

# Impact and Improvement Method of the Biological Effects during the Transmission Tower Being Lightning Struck

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**Abstract.** When lightning strikes the transmission line towers, the lightning current flow through the overhead line shunted along the grounding conductor dispersed in the earth, the lightning current amplitude of tens of thousands of amperes or even hundreds of thousands of amperes, making the local current density is very large, seriously affecting the surrounding biological safety. This paper analyzes that different fish fatalities in fish ponds after lightning strikes the transmission line towers, the typical accident towers were simulated and the correctness of the model was verified by CDEGS. Meanwhile the effects of lightning current on fish were simulated, according to the simulation results that the fish current density is related to body length and the current angle in the electric field. By comparing the simulated results with the fish tolerance limits, we can quantitatively evaluate the fish bioelectromagnetism of the relationship between soil resistivity and fishpond distance. The modification of the external grounding network based on the insulated lead wire can be used to guide the related grounding devices.

## 1. Introduction

When lightning strikes the transmission tower, most of the lightning current will be dissipated in the earth, however, the transient electromagnetic field generated by the lightning current propagating in the ground is likely to endanger the surrounding area with the application of sensitive electronic and digital equipment. Especially in the environment of frequent lightning and numerous lakes, the current effect caused by the lightning impulse current in the ground will seriously affect the normal life of the surrounding creatures, and even cause death. For example, in recent years, the transmission line towers in the Pearl River Delta region threatened or even created biosafety cases. For example, fish in the fish ponds near the transmission line towers were dead after a thunderstorm. According to biological point of view, nerve impulses spread in the nerve fibers in the form of electrical signals to control the biological response and action; when the lightning impulse current strikes through the organism, the biological behavior disorder occurs, such as electrical burns, ventricular fibrillation, muscle twitching, cramps and stiffness, and large area of death even occurs [1-5]. In order to solve this problem, it is necessary to carry out detailed theoretical research and simulation modelling to the dynamic physical flow of the ground current of the lightning



transmission line to ensure the security of the surrounding biology and the safety of production.

Current research on transmission line tower grounding device mainly focus on the impact of ground characteristics and soil ionization parameter calculation aspects considering the nonlinear effects. He Jinliang, Gao Yanqing from Tsinghua University and other studies consider the impact ionization conductor grounding characteristics [6-7]; Sima WenXia from Chongqing University studied properties model for grounding device considering frequency variation characteristics, current diffusion law of grounding device is analyzed by the method of combining experiments and simulation [8-10].

In this paper, according to the situation of a power supply bureau in Guangdong after the thunderstorm, the phenomenon of the death of different fish in the fish pond near the tower of the transmission line occurs, diffusion model of grounding device is established, the simulation results of the grounding impedance are compared with the results of the internationally recognized grounding software CDEGS to verify the correctness of the model.

In considering the electromagnetic influence of the diffusion current on the fish, the typical electrical model of fish is established. Based on the field survey results, the influence of the scattered flow on the surrounding organisms in the lightning rod tower is quantitatively evaluated, and the improvement method of the grounding wire through the insulated lead wire is put forward, which greatly improves the safety of the surrounding organisms and can be related to optimize the transformation of the project to give guidance.

### 1.1. The description of the physical field in the ground

The electrical parameters of the soil are the most important factors in the analysis of the diffuse characteristics of the grounding device. In the course of lightning current impulse discharge, it is considered that the discharge of soil occurs under the impact of certain intensity, which is mainly caused by the breakdown of the air gap between soil particles. Lightning current along the direction of the conductor in the process of dispersion, in surrounding time-varying electromagnetic field generated in the soil field strength:

$$E = J_o \rho \quad (1)$$

Where  $J_o$  is the current density,  $\rho$  is the soil resistivity. As the amplitude of the lightning current increases, the electric field strength of the soil around the grounding conductor becomes larger and larger, and when it exceeds the critical breakdown field of the soil, the soil in the region produces a spark discharge. Amplitude is reduced, equivalent to the size of the grounding body increased. The radius of the soil spark discharge area around the grounding device can be regarded as the equivalent radius in the transient process of the grounding body.

According to Ohm's law in differential form, grounding conductor conduction current density  $J_c$  is:

$$J_c = \gamma E = \gamma E_m \sin \omega t \quad (2)$$

Grounding conductor displacement current density  $J_d$  is:

$$J_d = \frac{\partial}{\partial t} (\epsilon_0 E_m \sin \omega t) = \epsilon_0 E_m \cos \omega t \quad (3)$$

$$\left| \frac{J_d}{J} \right| = \frac{\omega \epsilon_0}{\gamma} \approx 10^{-17} f \quad (4)$$

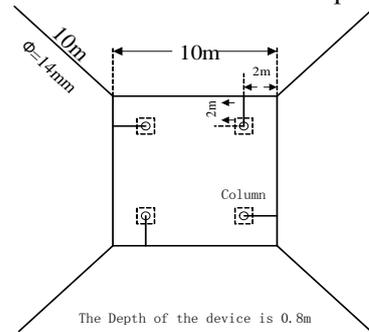
Where  $\gamma$  is the conductivity,  $\epsilon_0$  dielectric constant,  $\omega=2\pi f$ . When the lightning current when the frequency is less than  $f=10^{13}$  Hz, In the grounding conductor, the displacement current can be neglected. However, when the current is dispersed in the ground, especially in the areas with high soil resistivity, the soil is a poor conductor, the conductivity is far less than the conductivity of the metal conductor, when the simulation model is established, the displacement current can not be ignored.

### 1.2. Verification of finite element dynamic model

In order to verify the correctness of the finite element dynamic model of the lightning current in the earth, The grounding impedance values obtained from the model are compared with the

results obtained by the internationally recognized CDEGS, verifying the effectiveness of the method.

Shown in Figure 1, we use the 220kV line tower typical B Rodin grounding device KR-1G type verify, under the assumption of a uniform soil stratification in CDEGS in the case, galvanized steel bar grounding conductor length 10m, diameter  $\Phi=14\text{mm}$ , to the depth of 0.8m; ground deflectors are introduced by ground pillar where the conductor length 4m, diameter  $\Phi=14\text{mm}$ , the simulation of grounding impedance of grounding device is carried out by injecting the 1A current with different frequencies along the end of the grounding line.



**Figure 1.** KR-1G Grounding device schematic

Based on the multi physics field simulation and simulation software COMSOL Multiphysics, the finite element model of the lightning current in the ground is established, modeling of grounding device using the structure parameters of grounding device in CDEGS software model, injecting into the same frequency and amplitude in the same location current value, galvanized steel COMSOL Multiphysics software built-in copper material resistivity of  $1.72\text{e-}8$  ( $\Omega\cdot\text{m}$ ), then take the use of specific resistance of  $1.72\text{e-}7$  ( $\Omega\cdot\text{m}$ ), the relative dielectric constant is 1 and the relative permeability is about 300; The relative permittivity and relative permeability of soil were all 1. The change of soil resistivity was calculated by multiple sets of simulation to verify the validity of the finite element model under different soil conditions.

As can be seen from Table 1, in this paper, the simulation model is consistent with the results of the calculation results of the grounding of the professional software CDEGS, it can be concluded that the simulation model can be used to characterize the inductance characteristics of the current at different frequencies, and to reflect the current state of the grounding device.

**Table 1.** KR-1G Grounding device ground-impedance

frequency (Hz)	Ground impedance ( $\Omega$ )	
	CDEGS	COMSOL
50	$2.933 \angle 0.345$	$2.956 \angle 0.119$
100	$3.000 \angle 0.533$	$2.972 \angle 0.259$
500	$3.027 \angle 1.567$	$3.004 \angle 1.298$
1000	$3.051 \angle 2.577$	$3.023 \angle 2.457$
5000	$3.191 \angle 8.663$	$3.169 \angle 9.247$
10000	$3.369 \angle 14.565$	$3.372 \angle 15.186$
50000	$5.172 \angle 37.868$	$5.231 \angle 37.578$
100000	$7.471 \angle 46.410$	$7.502 \angle 46.203$

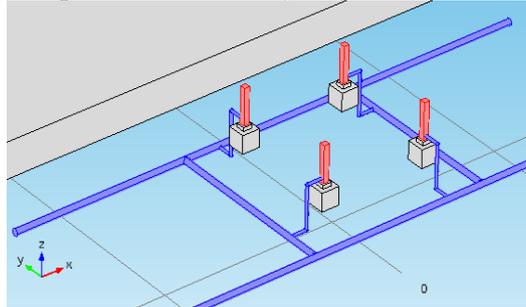
## 2. Simulation analysis of dispersed flow in lightning tower

### 2.1. Simulation of lightning surrounding by biological magnetic effect

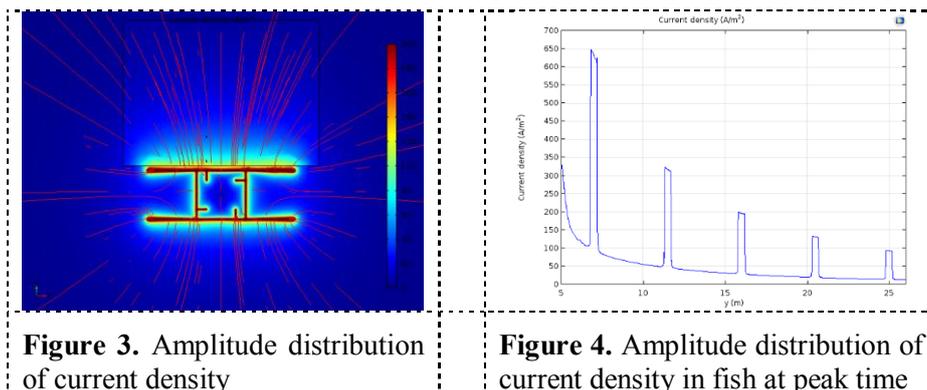
Tower grounding apparatus body model is KR-1G-type (Figure 2, blue), the use of galvanized round steel grounding conductor length is 10m, diameter  $\Phi = 14\text{mm}$ , depth is 0.8m, due to the surrounding geographical factors (the objective existence of ponds), so the level of the ground electrode and the outer lead ponds were parallel; ground deflectors length is 4580mm, diameter  $\Phi = 14\text{mm}$ . The grounding wire is led out from the tower, good welding and grounding conductor, and on the application of 30kA 8/20us standard lightning current. Soil

as homogeneous soil, Soil resistivity is  $100\Omega\cdot\text{m}$ , The pond is for a long  $40\text{m}\times 40\text{m}$ , deep 2m square area, away from the grounding device 1 m. According to the foregoing chapters, the 40cm length of the fish body is selected, and the head of the fish is set to the grounding device, so that the lightning current can generate the maximum current density on the fish body.

According to Fig. 3, the ground current flows along the ground lead line through the grounding device conductor in the ground, it can be seen that the current density on the grounding device is larger, and the end effect is produced at the end of the horizontal grounding conductor; Compared with the two sides of the grounding device, the current density in the side of the fish pond was obviously larger than that of the soil.



**Figure 2.** Model of Proportional Grounding Device for Typical Accident



**Figure 3.** Amplitude distribution of current density

**Figure 4.** Amplitude distribution of current density in fish at peak time

As can be seen from Figure 4, the body of the fish is much larger than the current density current density of water in ponds, fish ponds and along a direction perpendicular to the grounding device, as the distance between the fish and the grounding means larger and larger, its body current density decreased; in the place of 2m, the current density of fish body is more than  $600\text{A}/\text{m}^2$ , which is far greater than that of fish, far greater than the tolerance threshold value of the fish, when the fish body is about 25m from the grounding device, the current density reaches the threshold of fish body death, which shows that when the fish pond is closer to the grounding device, the area affected by the fish pond will be very large

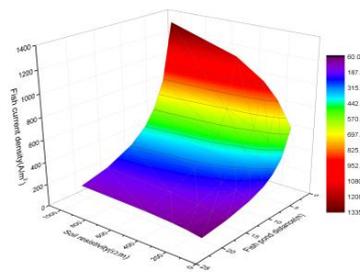
### 2.2. The relationship between the distance of fish pond and the electromagnetic effect in different soil resistivity

Suppose the overall structure of the soil is uniform soil structure, soil resistivity  $\rho$  from  $100\Omega\cdot\text{m}$  respectively adjusted to 300,500, and  $1000\Omega\cdot\text{m}$ , simulation under different soil resistivity, current density of fish the variation results in Table 2.

Relationship between current density and fish ponds distance as shown in Figure 5. From Figure 5 can be obtained:are: for the same soil resistivity  $\rho$ , with increasing distance from the fish ponds, the current point of fish is more and more far away from the grounding device, the area of the flow is increasing, the proportion of the fish pond in the area is getting smaller and smaller, and the current density of the fish is more and more slow; for different soil resistivity  $\rho$ , the current density increased fish similar trend, and with  $\rho$  increases, the rate of rise curves are getting steeper, the greater the impact from the greater the current density.

**Table 2.** Different soil resistivity and the distance from the fish pond under the current density

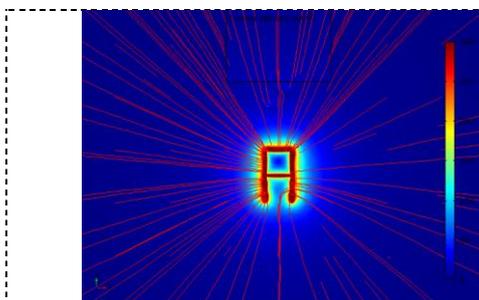
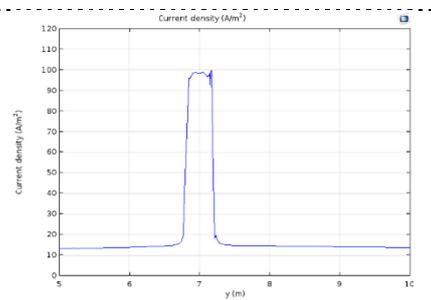
Pond distance / (m)	Fish body current density/ ( $A/m^2$ )			
	$\rho=100\Omega\cdot m$	$\rho=300\Omega\cdot m$	$\rho=500\Omega\cdot m$	$\rho=1000\Omega\cdot m$
2	625.46	972.77	1138.65	1330.20
4	378.29	595.01	696.47	813.64
6	271.01	426.28	498.96	582.91
8	205.25	322.85	377.90	441.47
11	148.54	233.65	273.49	319.50
16	93.32	146.78	171.81	200.71
21	63.57	99.99	117.04	136.73

**Figure 5.** Relationship of soil resistivity, the distance from the fish pond and the fish body current density

When the soil resistivity is small, ponds and grounding distance greater than 15m, when strikes on fish ponds current maximum is less than  $100A/m^2$ ; and when the soil resistivity  $\rho = 1000 \Omega\cdot m$ , because the surrounding soil diffuser ineffective, most lightning current will be concentrated to the ponds, at this point, although the distance between the fish pond and the grounding device is greater than 20m, the peak value of the fish body current can also reach about  $150A/m^2$ , which is far beyond the limit of tolerance of fish, and the fish ponds will be seriously damaged

### 2.3. Based on an insulated lead network transformation program

Based on the above-mentioned analysis of the influence of the fish pond distance on bio-electromagnetic, the grounding device of the transmission line tower can be covered by insulating grounding from the tower base, which will lead the current to dispersal far away from the pond. The lead direction of the horizontal ground electrode is changed, namely, the horizontal ground electrode which is original parallel to the pond is led away from the pond direction. And a 2m long  $\angle 50\times 5$  angle steel is built on the horizontal ground electrode to increases the diffusion effect. In this case, the grounding device is connected by a flat copper grounding to reduce the skin depth of the current, which solves the problem of impedance rise because of outer lead of the grounding device.

**Figure 6.** Amplitude distribution of current density and current flow in ground**Figure 7.** Amplitude distribution of current density in fish at peak time

According to figure 6, the current density around the ground device is still large, however, because of the increased distance between the ponds and the grounding device, difference on current density in the ponds and that of the earth is very small, most of the lightning current dispersal through the surrounding soil of the grounding device, only a relatively small current dispersal through the ponds. According to figure 7, after leading the insulation lead to an outside grounding grid, the current density of the fish body at 2m away from the fish pond is

less than  $100\text{A}/\text{m}^2$ , which is less than 6 times as much as that of before and it is below the threshold of fish death, indicating that the transformation scheme is effective and can greatly reduce the affected area of the ponds. However, when the soil resistivity is larger, the ponds, according to the above analysis are easier to gather current, it is necessary to increase the distance between the ponds and grounding devices.

### 3. Conclusion

In this paper, through the establishment of a typical accident transmission tower grounding device model, combined with the typical fish in the lightning under the biological effects of simulation analysis, the phenomenon of the death of different fish in the fish pond after the thunderstorm is studied. As the problem involves a wide range of influential parameters, in order to fully understand and master the impact of the law, a lot of detailed theoretical research and related experimental research are needed. From the analysis of this paper, we can draw the following conclusions:

1) Because the resistivity of the fish is less than the resistivity of the water, the current density in the fish will be much larger than the current density in the water. When the current flows from the tip of the fish head to the end of the fishtail, the current density of the fish center is the largest. When the current flows from the side of the fish, the current density of the fish center is the smallest, but the fish cross section is larger and the current flows through the fish body is not the minimum.

2) In the same soil resistivity, the linear increase of the fish pond distance makes the distance between fish and the grounding device of the current injection point farther and farther, but the proportion of fish pond scattered area is getting smaller and smaller, the higher the soil resistivity is, the higher the fish current density will be, because the water resistivity is less than the soil resistivity so the lightning current is more likely to concentrate in the water, but the total amount of lightning current do not change, so the fish current density will rise slowly.

3) For a typical accident transmission line tower grounding device through the cover of the insulation of the grounding from the tower at the base of the lightning current from the fish pond away from the local flow. Increasing the distance between the fish pond and the grounding device to 25m or further, the fish body current density can be significantly reduced of more than 6 times, which successfully controls the lightning current impact of the local flow in the death threshold. And the grounding impedance rise problem because of the external grounding device is solved through the flat copper grounding. On the basis of considering the safety parameters and safety requirements of the tower grounding, this method ensures the biological safety around the lightning transmission line tower and improve production safety.

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