Live Processing of SF6 Insulated Gas Equipment in High Humidity Environment

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Abstract. The trace moisture content in the sulfur hexafluoride electrical equipment is a non-negligible factor that may be influential on the gas insulation performance. If the humidity of sulfur hexafluoride gas exceeds the standard or any condensation occurs, it will pose a serious threat to the safety of the equipment. The current methodology counts on power outage for maintenance work. This often incurs high cost and cannot ensure continuous supply of electricity under certain special circumstances where power outage for maintenance is not possible. This work was performed to explore the processing technology of sulfur hexafluoride gas humidity. By taking care of the state condition of non-power outage, a complete system solution was specially designed for low temperature environment. In this context, on-line dehumidification of sulfur hexafluoride gas was implemented on the premise of ensuring the safety of gas insulation equipment and operators. The study provides feasibility results for the safe and continuous operation of SF6 gas electrical insulation equipment in a short time after the humidity exceeds the standard.

1. Introduction
Known for its excellent electrical insulation and arc extinguishing properties, Sulphur hexafluoride (SF6) gas is widely used in gas-insulated electrical equipment. The important factor influencing the gas insulation performance is the trace moisture content in the SF6 electrical equipment, that is, the humidity of the gas. If the humidity of the SF6 gas exceeds the standard or any condensation occurs, it will pose a serious threat to the safety of the equipment. References [1] - [3] studied more on internal faults, decomposition characteristics, products, and detection methods of SF6 electrical equipment. The current method is to arrange power outage for maintenance. The implementation of this approach is costly and cannot guarantee continuous supply of electricity under certain special circumstances where maintenance cannot be done without having an outage. To tackle this issue, there is a need to develop a device that can process trace moisture in gas under no power outage in SF6 electrical equipment in order to meet the standard requirements. This can also delay the equipment maintenance time, avoid the peak period of electricity consumption, and ensure the safe and stable supply of electricity.
2. Description of Device

2.1. System Design

According to the national standards and procedures [4-5], the safe operation of electrical equipment should first be kept within the pressure range, and then the pressure balance is used to remove part of the gas for dedicated dehumidification. Subsequently, the processed gas with low humidity is sent back to the equipment. In the air chamber, the gas is taken out again for dehumidification, and the air humidity of the electrical equipment is reduced through the repeated cycles of dehumidification. The schematic diagram of the installation is shown in Figure 1.

![Schematic Diagram of Live Processing of Insulating Gas Device](image)

This device consists of multiple systems designed for vacuum pumping and compression, drying purification with molecular sieve, gas storage and measurement and control. The principle of operation is to replace the moisture and decomposition products in the insulating gas in the GIS (Gas Insulated Substation) by way of exhalation and suction. The SF6 gas with excessive humidity can be uninterruptedly dried and purified. Many other GISs may also be recycled and purified and recharged.

In this design, the pipeline is made of stainless steel corrugated pipe and metal connection, which is reliably connected to the grounding protection of the gas-insulated equipment and can effectively prevent the electric shock damage to the gas humidity purification device and the operator. The dedicated desiccant is a composite adsorbent. After many experiments, the ratio is 1:1 alumina and 4A molecular sieves. The gas was first adsorbed by activated alumina and then processed further by 4A molecular sieve to obtain a good effect of treating 200 kg of SF6 gas per kg of the adsorbent (having a humidity of 1000 μL/L). According to the gas displacement safety test, the process of the pressure safety control system in the gas dehumidification process was determined and the index requirements for electrical safety design were achieved. Through the complete system design, the application of the key technology of the project was completed.

2.2. 110KV GIS test platform in physical form

2.2.1. Building a test platform. In order to verify the dehumidification effect of the molecular sieve on the SF6 gas and the pressure difference of the SF6 gas in the GIS container during the working process, a 126KV GIS model was constructed, as shown in Figure 2. The model incorporates two inflatable joints, casings, busbars, voltage transformers, horizontal test chambers, vertical test chambers, etc. Various types of defects were set, such as floating potential, creeping discharge of pot insulators, and free particle discharge inside the chamber. The model was configured with the functions of SF6
recovery, aeration, purification, purity, and humidity adjustment. Depending on certain experimental conditions, the SF6 gas with known humidity was charged and tested on the 126KV experimental platform.

2.2.2. Operation Process. This operation went in single-interface switch mode, as shown in Figure 3. The single interface of the device was connected with the special pipeline for 126KV GIS model, and the single interface switch mode was started. The program would judge whether to first perform SF6 inflation operation to the GIS model according to the pressure in the air chamber, and allow the SF6 pressure in the GIS model reach the rated value. The suction operation was performed under the condition that the GIS was at rated pressure, and the pressure sensor at the GIS interface was used to judge whether the SF6 gas in the GIS reached the lower limit of the pressure alarm. The suction process was stopped before reaching the lower limit. This process is based on the pressure within the GIS is greater than the pressure of the device inner device for automatic gas flow. Before the gas entered the GIS and flew into the vessel inside the device, trace moisture adsorption and impurity purification were performed through the molecular sieve. 30s later after the inhalation stopped, exhalation operation was performed. The SF6 gas was compressed back to the GIS by an oil-free compressor and the expiration state was determined based on the feedback value of the GIS pressure sensor.

2.2.3. Test results. Before the processing, the gas humidity in the gas chamber reached 1460 μL/L. After an hour of processing, the gas humidity decreased significantly. After 4 hours of continuous work, the molecular sieve in the ventilator equipment needed to be regenerated. The molecular sieve in the ventilator was heated and evacuated to release the trace moisture adsorbed on the molecular sieve, allowing the molecular sieve to be cooled. The regenerated molecular sieve will have a stronger adsorption effect. Molecular sieves can achieve recycling through this regenerative adsorption. The test data is shown in Table 1.
Table 1. Test Data

| Time (h) | 1st trace moisture μL/L | 2nd trace moisture μL/L | 3rd trace moisture μL/L |
|---------|-------------------------|-------------------------|-------------------------|
| 0       | 1460                    | 1440                    | 1420                    |
| 1       | 800                     | 810                     | 780                     |
| 2       | 350                     | 380                     | 401                     |
| 3       | 200                     | 240                     | 320                     |
| 4       | 90                      | 110                     | 120                     |

In the experiment process, the UHF PD instrument may also be used to perform real-time online monitoring of partial discharge changes [6]. As shown in Figure 4, the analysis of the charged test spectra indicated that there was no equipment discharge during the work process.

3. Site Trials
A municipal maintenance company discovered that the content of SF6 in the surge arrester exceeded the standard value. The unpowered dehumidification equipment developed by this subject was brought to the site for processing, as shown in Figure 5.

Before the dehumidification work began, the pressure drop in the air chamber was found through the density relay installed on the arrester, and the air chamber pressure was first replenished to the rated value. Then set the respiratory rate as 1.2m3/h; the field device had only one inflated interface, and use the single interface mode to dehumidify the arrester, then record the trace moisture change curve within a time range of 3 hours, as shown in Figure 6.
Before the processing, the gas humidity in the gas chamber reached 837 μL/L. After a one-hour processing, the humidity of the gas decreased significantly and reached the allowable index range. By replacing the trace moisture in the SF6 gas by such electrical device on-line, the purpose of uninterrupted dehumidification could be achieved.

4. Conclusion
This research aimed at the processing device of the hydrated sulfur hexafluoride gas and provided the core solution for online dehumidification. Meanwhile, the gas displacement safety was investigated by means of properly selecting and protecting the key components. A system platform that satisfied the practical application in a high-humidity environment was designed. A complete system scheme was prepared to be available for the technical indicators of the project. This project is concluded with the feasibility results for the safe and continuous operation of SF6 gas electrical insulation equipment within a short time after the humidity exceeds the standard.

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