Development Status of High Voltage Insulation Technology

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Abstract. High-voltage insulation technology is a technology related to the development, selection, design, manufacture, operation and maintenance of high-voltage electrical equipment insulation structures. In high-voltage electrical equipment, insulation structures are used to separate conductors with different potentials, so the insulation structure is an important part of electrical equipment. With the increase of power consumption and the increase of transmission distance, the maximum voltage level of the power system will be further increased, and it is becoming more difficult to solve the insulation problems related to high-voltage electrical equipment. This article gives a brief description of sulfur hexafluoride gas insulation, power cable and power transformer insulation technologies. In addition, new insulation materials and improved manufacturing processes can be introduced to improve the electrical insulation strength.

Key words: High-voltage; Insulation; Technology.

1. Sulfur Hexafluoride Gas Insulation
Sulfur hexafluoride is a gas generated by the reaction of fluorine and sulfur. It was used as an insulating gas in nuclear physics high-voltage research equipment in the 1940s. Since the 1950s, it has been used as the insulation and arc extinguishing medium of circuit breakers. Sulfur hexafluoride gas is now widely used in high-voltage circuit breakers, gas- insulated metal-enclosed switchgear, gas-insulated transmission lines (GIL), and transformers. Sulfur hexafluoride is widely used in high-voltage electrical equipment because electrical equipment using this gas has many advantages. For example due to the high electrical strength of sulfur hexafluoride gas. The metal-enclosed substation with sulfur hexafluoride insulation has a much smaller footprint than the air-insulated open-type substation. For the 500kV system, the former covers only 5% of the latter. The insulation of metal enclosed substations is not affected by environmental conditions (rain, snow, etc.) and environmental pollution, and the operation is safe and reliable.[1]

Sulfur hexafluoride is a colorless and odorless gas with high electrical strength, excellent arc extinguishing performance, good cooling characteristics, and nonflammable. It is used in electrical equipment to avoid fire threats, reduce equipment size, and improve the system Operational reliability. Its disadvantage is that it will decompose to form low-sulfur compounds of sulfur during discharge. These products are toxic and can corrode many insulating materials and conductive materials. Under high pressure, sulfur hexafluoride will liquefy. Sulfur hexafluoride gas is mixed with nitrogen, air or carbon dioxide gas at a certain volume ratio to form a mixed gas containing sulfur hexafluoride. Although their electrical strength is lower than that of pure sulfur hexafluoride gas, as long as the mixing ratio is...
appropriate, the decline in electrical strength is not great. Using these sulfur hexafluoride-containing mixed gas to manufacture electrical equipment can reduce the amount of sulphur hexafluoride used, and because of its low price, is also very economical.

2. Power Cable Insulation

Power cables are often used as the incoming (out) lines of power plants and substations. They are also commonly used when the line meets rivers, railways, etc., and are now widely used in urban power grids. Compared with overhead lines, cables have the advantages of being less affected by climate, higher safety and reliability, but higher costs. Generally, 1kV and below cables are usually rubber or PVC insulation; in the past 6 ~ 35kV were commonly used viscose impregnated oil-paper insulation, and higher-voltage oil-filled or gas-filled paper-insulated cables, but many of them have now been replaced by crosslinked polyethylene XLPE insulated cables.

Because of its excellent mechanical properties, heat resistance and dielectric properties, XLPE is currently widely used in high-voltage DC cable insulation materials. However, during operation, the cross-linked polyethylene DC cable causes electric field distortion and insulation aging due to electrical conductivity temperature characteristics and space charge accumulation, and in some cases causes partial discharge and insulation breakdown. Therefore, the most serious problem facing high-voltage DC cable polyethylene insulation is the regulation of DC conductivity and space charge under temperature gradients.[2]

Current research shows that nanocomposite dielectrics have excellent properties in many aspects such as space charge, partial discharge, breakdown strength, and DC conductance. Dielectric properties such as breakdown strength, resistance to partial discharge, resistance to corona, resistance to electrical tree aging, and space charge are different compared to dielectrics that are not doped with nanoparticles or doped with micrometer particles Degree of improvement. The modification of polyethylene polymers with inorganic nanoparticles is an important means to improve the performance of polyethylene insulation materials. Although the experimental conditions of various studies have been different, leading to some differences in the experimental results of different scholars; but different experimental results indicate that the addition of suitable inorganic nanoparticles can significantly improve the electrical properties of nano-dielectric materials. Based on the qualitative characterization of the properties of the inorganic nanofiller, quantitative investigation of the optimal ratio of different inorganic nanoparticles is of great significance for the practical engineering application of inorganic nanoinsulating materials.

3. Power Transformer Insulation

Transformer insulation systems age with the operating conditions of the transformer. During the operation of the equipment, thermal, electrical, and chemical stresses act on the insulation system, resulting in irreversible changes in the performance of the insulation system. This aging stress may cause internal or external degradation of the insulating material.

Solid insulation and mineral oil make up the insulation system in transformers. Cellulose-based solid insulation and mineral oils in transformers degrade over time. The degree of insulation aging depends on the heat, electricity, Chemical and mechanical stress. The temperature of transformer oil and cellulose solid insulation plays an important role in affecting the mechanical, chemical and electrical properties of the material.

Power transformers are often divided into oil-immersed and dry-type. As the cooling and insulation material of oil-immersed power transformers, insulating oil plays an important role in the operation of transformers. The traditional transformer insulating oil uses mineral oil, but as the environmental problems and hidden safety problems of mineral oil become more and more serious, it is urgent to find a green, safe and reliable product to replace mineral oil. Natural renewable vegetable insulation oil has the advantages of high ignition point, excellent biodegradability, and environmental protection. It has received widespread attention in recent years and is increasingly used in power transformers. As people's awareness of environmental protection is gradually increasing and the storage of fossil energy such as
petroleum is decreasing, vegetable oils with green environmental protection and sustainable use characteristics are used in many industrial industries, such as industrial lubricants, transformer insulation oil, etc. [3] The high- and low-voltage coils of the dry-type transformer have a cylindrical structure. Due to the chimney effect, during the heat dissipation process, cold air enters from the lower air duct inside the coil and is then discharged from the upper part. Therefore, the temperature field distribution appears to be cold on the heat, as shown in Fig.1.

![Figure 1. Distribution of temperature field in dry-type transformer.](image)

It can be seen from the figure that the hotspots of dry-type transformers are mainly concentrated in the upper and middle positions, and the thermal aging rate of the corresponding parts is bound to accelerate. This is also one of the main reasons for coil faults in the upper and middle parts. The hybrid insulation type can be used to divide the coil into two or more regions with different temperature rise levels according to the operating temperature of each part. For areas with a temperature rise, an insulation structure with a higher temperature index (insulation level) is used to improve the Reliability of hot parts, and for areas with low temperature rise, a relatively low insulation level insulation structure is used. In this way, the overload capacity and life of the dry-type transformer can be effectively improved on the basis of adding less material cost, thereby ensuring its operational reliability and having a good application prospect. The current research directions of hybrid insulation structures mainly focus on the fusion and compatibility of different materials, the correspondence between the insulation level and temperature rise of different parts, evaluation standards, and reliability assessment. [4]

4. Conclusion
With the advent of the age of electricity, it is not only changing the rhythm of human life, but also drawing closer the world, laying a good foundation for human industry and agricultural production, and electricity has therefore become the most important part of people's lives. In-depth research and reform and innovation of high-voltage insulation technology in power systems have provided society with more stable and reliable electrical energy, and the environmental impact and use of energy have also developed in the direction of environmental protection.
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