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Study on Ventilation Scheme of Electric GIL Integrated Pipe Gallery Crossing Yangtze River

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Abstract. Sutong GIL Integrated Pipe Gallery Project is a 1000 kV AC UHV transmission project, which is the world's first long-distance 1000kV GIL equipment cross-river power tunnel. The long distance of this project, the large amount of heat generated by the equipment, and the possibility of SF_6 gas leakage inside the tunnel make the design difficult for the ventilation system. In this paper, the ventilation problem of Sutong GIL integrated pipe gallery is studied to determine the ventilation condition in this pipe gallery.

1. Introduction

Construction of the Huainan-Nanjing-Shanghai 1000 kV UHV transmission and transformation project, forming the Yangtze River Delta end ring network and the "three vertical and three horizontal" backbone network frame, which is conducive to improving the power capacity from outside the receiving area and internal power exchange of the East China Load Center, and improve the safety and stability level of the power grid and the reliability of the "Power Transmission from Anhui to the East", which is also of great significance for easing the power shortage in Jiangsu and Shanghai and enhancing the ability of the Yangtze River Delta power grid to withstand terrible failures. The Sutong GIL Integrated Pipe Gallery Project, as part of the cross-river section of the 1000kV Taizhou-Suzhou exchange UHV line, is an important guarantee for the completion of the 1000kV Taizhou-Suzhou exchange UHV line.

The Sutong GIL integrated pipe gallery project uses the gas-insulated metal-enclosed transmission line (GIL) to cross the Yangtze River. The GIL pipe is arranged in the pipe corridor tunnel across the Yangtze River. The two ends of the GIL pass through the ground connection station and special High-voltage overhead lines are connected. Sutong GIL integrated pipe gallery has a length of 5468.5m, an inner diameter of 10.5m and an outer diameter of 11.6m. The single phase GIL is approximately 5,820 m in length.

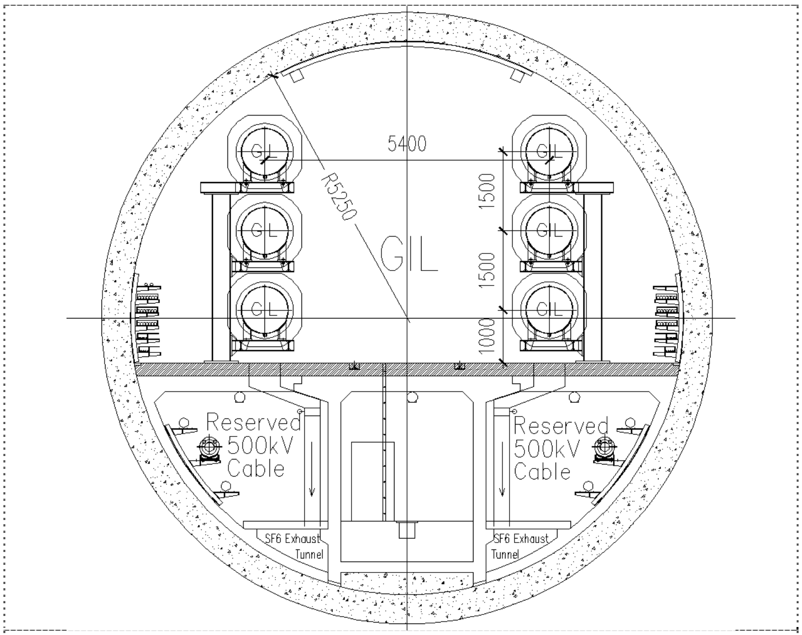

Figure 1. Cross-section layout of the tunnel pipe gallery

The cross section of the pipe gallery is shown in Figure 1. The two 1000kV GILs are arranged separately on both sides of the upper chamber of the pipe gallery. Two 500kV cable passages are reserved on both sides of the lower chamber of the pipe gallery; Sutong GIL integrated pipe gallery is the deepest underground tunnel project with the highest water pressure in China. The GIL equipment installed in the pipe gallery is the GIL equipment with the highest voltage level and the largest conveying capacity in the world.

At present, domestic power tunnels are generally dominated by cable tunnels, and the more common voltage levels are 220kV and 110kV. In some large cities, such as Shanghai, there are also construction experiences with 500kV voltage grade cable tunnels [1]. These power tunnels are generally located in cities and the ventilation section is no longer than 2km. The Sutong GIL integrated pipe gallery project has a voltage rating of 1000kV, and because the ventilation shaft cannot be added in the Yangtze River, the ventilation section reaches 5.468km. Therefore, the system with complicated ventilation and cooling is complicated. In addition, there is a possibility of SF_6 gas leakage in the pipe gallery of this project. At present, there are some studies on the elimination of harmful gases in subway tunnels in the pipe corridor project [2-3], but there are few research literatures on GIL pipe leakage.

2. Research on ventilation of pipe gallery exhaust heat conditions

During the operation of this project, the GIL pipeline will generate different heat generation according to different current carrying capacity. When the rate of rated flow is 3150A, the calorific value of each piece is about 80W/(m.), a total of 6 pieces, and the residual heat removal pipe needs to be passed through the ventilation system to outside the gallery. The local summer ventilation outdoor calculation temperature is 30.5 °C. According to the survey data, the soil temperature outside the pipe gallery is 19 °C. The duct air temperature is controlled at 40°C.

When the effect of the soil outside the pipe gallery on heat dissipation is not considered, the ventilation can be used to calculate the following:

$$L = \frac{Q}{Cp \cdot \rho \cdot \Delta t} \quad (m^3/s)$$

In this formula, L is the calculated ventilation, unit: m^3 / s; Q is the residual heat, unit: kW; C_p is the specific heat of the air, set as 1.01kJ / kg·K; ρ is the air density, set as 1.2 kg / m^3; △t is the row Wind temperature difference, unit: °C.

It is calculated that at least 230 m^3/s of air volume is required to meet the outlet temperature of the pipe gallery should be equal to or smaller than 40°C.

In the heat calculation of the power pipe gallery, the effect of the soil on the internal heat dissipation is very large. According to the difference between the pipe section and the soil temperature, according to the existing engineering calculation experience, the soil absorbs heat and accounts for the total heat generation of the pipe gallery is about 20%~50%[1][4][5].

This project uses the SES-Subway Environmental Simulation software to simulate the whole process of heat removal in the pipe gallery. The results are as follows:

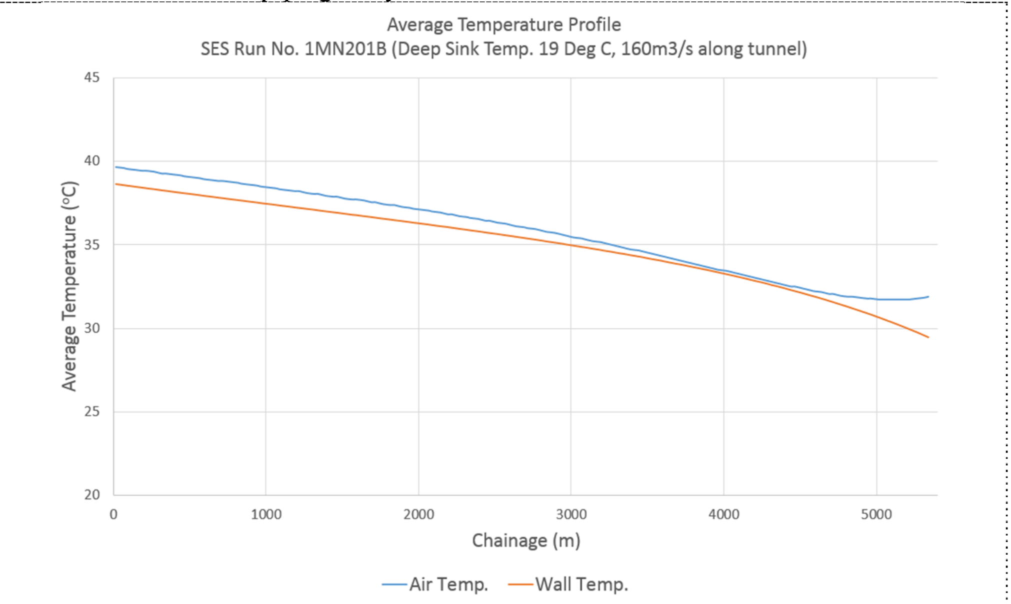

Figure 2. Temperature and wall temperature curves in a 160m^3/s air duct

In this figure, the abscissa is the length of the pipe gallery, the ordinate is the temperature, the upper blue line is the air temperature of the pipe gallery, and the lower red line is the wall temperature of the pipe gallery. The results show that for the GIL rated current capacity of 3150A, the air volume of 160 m^3/s can be used to control the outlet temperature of the pipe gallery should be equal to or smaller than 40°C, which is reduced by about 30% compared to the condition of 230 m^3/s air volume, that is, the heat absorbed by the soil accounts for about 30% of the total heat generated by the corridor.

The heat absorption of soil is determined by many factors, such as soil composition, soil temperature, pipe gallery size, and wind speed in the pipe gallery [6]. The soil heat absorption plays an important role in the economic operation of the cooling and ventilation of the pipe gallery. For this project, the effect of wind speed and air volume on the soil heat transfer in the pipe gallery is simulated. When the air volume is 160 m^3/s, the heat absorbed by the soil accounts for about 30% of the total heat generated by the pipe. When the air volume is 180m^3/s, the heat absorbed by the soil accounts for 27%. When the air volume is 200m^3/s, the heat absorbed by the soil accounts for 23%. When the air volume is 250m^3/s, the heat absorbed by the soil accounts for 10%; when the air volume is 280m^3/s, the heat absorbed by the soil accounts for 1%. It can be seen from the above data that when the temperature in the pipe gallery is lowered by increasing the air volume, the heat transfer efficiency between the air and the pipe wall is reduced due to the increase of the wind speed in the pipe gallery. When the wind speed in the pipe gallery is close to 6 m/s, the soil heat transfer is basically Does not work, all residual heat in the pipe gallery must be excluded by the ventilation system. Therefore, it is necessary to control the wind speed and the outlet temperature in the tunnel reasonably. It is essential to select the economical and reasonable air volume for the long-term operation of the pipe gallery. In order to make full use of the soil heat transfer and cooling, the airflow cooling speed in the pipe gallery should be about 3m/s~ 4 m/s.

3. Analysis of thermal field in pipe gallery

For sites where there is a general heat source, the heat goes up, and the internal heat field distribution shows the upper heat accumulation. For the distribution of the thermal field inside the power pipe gallery, especially the distribution of the heat field after ventilation, further research is needed. The analysis of the internal thermal field has important guiding significance for the safe operation inside the pipe gallery and the installation of the internal temperature monitoring system.

Modelling and analysis were carried out in the pipe gallery by means of computational fluid dynamics (CFD-Computational Fluid Dynamics). The temperature field of the section is shown as follows:

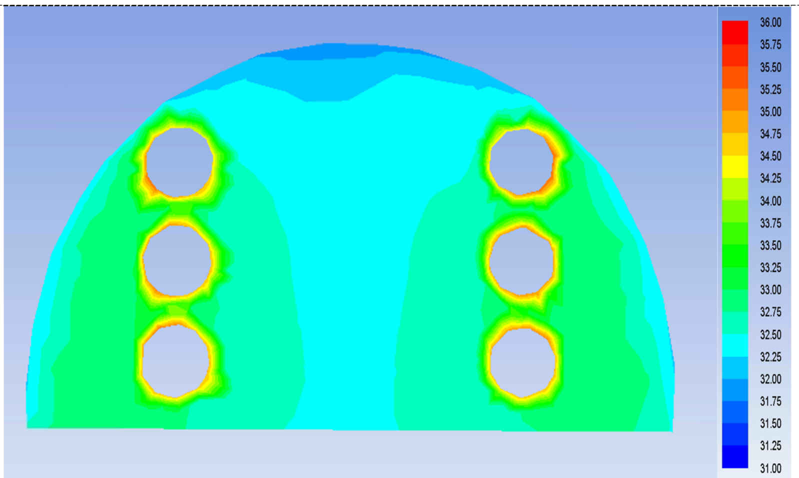

Figure 3. Temperature profile at 500m section

The results show that when there is ventilation, there is no hot and cold in the pipe gallery, the temperature near the GIL pipe is higher, and the temperature in the middle and upper regions is lower. There is no obvious hot spot in the current ventilation scheme, and there is no obvious thermal stratification, and the ventilation effect is good.

4. SF_6 leakage accident ventilation study

The GIL pipe in the pipe gallery is filled with SF_6 gas, and the GIL shell may breakdown and cause SF_6 gas leakage during operation process. Due to the high density of SF_6 gas, which is 6.16kg/m^3 and about 5 times the density of air. After the accident, it will deposit at the bottom of the tunnel. In the event of an accident, only a 100mGIL chamber is set to have a breakdown, and all SF_6 in the tube is leaked. The amount of leakage is about 260 m^3. When the SF_6 gas leaks, the ventilation system in the pipe gallery is opened to the maximum, and the SF_6 special exhaust system is installed under the GIL pipe. The strong air discharge is carried out every 100m pair of air outlets, and the working wells on both sides of the river are discharged to the outside.

The computational fluid dynamics (CFD) method was used to model and analyze the leakage of SF_6 gas in the pipe gallery, which is shown as follows:

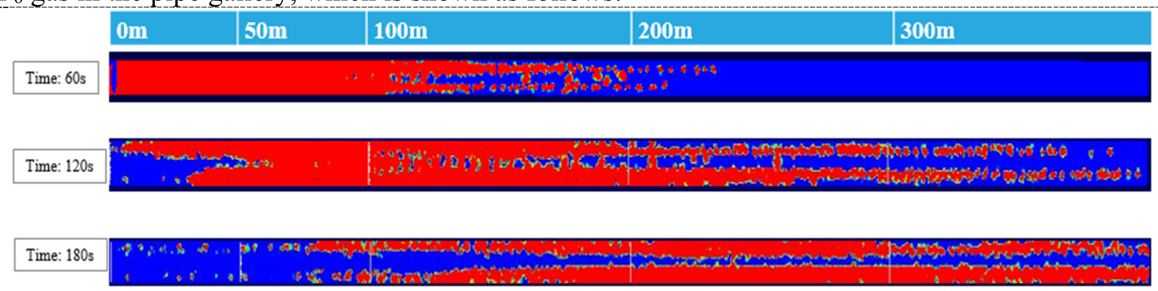

Figure 4. SF_6 concentration distribution in the plane of 0.3m height

In the above figure, the 0 m is the SF_6 gas leakage point, and the three groups are the distribution of SF_6 gas in the pipe gallery at 60s, 120s and 180s after the leakage, and the ventilation direction in the pipe gallery is from left to right.

The results show that when the cross-section wind speed is ≥ 5m/s, all the leakage gas can be reversely flowed along the 0.5% slope of the pipe gallery. The SF_6 special exhaust system below the GIL pipe has a reinforcing effect on the elimination effect. The leaked SF_6 gas moves forward along the position where the GIL pipe is laid, and the concentration in the middle portion is relatively small. Therefore, in this way, the SF_6 leakage gas can be excluded from the pipe gallery.

5. Conclusion

In the Sutong GIL integrated pipe gallery project, when the electrical GIL pipeline is running, it will generate different calorific values according to its different current carrying capacity. The calorific value at the rated flow rate of 3150A is about 80W/m each piece, which needs to be ventilated. The system removes the waste heat from the outside of the pipe gallery. Through software simulation analysis, it can be seen that the air volume of 160 m^3 / s can control the outlet temperature of the pipe gallery ≤ 40°C. At this time, the heat absorbed by the soil accounts for about 30% of the total heat generated by the pipe gallery.

For the same pipe gallery, the internal increase of wind speed will reduce the residual heat absorbed by the soil. When the wind speed is about 3m/s~4 m/s in this project, the heat absorbed by the soil accounts for about 20~30% of the total heat generated by the pipe gallery. When the wind speed is greater than 6m/s, the soil heat transfer has basically no effect, and all waste heat in the pipe gallery needs to be excluded by the ventilation system.

Through the analysis of the thermal field in the pipe gallery, it can be seen that when there is ventilation, there is no hot and cold in the pipe gallery, the temperature near the GIL pipe is higher, and the temperature in the middle and upper regions is lower.

For the SF_6 leakage accident, the pipe gallery ventilation and the SF_6 special exhaust system work together to eliminate harmful gases. When the wind speed of the pipe gallery section is ≥ 5m/s, the SF_6 leakage gas in the pipe gallery can be effectively excluded to the outside of the pipe gallery.

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