Transient overvoltage calculation on the floating roof tank stroked by lightning using boundary element method

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ABSTRACT: Due to the large floating plate of large floating roof tank, and direct exposure to the atmosphere, it can be easily affected by the thunder and lightning induction. The paper mainly studied the transient overvoltage calculation on the floating roof tank stroked by lightning by using boundary element method with transient voltage calculation of cable. A calculation model of floating roof oil tank was set up, then the lightning current was Fourier transformed in frequency domain. Then the copper braid inductance which connected the floating roof and tank wall was calculated using boundary element method in each corresponding frequency. Finally, the transient voltage across the cable can be obtained. To verify the calculation model and its accuracy, small scale model of floating roof tank was built in the lab and the experiments had been done. The voltage across copper cable was measured using transient measurement system. By comparing the experimental measured values and calculated values, the error was only 1.7% which proved the validity of the calculation method.

INTRODUCTION

It is both dangerous that the floating roof tank is directly stroke by lightning at any part of it, such as tank wall and floating roof, or the nearby earth and objects are stroke by lightning .When lightning occurs, lightning current will pass through the stainless steel conductive film between the floating roof and tank, causing a spark between the conductive film and tank wall. As shown in Figure 1. the floating roof was stoked and the lightning current will flow in the earth through connection between the floating roof and tank wall.

There are some calculation methods about the tank worldwide. Guanjun Zhang calculated the induced charge distribution on the spherical tank with the analytic method which is charge simulation method (CSM). C. Buccella calculated the induced transient voltage of the liquid container tank using circuit method. The researches focused on the lightning induced overvoltage calculation and the paper mainly calculated transient overvoltage using the boundary element method when floating roof tank was stoked by lightning.

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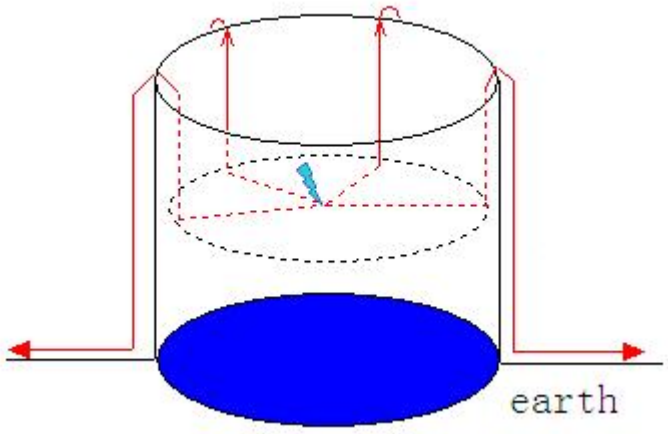

Fig.1 Lightning strikes the floating roof of oil tank

THE BOUNDARY ELEMENT METHOD

The boundary element method is developed based on Maxwell integral equations. The boundary value problem is equivalently transformed into boundary integral equation using the finite element discrimination constructed method. Its main features are: the boundary problem of the given boundary space region represented by the boundary integral equation, thereby reducing the dimension of the space. The more reduced order of equation, the decreased of the input data. As mentioned before, the values need to be calculated will be confined in the boundary nodes which not only simplify the pretreatment process problem, but also greatly reduce the order of discrete equations. In addition, because of the boundary discrimination, discrimination error is derived from the boundary, the boundary element method is expected to have higher accuracy than the finite element method.

THE TRANSIENT VOLTAGE CALCULATED BY BOUNDARY ELEMENT METHOD COMBINED WITH THE COPPER BRAID TRANSIENT CALCULATION FORMULA

Due to the relatively thin floating roof, tank wall and the copper braid, boundary element method is appropriate for the calculation of the floating roof tank. It only needs to split surface, and the result is more accurate when the key parts can be split more carefully. The specific method of calculation is as follows: Firstly, a calculation model of floating roof oil tank was set up, then the lightning current was Fourier transformed in frequency domain. Secondly, the copper braid inductance which connected between the floating roof and tank wall would be calculated using boundary element method in each corresponding frequency. Finally, the transient voltage across the cable can be obtained.

1) The simulation of lightning current

The vast majority of lightning impulse waveforms can be defined as double exponential function, the general mathematical form is as follows:

$$i_s(t) = KI_0(e^{-\alpha t} - e^{-\beta t}) \qquad (1)$$

Where $\alpha = 1/T_1$, $\beta = 1/T_2$ T_1 is the head time of wave, T_2 is the tail of wave.

Double exponential waveform of 10kA 8/20μs can be expressed for:

$$i(t) = 10011000 * (e^{-128700*t} - e^{-129050*t}) \quad (2)$$

Waveform was shown in figure 2. The given lightning current waveform needs to be discredited according to the sampling theorem. Since the boundary element computational ability can not achieve the 3-D transient calculation at present, but can be finished through the parameter calculation in frequency domain, therefore the Fourier transform is needed for the lightning current.

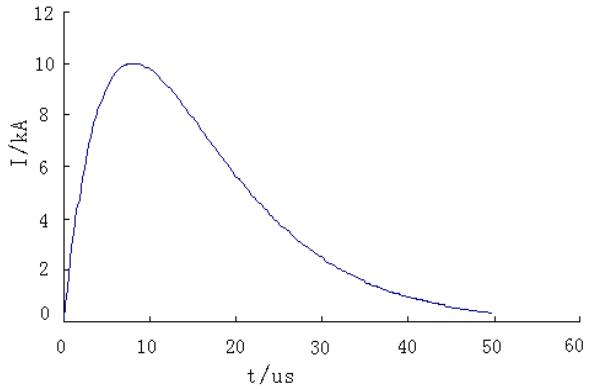

Fig.2 10kA 8/20μs waveform

2)Modeling and mesh

The small scale model of floating roof has been established according to the size of figure 3. Floating roof and tank wall was connected with six copper braided belts. lightning current was injected from the floating roof center. The material of floating roof and tank wall was iron, the width of copper braided belt is 2cm, the thickness is 0.2cm, and the length is 0.57m. One-sixth of the computer model was shown in figure 4. The split result was shown in figure 5.

Fig.3 Small scale of floating

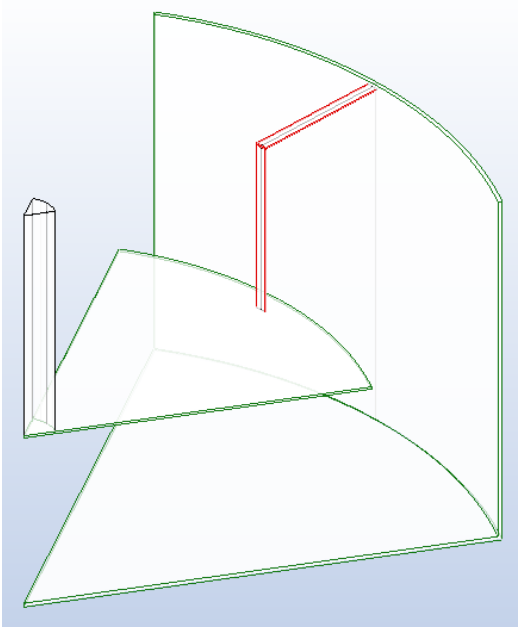

Fig.4 1/6 Computer model of floating roof oil tank

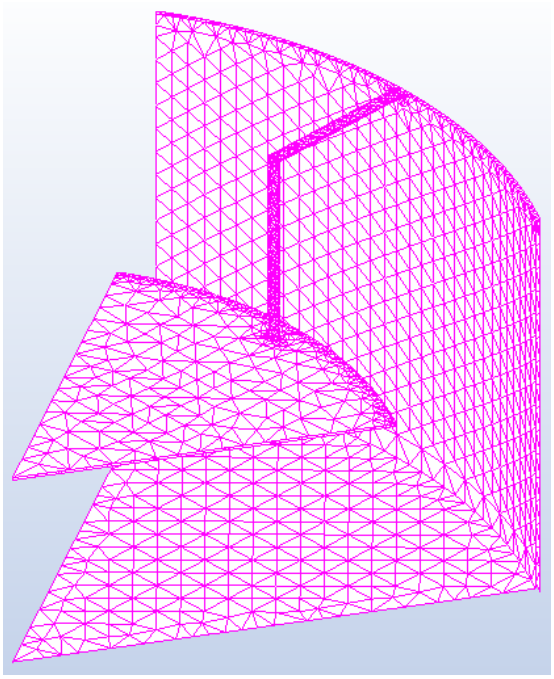

Fig.5 The boundary mesh result of the floating roof tank

3) The incentive

The amplitude and phase at each frequency point was input in the center of calculating model of the floating roof.

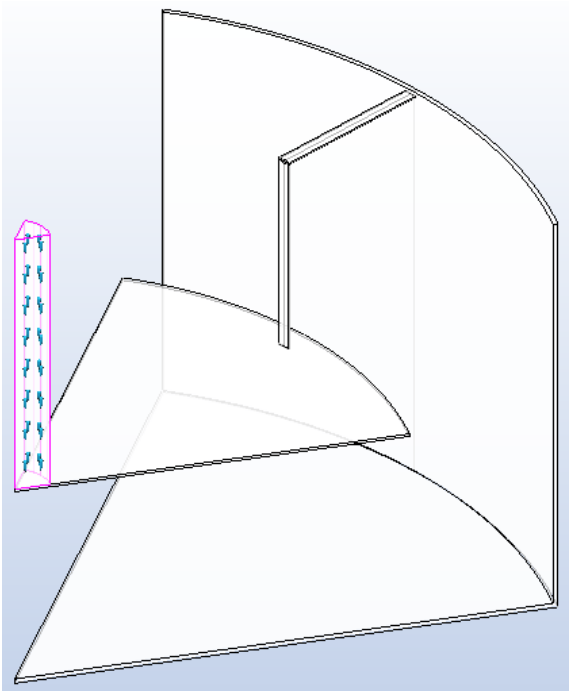

Fig.6 Imposing volume current

4）The inductance of copper braid

The inductance value is 0.46μH in agreement with each frequency point.

5）The transient voltage of copper braid

The calculation formula of resistance of straight cable:

$$R = \rho * \frac{l}{s} \tag{3}$$

The resistivity of copper is $1.724 * 10^{-8} \Omega \cdot mm^2 / m$, while the R value is $0.152 * 10^{-3} \Omega$.

If there were six copper braids uniformly connected floating roof and tank wall, when 10kA lightning current was applied into center point of floating roof, then lightning currents flowed through each braided copper is about 1.67kA. The expression for 1.67kA lightning current is as formula 4:

$$i(t) = 1671837 * (e^{-128700*t} - e^{-129050*t}) \tag{4}$$

The calculation formula of transient voltage for the copper braid:

$$U = R * i(t) + L * \frac{di(t)}{dt} \tag{5}$$

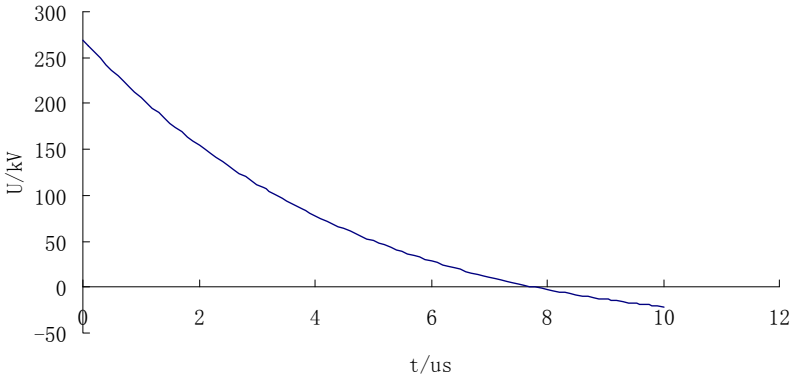

Fig.7 The transient voltage waveform

The maximum value of transient voltage was 269.17V.

THE TEST VERIFICATION OF TRANSIENT CURRENT WHEN THE COPPER BRAID WAS USED

The test was shown in Figure 3, when the 10kA lightning current hit the roof center, 264.51V transient voltage across the copper braid were measured. Compared with the test values, error was 1.7%.

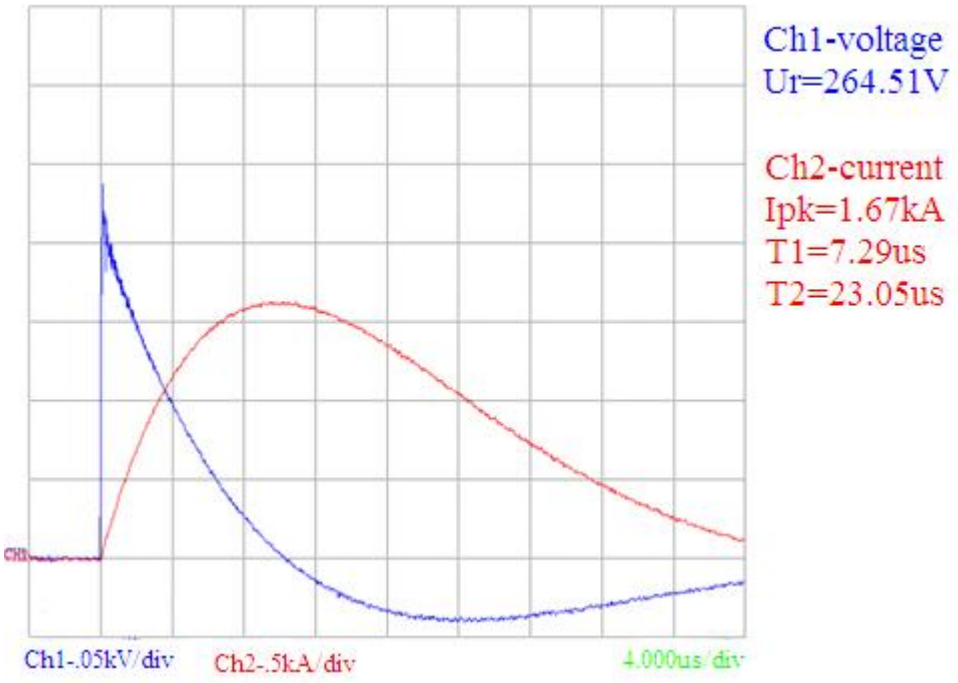

Fig.8 The measured waveform of transient voltage

CONCLUSIONS

The paper mainly studied the transient overvoltage calculation on the floating roof tank stroked by lightning by using the boundary element method with transient voltage calculation of cable. To verify the correctness and the accuracy of the calculation model, small scale model of floating roof tank was built in the lab and the experiments have been done. The voltage across copper cable was measured using transient measurement system. By comparing the experimental measured values and calculated values, the error was only 1.7% which proved the validity of the calculation method.

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