A new detection device for decomposition products of insulating gas in electrical equipment

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Abstract. In this paper, a multi-functional SF₆ gas decomposition products comprehensive analysis device is realized by using spectral absorption technology, integrating the existing electrochemical sensor technology, and integrating a variety of detection modules. In this paper, a set of hardware system is researched and implemented, which takes microprocessor as the control core and touch LCD as the human-machine interface to realize the SF₆ Electrical Equipment multi-functional gas analysis equipment.

1. Introduction
Electrical equipment with SF₆ gas as insulating medium is called SF₆ Electrical equipment[1]. There are hundreds of thousands of SF₆ Electrical Equipment in China, which has become the main equipment of power system. Under the action of heat and electricity, SF₆ gas and solid insulation materials in fault area will decompose, insulation performance will continue to decline, and even lead to accidents, which seriously affects the safe and economic operation of power production. A new detection device of insulating gas decomposition products for electrical equipment is urgently needed.

2. Research and implementation of the detection technology of SF₆ gas CF₄ component content by spectral absorption method
This paper adopts the principle of infrared spectrum absorption[2] + ultraviolet spectrum absorption to accurately detect the content data of CF₄ component in SF₆ gas. The schematic diagram of detection components is shown in Figure 1:
According to the schematic diagram 1, the spectral absorption component[4] includes four parts: light source component, light splitting component, absorption component and detection component.

Firstly, the infrared light source and the ultraviolet light source are mixed through the "mirror 1", and processed through the "slit grating 1", "diffraction grating" and "slit grating 2" to obtain the illumination light source of specific frequency band; then the light is reflected to the "half mirror" through the "mirror 2", the infrared light source is directly reflected to the "mirror 3", and the ultraviolet light source is refracted and transmitted through the "half mirror". The "half mirror" irradiates the "mirror 4", the "mirror 3" projects the infrared beam, and the "mirror 4" projects the ultraviolet beam, so that the light splitting is completed; then the two frequency bands of the beam irradiate the sample gas in the absorption cell, and according to the different absorption curves of different components, the absorption spectrum passes through the "crystal filter 1" and "crystal filter 2", and is detected by the "photoelectric detection 1". By comparing the characteristic spectral data of the spectral database, the data of the component content of the sample gas can be obtained.

Because the detection process of the spectrum module does not change the composition and properties of the sample gas, the components of the sample gas are detected by the spectrum module. After pre-analysis, the content data of CF₄ component is obtained, and then the sample gas enters the subsequent electrochemical module for the content detection of the remaining components.

3. Integration of multiple test functions

In this paper, while realizing the CF₄ detection by infrared spectroscopy, the thermal conductivity method and resistance capacitance method are used to realize the detection of SO₂, CO, H₂S and HF components, realize the simultaneous detection of multiple gas components, and deal with the interference between each other, so as to perfectly realize the multi-purpose of one machine and realize the detection of multiple gas components [5]. The structure diagram of multi-gas component detection system is shown in Figure 2:
Figure 2 structure diagram of multi gas component detection system

This module is divided into "gas shunt module", "gas channel", "sensor array" and "data output module".

In the detection process of electrochemical module, the corresponding components of gas decomposition will be absorbed and transformed by the corresponding electrochemical sensor, so the amount of gas will change. In this module, the solution is to divide the sample gas into multiple channels through the shunt metering device, and each channel of gas corresponds to a kind of sensor for separate metering. If there is a component corresponding to the sensor in the gas, the corresponding sensor will output data.

The data of sensor array is collected by computer and processed by data processing module.

4. Research on water content detection module

In addition to the above decomposition product component detection, the instrument also integrates the water content detection module[6-7]. The structure diagram of the water content detection module is shown in Figure 3.

Figure 3 structure diagram of water content detection component

The principle of water content detection module is the cold mirror principle, and the cold mirror module is used for testing. The cold mirror component is composed of a base, a semiconductor...
retrieval, a heat conduction and temperature measurement component and a refrigeration mirror. The refrigeration mirror is a high-precision mirror element, which is pasted on the temperature measuring component with good heat conduction. If there is condensation on the mirror, it will be detected by the optical detection sensor. The cold mirror is pasted on the temperature measuring component, and the thermal conductivity of the temperature measuring component is excellent, which can ensure that the temperature of the cold mirror is the same as that of the thermal conductive component. The thermal conductive component is pasted on the cold side of the semiconductor refrigeration chip, and the temperature of the semiconductor refrigeration chip is controlled.

The detection module is composed of illumination light source, uniform light module and optical condensation detection module. At the beginning of the detection, the illumination light source irradiates the cold mirror through the light equalizing assembly to make the optical detection assembly achieve the maximum detection sensitivity.

When the detection gas passes into the sample gas channel, the module begins to cool down. When the optical module detects condensation, the equipment will automatically record the temperature at this time, which is the dew point. The corresponding water content can be obtained by looking up the table.

5. Conclusion

In this paper, a new type of electrical equipment insulation gas decomposition product detection device can realize the test function of a variety of instruments, including: CF₄ component content detection, multi gas component simultaneous detection, water content detection. The device is portable, easy to operate, and can accurately detect the SF₆ gas composition of CF₄ content in the field of electrical equipment. It is of great significance for the development of SF₆ gas decomposition products on-site real-time detection and real-time analysis of electrical equipment fault status, improving the state detection level and improving the operation stability of electrical equipment.

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References

[1] Tang J, Liu F, Meng Q, et al. Partial discharge recognition through an analysis of SF₆ decomposition products part 2: feature extraction and decision tree-based pattern recognition[J]. IEEE Transactions on Dielectrics and Electrical Insulation, 2012, 19(1):37-44.
[2] Yanhua Z, Liqun D, Shaojun B, et al. Design and Implementation of Full-spectrum Spectral Imager System[J]. Spacecraft Recovery & Remote Sensing, 2018.
[3] Wang Y, Ma G, Zheng D, et al. Detection of Dissolved Acetylene in Power Transformer Oil Based on Photonic Crystal Fiber[J]. IEEE Sensors Journal, 2020, PP(99):1-1.
[4] Feng Z, Feng-Xiang M A, Zhen-Xi S U, et al. Research of Gas Mixture Detection Technology in Electrical Apparatus[J]. Journal of Anhui Electrical Engineering Professional Technique College, 2018.
[5] Lu G, Liu Y. Research of the Relationship between Partial Discharge and Gas Decomposition Products in SF₆ Insulated Equipment[C]// 2nd International Conference on Intelligent Computing and Cognitive Informatics (ICICCI 2015). 2015.
[6] Lu G, Liu Y. Research of the Relationship between Partial Discharge and Gas Decomposition Products in SF₆ Insulated Equipment[C]// 2nd International Conference on Intelligent Computing and Cognitive Informatics (ICICCI 2015). 2015.
[7] Lai Y, Liu G Q, Li Z, et al. Research on the method of seed water content measurement based on electromagnetic induction[J]. Progress In Electromagnetics Research M, 2018, 74:191-200.
[8] Beyhan S, Kadrgan F, Leger J M. In-situ infrared spectroscopy study of ethanol oxidation on Pt and PtSn-based trimetallic anode electrocatalysts for direct ethanol fuel cell[C]// 217th Meeting of The Electrochemical Society. 2010.