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SIMULATION AND ANALYSIS OF TIME-VARYING TEMPERATURE FIELD OF DC ZINC OXIDE ARRESTER

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ABSTRACT

The multi-column parallel zinc oxide arrester has the characteristics of strong absorption capacity on overvoltage and low residual voltage, so it is widely used in high-voltage, extra-high voltage and ultra-high voltage transmission systems. But when the arrester is subjected to normal line voltage, there is a slight leakage current, and the core has a certain temperature rise, which causes the aging of the zinc oxide resistor valve. The degree of aging depends on the temperature distribution and the temperature rise rate. Therefore, when studying on the DC arrester time-varying temperature field distribution is of great significance. In this paper, YH20WDB1-188 multi-column parallel DC zinc oxide arrester is used as the model. According to the heat transfer differential equation and the supplementary equations, the time-varying temperature field simulation calculation is carried out, and the temperature distribution and temperature rise rate of the single core and the whole arrester are compared and analyzed. The simulation results contribute to structural optimization of multi-column parallel arrester and analysis of valve aging characteristics.

Keywords: Direct current, Zinc oxide arrester, Temperature rise, Time-varying temperature field, Multiphysics coupling

1. INTRODUCTION

DC zinc oxide lightning arrester is one of the most important protective devices in HVDC and UHVDC systems. It can effectively prevent various faults produced by overvoltage [1]. But if the arrester endures normal working voltage for a long time, heat will be generated by the leakage current which is one of the reasons for aging of zinc oxide valve sheet. When the aging is serious, the arrester will lose its protection ability. The aging of the valve is related not only with the temperature distribution but also with the temperature rising speed. Therefore, it is necessary to study the time variation temperature characteristics of multi-column DC zinc oxide arrester under normal operating voltage.

Most wok has been done on the transient thermal characteristics of arrester, but the analysis and calculation of temperature field of multi-column parallel arrester are relatively few. In refernce [2] the temperature rise calculation is carried out by using the finite element model of multi-core parallel structure arrester. In addition, the temperature rise experiment and heat dissipation experiment are also carried out. In reference [3], the calculation methods of various physical quantities affecting the temperature change during the heat transfer process of metal oxide arrester (MOA) are given, and the thermal characteristic tests are carried out. In reference [4], the temperature simulation calculation of single-core gas insulated lightning arrester was carried out.

According to the actual structure size of YH20WDB1-188 type DC oxide zinc arrester, a two-dimensional temperature field simulation model of YH20WDB1-188 type DC composite sheath gapless metal oxide arrester was established by using COMSOL multi-physical field coupling analysis simulation software. Under normal non-pulse voltage, the temperature rise and its distribution with time are calculated. The calculation results can provide reference for structural optimization of multi-column arrester.

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2. CALCULATION MODEL OF DC ZINC OXIDE ARRESTER

2.1 *MOA Model Parameters and Structure*

Fig 1 is the structure of YH20WDB1-188 ZnO. The length of single arrester is 2700 mm, the length of small umbrella skirt and large umbrella skirt are 72.5 mm and 79.5 mm respectively, and the spacing is 40 mm. The outer and inner diameters of the epoxy insulating sleeve are 338 mm and 320 mm respectively. The diameter and thickness of the resistor are 105 mm and 22.5 mm respectively. The size of the small aluminium gasket is the same as that of the resistor. The size of the large aluminium gasket is 105 mm and the thickness is 105 mm.

The arrester is composed of a zinc oxide resistor and an aluminium pad arranged alternately, but the arrangement of the resistor and the pad is not symmetrical.

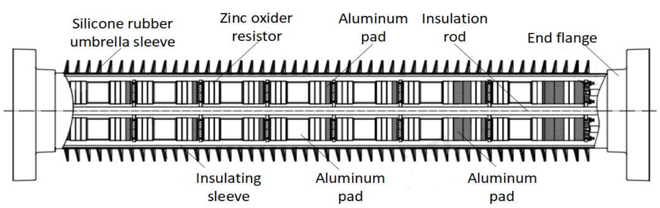

Fig 1 Structural schematic diagram of lightning arrester

2.2 Basic Hypothesis and Mathematical Computing Model

The calculation is made by the coupling of electric field and temperature field, and the assumptions are as following:

1) Without considering the variation of conductivity of zinc oxide resistors and aluminium gaskets produced by temperature change.

2) Ignore the influence of umbrella cover, corona ring and spring on heat dissipation[2].

3) Without considering the radiation heat transfer, according to the actual operating environment of the lightning arrester, the convective heat transfer coefficient is set to 5W/(m^2 • K)[4].

The parameters of the arrester coupling model are shown in Table 1.

The temperature of the arrester satisfies the following control differential equations:

$$d_z\rho C_p\frac{\partial T}{\partial t}+d_z\rho C_p\,\mathrm{u}\cdot\nabla T+\nabla\cdot q=d_z\mathrm{Q}+q_0+d_z\mathrm{Q}_{\mathrm{ted}} \quad (1)$$

$$q=-d_z k\nabla T$$

Where ρ is the density of material, C_p is the heat capacity of material, T is the temperature of the object, u is the velocity ,q is the heat conduction rate ,k is the thermal conductivity of the material, q_0 is heat source,Q_0 is convective heat flux.

Table 1 Main material parameters of lightning arrester

	Resistor chip	Aluminum pad	Epoxy insulation
Conductivity /s m^{-1}	0.000014	0.35	0
Relative permittivity	750	81	5.5
Thermal conductivity /W • (mK^{-1})	52	236.5	0.32
Density /Kg m^{-3}	5650	2850	91.4

The convective heat flux is expressed as follows:

$$q_0=h(T_{ext}-T) \quad (2)$$

Where h is the heat transfer coefficient which is chosen as 5 (W/m^{2}K).T_{ext} is the external boundary temperature and T is the internal boundary temperature.

The electric field equation is as follows:

$$\nabla\cdot J=\mathrm{Q}_{j,v}$$
$$J=\left(\sigma+\varepsilon_0\varepsilon_r\frac{\partial}{\partial t}\right)E+J_e \quad (3)$$
$$E=-\nabla V$$

Where σ is the conductivity,ε_0 and ε_r are the vacuum permittivity and relative permittivity, J_e is the current density, E is the electric field strength, V is the potential.

The calculation model is shown in Fig 2(a) and the meshing figure is shown in Fig 2(b).The temperature of the internal resistor varies obviously, the mesh is fine, and the minimum unit size is 16 mm. External temperature change is small, the grid is sparse, and the maximum cell size is 800mm.

3. ANALYSATION RESULTS

3.1 Calculation results of temperature distribution

The initial temperature in this paper is 283.15K, the voltage applied is 202 kV is lower than the line voltage and DC reference voltage, and the loading time is 25 minutes. Fig 3 shows the temperature distribution of the arrester and the curve of the maximum value of temperature rise.

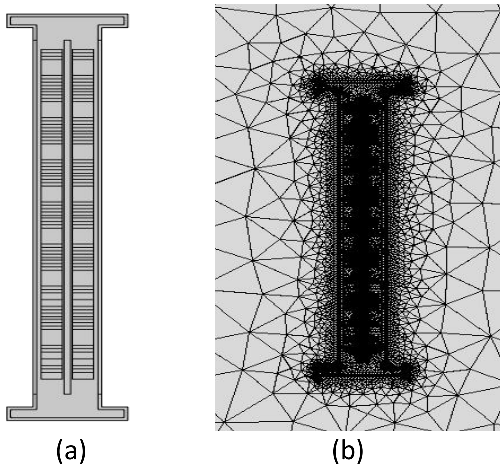

Fig 2 Simulation and meshing model

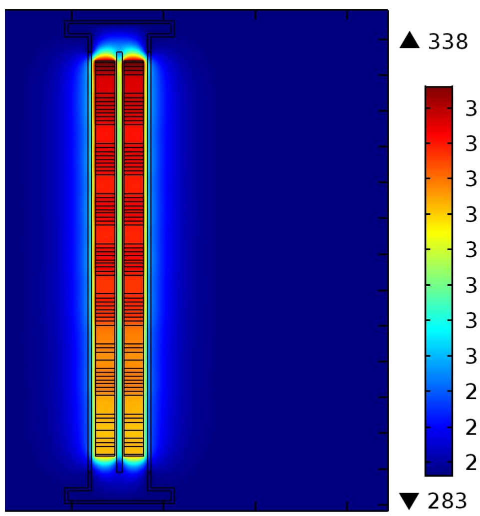

Fig 3 Temperature distribution of lightning arrester

The simulation results show that the maximum temperature of the arrester is 338K, and the temperature of the upper part of the arrester core is obviously higher than that of the lower part. This is due to the gradual reduction of the potential from the top to the bottom, which agrees with the operation experience.

3.2 *Comparison of Time Variation Temperature Rise in Different Positions of ZnO Arrester*

The different positions of the inner core of the arrester are selected to compare the time variation temperature rise. The selected positions are shown in Fig 4. are located on the upper, middle and lower parts of the core respectively. From top to bottom, they are named point 1, point 2, and point 3.

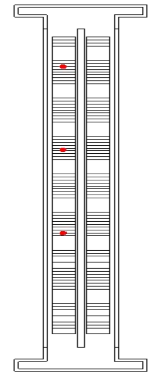

Fig 4 Schematic diagram of the selected point location

Fig 5 shows the time variation temperature rise curves at three locations.

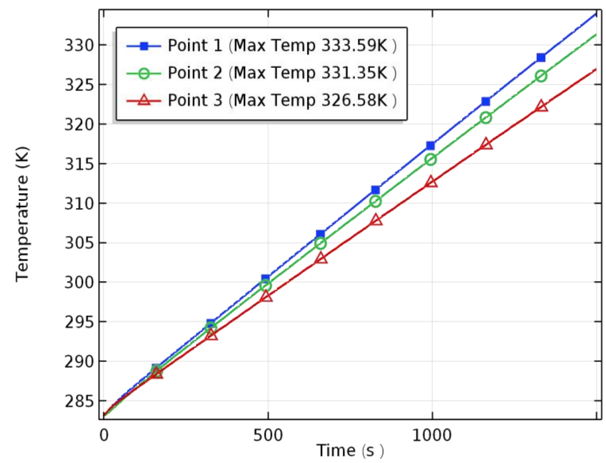

Fig 5 Comparison of time variation temperature rise curves at different positions inside the arrester

According to the temperature rise curve, the maximum temperature rise at the upper point 1 is 333.59K, and the maximum temperature rise at the lower point 3 is 326.58K.The difference between the two points is 7.01K.

Theoretically, the temperature of the upper position should be higher than other parts for the high potential and the rise of hot air, but the contacting area with the environment of the top and lower resistors is large which is good for heat dissipation, so the temperature rise of the middle part is larger than that of the upper part [5] which is also proved in reference [3]. The experimental data are shown in Table 2.

Table 2 Experimental Temperature at Three Points(K)

Time(s)	Point 1	Point 2	Point 3
0	284.75	284.75	284.75
300	293.95	296.38	298.38
600	309.45	314.44	317.44
900	314.65	319.55	322.55
1500	324.65	330.35	332.35

3.3 Effect of Insulation Sleeve on Temperature Change of Surge Arrester

After calculating the overall temperature rise and temperature distribution of the arrester, the temperature rise and temperature field distribution of the single core in the arrester are calculated by removing the sleeve and the end flange. Three points, which are the same as the overall position of the arrester, are also selected, which are named as point 4, point 5 and point 6 from top to bottom. In this simulation, the core is no longer closed in the sleeve but in direct contact with the external environment. The results compared with the overall calculation of the arrester are shown in Fig 6 and Fig 7.

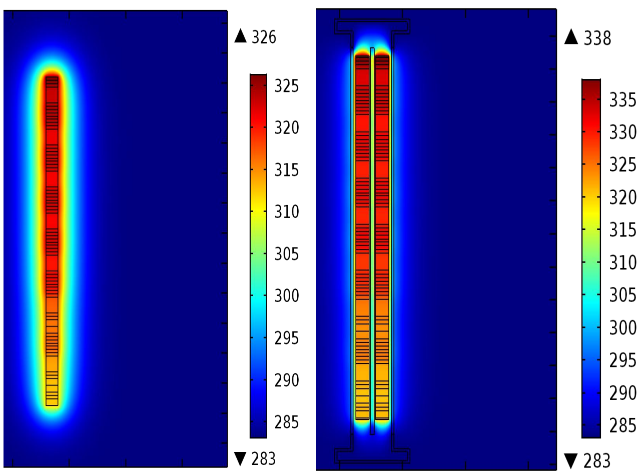

Fig 6 Comparison of temperature distribution between single core and arrester

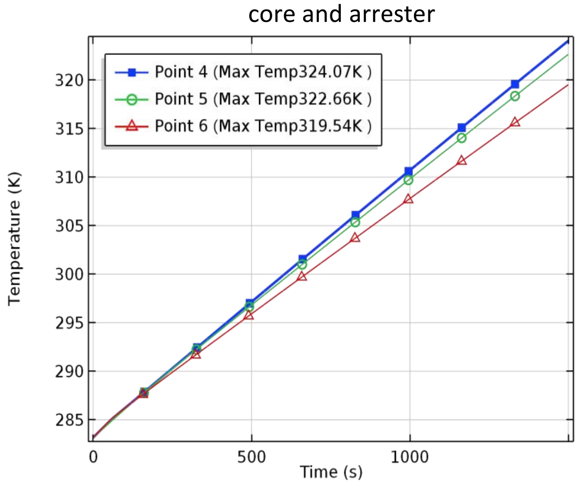

Fig 7 Time variation temperature rise at different positions of single core

It can be seen from the figure that the maximum temperature rise difference between single core and arrester is 12K. In the same power-on time, the temperature corresponding to three points is about 9K lower than that of the whole arrester which shows the heat dissipation of insulating sleeve has a vital influence on the heat dissipation performance of lightning ZnO arrestor.

4. *CONCLUSIONS*

In this paper, a time-varying temperature field calculation model of DC zinc oxide arrester is established, and its temperature rise and temperature distribution are simulated and calculated. The temperature variation processes at different locations are compared. The influence of sleeve on the heat dissipation performance of arrester is analyzed. The following conclusions are drawn:

(1) When the arrester is subjected to non-impulse voltage, the overall temperature rise increases linearly within 25 minutes, and the potential of the upper point is large, the temperature is high, and the rate of temperature rise is the fastest. The rate of temperature rise from top to bottom is decreasing.

(2) The simulation results show that the insulation sleeve of the arrester accelerates the temperature rise rate of the inner core and increases the temperature, which has a great hindrance to the heat diffusion of the inner core.

ACKNOWLEDGEMENT

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