resistivity to 5Ω·m, placed in water of pond closed proximatively to ground near the shore of the device, and distributed in the water at different distances from the shore.

4. Simulation calculation

4.1. Effect of inlet current on fish body without protection
Tower grounding device without any protective measures, select and study the y-axis direction a number of fish located at pond with depth of 1m, near the side of the grounding device at different distances. Set the y-axis coordinates as the abscissa, the current density mode as the ordinate, the result of the current density on fish body is shown in Figure 3.

![Figure 3. Current density curve of fish with coordinates.](image)

As can be seen from Figure 3, with the distance from the grounding device increases, the current density decreases on the whole mold, and the trend becomes more and more gentle. Due to the presence of fish, the current density of fish is much larger than the water. Leading to this phenomenon is that fish resistivity is far less than the resistivity of the water, although the fish is small, but local current density mold caused great impact.

Located in the y-axis coordinate at 10m from the shore side of the pond near the grounding device 1m away, the current density on fish body reached at 564A/m², that well above the tolerance threshold of the fish. Located in the y-axis coordinate at 29m from the shore side of the pond near the grounding device 1m away, the current density on fish body decreased at a level less than 100A/m², reaching at 90A/m² in extent, At this time the current density mode is within the range that the fish can bear.

The lightning current flows into the ground through the grounding lead line, disperses in the vicinity of the ground soil. Due to the presence of fish pond, water resistivity less than the resistivity of the soil, so there is a current trend to the fish pond.

4.2. Effect of inlet current on fish body when horizontal grounding electrodes are fully shielded

Figure 4 shows that the horizontal grounding electrodes of tower grounding device are fully shielded. The dark color part of the figure is the shell made of insulating material which tightly wrapped the horizontal grounding poles. And the current density distribution in this situation is shown in Figure 5.

![Figure 4. Schematic diagram of full-shield horizontal grounding pole.](image)

![Figure 5. Current density distribution of full-shielded horizontal grounding pole.](image)
In the case that horizontal grounding poles are fully shielded, the current density modulus in pond water decline than shield before, but declining slightly. The reason for this is due to the presence of vertical grounding. Because of the vertical grounding without shielded, most of the current flows from the vertical grounding to the fish pond.

Located in the y-axis coordinate at 10m from the shore side of the pond near the grounding device 1m away, the value of the current density on fish body decreased at a level of 450A/m², comparing with the shield before level of 564A/m², the result decreased by about 20%, the value of current density of fish body located at rest situation has decreased, but the decline can be ignored. Located in the y-axis coordinate at 29m from the shore side of the pond near the grounding device 20m away, the current density on fish body decreased at a level less than 100A/m², reaching at 85A/m² in extent, At this time the current density mode is within the range that the fish can bear.

4.3. Effect of inlet current on fish body when vertical grounding electrodes are half shielded based on horizontal grounding electrodes fully shielded

The result simulation of vertical grounding electrodes shield with 1m, the y-axis direction in a depth of 1m ponds near the side of the grounding device at different distances of several fish body current density modulus value curve changing with y-axis coordinate, is shown in Figure 6.

![Figure 6. Current density distribution of semi-shielded vertical grounding pole.](image)

As can be seen from Figure 6, in the case of the vertical grounding electrodes with half shielded based on the horizontal grounding electrodes fully shielded, the value of current density modulus in pond water has not changed much compared to before. Because the vertical grounding electrodes aren’t fully shielded, there’re also many flow paths for current.

Located in the y-axis coordinate at 10m from the shore side of the pond near the grounding device 1m distance, the value of the current density on the fish die down to 340A/m², and the front half of the shield 450A/m² decreased by about 24%, the rest at a current density of fish die value has decreased, but the decline can be ignored. Located in the y-axis coordinate at 29m from the fish ponds near the shore 20m far side of the grounding device, the current density on the fish die 95A/m², slightly higher compared to the previous half-shield.

4.4. Effect of inlet current on fish body when horizontal grounding electrodes are extended

Result that vertical grounding poles with half shield was ineffective mainly because of the fact that lightning current diaspora from the unshielded vertical ground poles. In other words, if make the vertical grounding electrodes that the upper end of the package to a sufficient insulation shield deep
into the ground, the value of the current density on fish body will be reduced to lower than tolerance threshold. However, from the point of view of construction, this measure is too costly, and divorce from reality. Therefore, this section presents another measure, namely on the basis of horizontal grounding electrodes fully shielded, removing all vertical grounding electrodes, and extending grounding electrodes in the opposite direction along the ponds grounded. Diagram shown in Figure 7 after prolonged shown.

To study the impact of extending the horizontal length of the ground electrode on current density of fish, select the y-axis coordinate at 10m from the shore side of the pond near the grounding device 1m distance to observe the object, and get the curve that current density of fish variation with grounding electrodes extension length, as shown in Fig.8. Table 2 shows when horizontal grounding electrodes are extended lengths of 2m, 4m, 5m, 6m, 7m, 10m the tower grounding resistance, the values were calculated by CDEGS software simulation.

Figure 7. Schematic diagram of extended horizontal grounding pole.

Figure 8. Current density curve of fish with extension length of horizontal grounding pole.

| Extension length(m) | Grounding resistance (Ω) |
|---------------------|--------------------------|
| 2                   | 25.37                    |

| Extension length(m) | Grounding resistance (Ω) |
|---------------------|--------------------------|
| 4                   | 15.23                    |
| 5                   | 12.93                    |
Figure 8 shows that as the length of the ground electrodes extending gradually increasing, the current density of the fish also gradually reduce. When the horizontal length of the ground electrodes extends to a certain extent, the current density tends to be flat. When the length of the ground electrodes is extended greater than 2.5m, the current density of fish will be fall below the threshold. However, when extending length is small, tower grounding resistances are more than 10Ω required in the design, the ground cannot meet the targets. At the same time, in order to consider a certain margin, select the level of the ground electrodes extension length of 10 m, the current density of fish down to 72A/m², this time, the tower grounding resistance is 7.78Ω, which can meet the design requirements.

5. Conclusion

1) The tower without any protective measures, the current density of fish closed to the ground is much higher than the threshold tolerance, current density of fish at 20m away from the pond shore falls below the threshold of tolerance;
2) The current density of fish closed the grounding device under horizontal grounding poles fully shielded measure has decreased, but the decline is not obvious, and still higher than the tolerance threshold; the current density of fish under vertical grounding poles half shielded and horizontal grounding poles fully shielded measure is not substantially changing;
3) Measure that horizontal grounding poles fully shielded with grounding poles extension can effectively reduce the current density of fish. Considering a certain margin, and the tower grounding resistance meeting the design requirements, it is recommended horizontal grounding poles extended 10m to the opposite direction of the fish pond, for higher soil resistivity, it is recommend appropriately to further extend the length of grounding poles, and make amount of vertical grounding poles into earth, which can effectively reduce the grounding resistance of the tower.

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