The application of the Gas Insulated Transmission Lines in Electric Power Engineering

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Abstract: In order to adapt to the special requirement of the laying of lines and the requirement of long-distance transmission, GIL develops fast. This paper introduces GIL from the aspect of feature, advantages, disadvantages and the typical construction. And this paper prospects the development of GIL.

1. Introduction
Gas-insulated metal-enclosed wiring (GIL) is a new type of transmission line. Compared with traditional transmission lines, GIL has great advantages in terms of insulation, safety and environmental friendliness. Compared with traditional bare wires and cables, the cost of GIL is relatively high. As the production technology of production processes continues to increase, the cost of GIL is also decreasing. Under the background of the current ubiquitous smart grid and the global energy Internet, the requirements for the transmission and transmission of various links are getting higher and higher, and the application of GIL is becoming wider and wider. The world's giants in the field of transmission and distribution have invested in research on GIL[1]. At present, Japan, France, the United States and Germany have mastered the relatively mature GIL technology, and their products have been widely used in power engineering around the world.

With its special structure and excellent performance, GIL is used in some important hub power plants or power stations, where the laying method is special and the safety requirements are high. In the future, with the development of technology, it will be applied to long-distance transmission. However, due to cost and other reasons, GIL has not been widely promoted. At present, the GIL lines used in the world have reached thousands of kilometers. With the breakthrough of technology, the application of GIL will become more and more extensive [2]. This paper summarizes the technical characteristics and applications of GIL from the aspects of GIL structure, advantages and disadvantages and typical engineering.

2. GIL structure
Unlike traditional overhead lines and cables, GIL uses a special structure to improve its performance. The GIL consists of a concentric alloy aluminum conductor and an alloy aluminum grounded casing, and the conductor and the casing are connected by an insulator. For most GILs, a three-column insulator is often used to connect the conductor to the outer casing. When gas isolation is required, the disc insulator is also used for the connection. The conductor and the outer casing are filled with SF6
gas for insulation, and the new GIL is also insulated by a mixed gas of SF6 and N2, which makes the insulation performance stronger.

This structure is stronger than conventional overhead lines and cables. In addition, both GIL base brackets, conductor and housing connections, and SF6 gas density monitoring devices are manufactured in a special and rigorous process, making GIL perform well in actual operation.

3. Advantages of GIL

In actual operation, GIL has better performance than traditional overhead lines and cables, mainly in the following aspects:

- Can withstand harsh environmental conditions. Because GIL has an alloy aluminum outer casing, the alloy aluminum itself is not susceptible to corrosion, is not susceptible to contamination, and the performance is very stable. Therefore, under the harsh weather conditions, the performance and transmission capacity of GIL will not be affected. Therefore, GIL is very suitable for occasions with harsh weather conditions and high requirements for wire transmission performance.

- Suitable for long-distance large-capacity transmission. Because the GIL has a large diameter, a small capacitance, and a charging capacitor smaller than a conventional cable, no reactive compensation and cooling system is required during operation, which greatly reduces operating costs. And the line itself has low impedance, low line loss, and large critical transmission distance [4]. When the transport distance becomes larger, the advantage in terms of loss reduction is more pronounced than in conventional lines. Based on the above characteristics, GIL is very suitable for long-distance transmission.

- The electromagnetic interference intensity is small. During operation, the current in the conductor of the GIL is opposite to the induced current in the aluminum casing of the GIL alloy, so the generated electromagnetic fields cancel each other out, so that the intensity of the surrounding synthetic electromagnetic field during operation is very low, almost negligible [6].

- Less land. Because of the protection of the alloy aluminum casing, GIL is not very demanding on the surrounding environment and can even be laid underground. This can reduce the difficulty of land acquisition. In some places where natural landscape protection is needed, GIL can be considered for underground laying without re-routing.

- No insulation aging problem. Because the GIL is internally insulated with SF6 gas and the entire line is tightly sealed, the insulator is not exposed to the air. Therefore, even in areas with high contamination levels, there is no insulation aging problem, and the insulator can be reliably operated for a long time.

4. Problems facing GIL

The biggest problem that currently plagues the development of GIL is the cost problem. Due to the special structure of GIL [10], its cost is 6 to 8 times higher than that of ordinary lines. Therefore, at present, GIL is mostly applied to shorter connection lines, or some demonstration projects, and there is still no large-scale application. At present, the cost of GIL is mainly reduced from two aspects. On the one hand, the SF6 gas is replaced by a mixture of SF6 gas and nitrogen, and the cost is reduced by a more reasonable installation and unit setting. In actual operation, it often encounters thermal expansion and contraction [11]. Because the GIL will experience a very harsh environment during operation. The alloy aluminum casing exposed to GIL in the environment and the alloy aluminum conductor in the casing will exhibit thermal expansion and contraction under these severe conditions. On the one hand, the GIL is filled with gas, and the volume change will cause the gas pressure to change. On the other hand, thermal expansion and contraction caused the deformation of GIL, which seriously affected the safety of the line so that you can run, so the problem of thermal expansion and contraction is a problem that must be solved [12]. At present, the solution to this problem is mainly carried out in terms of material selection and structural design. For the casing, a temperature bellows should be designed at intervals to reduce the expansion and contraction of the casing. For the base bracket, the fixed bracket should be designed to withstand the force generated by the thermal expansion and
contraction of the outer casing, and the sliding bracket to absorb and consume the longitudinal longitudinal movement to reduce the displacement [13].

In operation, SF6 gas leakage problems may also occur, resulting in environmental pollution. Since the GIL is filled with SF6 gas and its operating sections often pass through harsh environments, SF6 gas leakage problems occur [14][15]. To solve this problem, we mainly take two measures. On the one hand, we will strengthen the maintenance and reinforcement of the pipeline to prevent its damage. On the other hand, we will replace the SF6 with a gas that does not pollute the environment, such as using high-quality compressed air instead of SF6 gas. Is the current research trend.

When applied to DC transmission, it will encounter insulation problems. On the one hand, due to the influence of the shape of the insulator, the electric field distribution of the GIL is uneven, and the breakdown phenomenon occurs under the DC voltage. On the other hand, the flashover voltage of different insulators in the GIL may be different, which affects the insulation performance of the GIL. At present, UHV DC is developing rapidly, and GIL’s insulation optimization in DC transmission has become a research hotspot.

5. GIL application occasions and typical projects

Due to its excellent performance and special structure, GIL has many properties that traditional wires and cables do not have. Therefore, GIL can be used to meet the requirements when some of the requirements are high and traditional wires cannot be used.

5.1 Alternative overhead line

When the overhead line is relatively harsh, and the requirements for transmission capacity are relatively high, or the corridor is limited, and the land acquisition is difficult, the existing corridor can be used to replace the conventional overhead line with GIL.

In 2011, in order to cope with the formation of the Shuanghuan network in southern Shanghai and improve the stability of the Shanghai power grid, two 500kV outlet expansions were required for the substation. The two outlets were originally planned to exit the northwest side of the substation, and the corridors running north and south along the west side of the substation flowed south into the backbone network via overhead lines. The west side corridor of the substation is very limited and close to the residential area. The residents of the community have already been moved, so land acquisition and relocation are very difficult. In response to this situation, the station was re-planned, and the overhead line was changed to pass through the GIL inside the substation. The project was to install GIL1050m, which reduced the erection of 220m overhead lines and brought social stability and economic effects. It is also very impressive.

In 1998, the French power company built a GIL transmission line with a length of 300Km and a rated voltage of 400kV using direct buried laying [17]. The line has a rated capacity of 2GVA and is insulated with SF6 and N2 mixed gas. The line has been maintained safely and steadily since its completion, and has maintained good performance under high load operation [18].

5.2 Power transformer and switchgear connection

GIL can also be used to connect power transformers to switchgear or switchyards. This type of connection reduces the chance of line damage and makes the connections between devices more reliable.

Guangdong Ling’ao Nuclear Power Plant, GIL equipment is used for the connection between the main transformer and the GIS switch station. The single phase of the project is 3008m long. It is connected through the underground tunnel, which saves the corridor and is more reliable. It also does not need other protection measures for the line.

5.3 Submarine high voltage cable laying

Due to the electromagnetic and capacitive problems of AC lines, the voltage level of conventional submarine cables often cannot be very high, but as the power consumption continues to increase. The
demand for high-voltage and large-capacity transmission lines across the river is increasingly urgent, but due to the increasingly urgent Some special topographical reasons, some areas cannot be unsuitable for the construction of overhead lines when crossing the river, only the submarine cable can be selected. Under high voltage conditions, the use of conventional submarine or river bottom cables cannot meet the needs of high voltage and large capacity [20]. The emergence of GIL solves this problem. Due to the good electromagnetic shielding of GIL and the control of the capacitance effect, it can be used for the laying of transmission lines on high voltage seabed or river bottom.

Huainan-Nanjing-Shanghai 1000kV UHV transmission and transformation project Sutong section, the transmission circuit line needs to cross the Yangtze River, and the local situation is not suitable for the construction of overhead lines, so GIL is adopted as the river bottom transmission line, the line is the world The Jiangdi line with the highest voltage rating has met the 35,000MW electricity demand after completion.

5.4 Special circumstances
It is not possible to meet the cable transmission capacity or strength requirements in a special mode with a normal cable. In this case, the GIL is required to be connected.

In the construction process of Xiluodu Left Bank Power Station on the Jinsha River, in order to take out the line, GIL vertical laying was adopted in the shaft. There are 7 laying lines with a total length of more than 11,700 meters. The seven lines are installed in two shafts, vertical height. With 470 meters and 480 meters, it is the largest vertically installed GIL project in the world.

The Laxiwa Hydropower Station in Qinghai has its 750kV main transformer and GIS switch station located in the underground powerhouse. It is required to set up an outlet station at a height of 210 meters and take it out to the main network. Due to the domestic production capacity of 750kV cable, we draw on foreign experience and use GIL for laying. The engineering switch station and the outbound station are connected by GIL through a 50m horizontal corridor and a 210m vertical well. The total length of the GIL is about 450m. The project uses GIL to skillfully solve the problem of wiring layout, which effectively improves the economics and safety of the entire project [21].

Due to the long construction time of Hangzhou Pingyao Substation, the breaking capacity of the circuit breaker is only 50kA. As the scale of the power grid continues to expand, in order to prevent the breaker from malfunctioning due to excessive short-circuit current, it is transformed into a busbar. The section is laid, and the bottle Joe 5411 line is interchanged with the bottle Wu 5905 line. The GIL is used at the intersection. The rated voltage of the GIL is 550kV, the rated current is 3150A, and the GIL length of the project is 663.3m. After completion, the safety of the bottle kiln is greatly improved.

6. summary
This paper summarizes the relevant research situation of GIL equipment based on the actual situation, and analyzes the structure, advantages, problems and typical engineering applications of GIL. GIL can be used in situations where traditional lines cannot be used, and can make up for the shortcomings of traditional technologies. In recent years, research on GIL has become more and more in-depth, and GIL will also play a more important role in all aspects of transmission and distribution.

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