Numerical Analysis of Temperature Field of Outdoor Transformer with Noise Barrier

Lei Peng*, Xiaopeng Fan, Li Li, Yongyan Zhou, Linyong Li, Zhuanglei Zou, Yibo Wang
Electric Power Research Institute of Guangdong Power Grid Co., Ltd., Guangzhou, China

*Corresponding author e-mail: 13657209328@163.com

Abstract. In order to meet the heat dissipation requirements of outdoor transformers equipped with sound-absorbing barriers, this paper uses the finite element analysis software ANSYS Fluent to simulate the temperature field of outdoor transformers. Firstly, the simulation calculation model is established according to the actual typical outdoor transformer, and the finite element mesh is divided accurately. Secondly, the simulation parameters are set according to the field operation. Then, the distribution of the temperature field of the outdoor transformer and the effect of noise barrier on heat dissipation of outdoor transformer are obtained by the simulation calculation model. The simulation results in this paper provide a preliminary reference for the design of noise barriers of outdoor transformers.

1. Introduction
The noise barrier has good effect on noise reduction of outdoor transformers. The noise barrier obtained based on reasonable calculation and design can reduce the impact of outdoor transformer noise on the surrounding environment to a reasonable range. However, outdoor transformers, as a kind of high-power electrical equipment, will generate a large amount of heat during operation. The mainly heat dissipation method of existing outdoor transformers is oil-immersed self-cooling, which uses the circulation of the insulating oil inside the transformer to bring heat to the cooling fins, and then radiate the heat to the air. The noise barrier separates the outdoor transformer from the surrounding atmosphere, which may have a certain effect on the heat dissipation of the transformer [1-2].

This paper uses finite element analysis software ANSYS FLUENT to simulate the effect of noise barrier on the heat dissipation of outdoor transformers, and provides theoretical support for the design of sound absorption barriers of outdoor transformers.

2. Temperature field model of outdoor transformer
The location of the noise barrier is shown in Figure 1 (top view). Among them, # 1, # 2, and # 3 are the main transformer positions, which are located behind the main control building of the substation. The parts marked in bold and marked in red are the noise barrier positions.
2.1. Model establishment

Since the heat dissipation problems of the three outdoor transformers are basically similar, their influence on each other is basically negligible. To simplify the calculation, the model of this case is simplified as follows:

a) The physical model only builds an outdoor transformer model;

b) Since the main control building is on the left and the back of the outdoor transformer, and the firewall is on the right, the three sides are set as walls when building the physical model, and only the “wall” boundary condition is applied;

c) An air inlet model is established on the side of the noise barrier, and other locations still give a “wall” boundary condition.

Finally, a physical model of 12 m × 10 m × 10 m is obtained, which is mainly an air area and a transformer model. Considering that the transformer mainly relies on a fin-shaped radiator for heat dissipation, the radiator is simplified into a plurality of small rectangular parallelepipeds. The physical model is shown in Figure 2.

2.2. Meshing

The meshing tool was used to mesh the model, and finally about 2.1 million cells were obtained. In mesh quality, the maximum skewness is 0.57, and the minimum orthogonal quality is 0.70, which fully meets the requirements of FLUENT software for meshes and can effectively improve the calculation accuracy. Figure 3 shows the results of meshing.
2.3. Boundary conditions and physical properties

Import the meshing model into Fluent software. According to the nameplate, the no-load loss of the transformer is 22.8 kW, and the load loss is 130.9 kW. Assuming a load factor of 50%, the volumetric heat of the transformer model is calculated to be about 1000 W/m³, which is defined as a heat source. The interface between air and transformer is defined as the coupling surface, and the wall is defined as “wall”, which is adiabatic. The noise barrier side is defined as two types according to whether there is a sound insulation ventilation window:

a) If there is no sound insulation ventilation window on the side of the noise barrier, the side is defined as “wall”;

b) If there is a sound insulation ventilation window on the side of the noise barrier, then the side of the air inlet channel is defined as “pressure inlet” and the other positions are “wall”;

The “boussinesq” assumption is used for the air density (as shown in Figure 4), which is defined as the air density at 35 °C. The thermal expansion coefficient is approximately calculated as $1/T = 0.0033$.

![Figure 3. Meshing model](image)

**Figure 3. Meshing model**

2.4. Solver Settings

Solver settings are shown in Figure 5. Open the energy equation program, select “realizable k-epsilon” for the turbulence model, select the “Enhanced Wall Treatment” and “Full Buoyancy Effects” options, turn on the gravity item, and set it to -9.8 m/s² in the Y direction. Set the operating temperature to 35 °C.

![Figure 4. Air parameter setting](image)

**Figure 4. Air parameter setting**
In “methods”, select Scheme as “coupled”, pressure as “body force weighted”, and select “pseudo transient”, “Warped-face gradient correction”, and “high order term relaxation”.

In both cases, only natural convection heat transfer is considered, and the effects of radiation are not considered.

2.5. Calculation
Set the temperature to 35 °C. Calculation is started after all conditions are initialized. The residual curve remains the default. For the case with noise reduction ventilation window, the residual curve after calculation is shown in Figure 6. The energy equation satisfies the residuals less than $1 \times 10^{-6}$. Except for the continuity equation, all other equations satisfy the residual error less than $1 \times 10^{-3}$. From the calculation of the flow difference between the inlet and outlet, it can be known that the flow difference is less than 0.05%, which also indicates the iterative convergence.

For the case without noise reduction ventilation window, the residual results is similar to Figure 6.

3. Results and analysis
According to different boundary conditions of noise barriers, we named the two cases as a (noise barrier without ventilation window) and b (noise barrier with ventilation channel). Based on the overall temperature of the transformer model under steady state conditions, the heat dissipation of the two cases was judged. In both cases, the overall temperature of the transformer model is shown in Figures 7 and 8. According to the actual situation of the two cases, the temperature range is set to 53-70.8 °C.
It can be known from Figure 7 and Figure 8 that the main temperature range of case a is 59-62 °C, and the main temperature range of case b is 58-61 °C. For noise barriers with noise reduction ventilation windows, the overall temperature of the transformer is lower than the that of noise barriers without noise reduction ventilation windows. This is because the position of the ventilation window is located at the bottom of the noise barrier, which conforms to the natural convection wind flow and accelerates the heat loss. However, the temperature difference between a (noise barrier without ventilation window) and b (noise barrier with ventilation channel) is not very obvious. Therefore, when designing noise barriers, it is possible to consider using noise barriers without ventilation windows.

4. Conclusion
This paper simulates the effect of noise barrier on the heat dissipation of outdoor transformers. The results show that the main temperature range of transformer installed noise barrier without ventilation window is 59-62 °C, and the main temperature range of transformer installed noise barrier with ventilation window is 58-61 °C. Although the temperature of the latter is slightly lower than the former, the temperature difference between the two is not obvious. Therefore, when designing noise barriers, it is possible to consider using noise barriers without ventilation windows.

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