Research on Defect Pattern Recognition of GIS Equipment Based on X-ray Digital Imaging Technology

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Abstract: **In this paper, the experimental platform composed of Computed Radiography (CR) imaging system and Gas insulated switchgear (GIS) model is established to carry out the gas dissociation and withstand voltage test of SF_6 gas under different tube voltage levels. Taking the loosening of metal screws in the grading shield as an example, the GIS defect type is irradiated by X-ray. Then a typical defect library with three levels of defect: general, severe and critical is established. Meanwhile the corresponding identification criteria belongs to image defect is offered. The experimental results show that the composition and withstand voltage of SF_6 gas in GIS equipment are unaffected by the X-ray irradiation. In addition, X-ray digital imaging technology can effectively diagnose the internal defects and realize visual detection of GIS.**

I. INTRODUCTION

Image processing technology has been widely used in abnormal detection of electrical equipment course of its high processing accuracy and rich processing content to image [1]. Among them, X-ray digital imaging technology, carries out non-contact and nondestructive testing of electrical equipment so that the internal structural anomalies of GIS can be observed in operation [2-3]. GIS is one of the important equipment in power system. And accurate diagnosis to its internal defects is of great significance to the safe, stable and reliable operation of the power network [4-6].

Ultra-high frequency (UHF) method is an indirect detection method for gas dissociation of SF_6 [7-10]. It can't accurately diagnose the physical types of defects that lead to internal partial discharge (PD). Although X-ray irradiation can effectively solve this problem due to its advantages of high resolution images, it can ionize the inner seal gas of GIS. In order to ensure the practicability of the method, the effect of ionization on SF_6 gas in GIS needs to be further explored.

Based on this, an experimental platform composed of CR imaging system and GIS model is set up to irradiate SF_6 gas under the different tube voltage levels. The results showed that the withstand voltage and composition of SF_6 gas remained unchanged after irradiated by X-ray. Secondly, the method was used to detect the metal defects of the grading shield under the different defect grades. Finally, the general, severe and critical defect library based on different defect types is established, and the criterion of X-ray detection under different defects is shown, which further proves the effectiveness of digital X-ray imaging in GIS defect detection.

II. X-RAY DIGITAL IMAGING DETECTION TECHNOLOGY

A. Principle of X-ray digital imaging

When the X-ray emitter radiates, the image signal is recorded on the imaging board, which contains photosensitive phosphor to preserve the hidden image [11-14]. When the imaging board is scanned by a laser beam in a digital converter, the hidden image information is released in the form of visible light. Then the released visible light is captured and converted into a digital signal stream, and the digital image can be obtained by the calculation. By scanning the screen with a laser beam derived from the CR readout, the energy of the laser releases the trapped electrons, resulting in visible light radiation, which is captured and converted into a digital bit stream and the digital image is coded further. X-ray digital imaging system is shown in Fig. 1

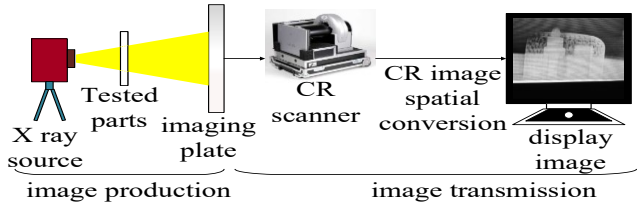

Figure 1. Schematic diagram of X-ray digital imaging system

B. Experimental platform construction

In this paper, the advanced CR imaging technique is applied to detect high-fault parts in GIS equipment, such as circuit breaker, isolator switch busbar connection, etc. The internal structure information of GIS equipment is formed through the photosensitivity of the imaging board, and the photosensitive information is quickly converted into digital image by the laser digital scanning technology, which realizes the analysis of the

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internal structure of the GIS equipment. This paper takes full account of the situation of field use. The CR imaging system used for GIS equipment is composed of a CR scanner, an imaging board, an image processing and analysis software, a field moving bracket, a moving workstation, etc., as shown in Fig. 2.

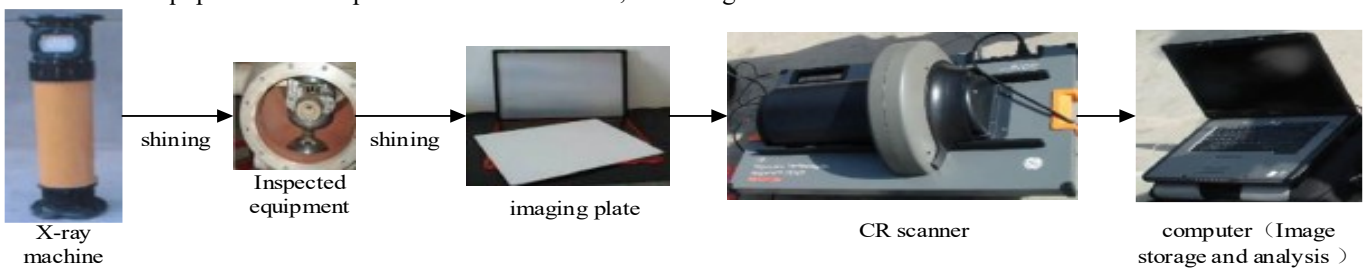

Figure 2. X-ray digital imaging system

III. Effect Of X-ray Irradiation On SF_6 Gas

Radiative X-rays can cause ionization of matter, which to some extent reduces the insulating properties of matter. In order to study the effect of X-ray insulation of SF_6 gas, the withstand voltage test and the dissociation test of SF_6 gas have been carried out.

A. SF_6 gas withstand voltage test under X-ray irradiation

In order to obtain the stable value of the test, the design of the test equipment is shown in Fig. 3, and the contact of the plate electrode is shown in Fig. 4. The pressure of SF_6 gas in tooling is 0.4mpa.

In order to obtain the experimental results of the system. Firstly, the initial breakdown voltage was obtained 5 times through the breakdown experiment of the tooling without any treatment. Then the test equipment was irradiated with X-ray. The tube voltage was 100 kV, 200 kV, and 300 kV respectively, and the tube current was 5 mA. After 5 minutes of irradiation, the breakdown voltage test was conducted again, and the average value of all the experiments corresponding to each voltage level was obtained. The breakdown voltage of tooling is shown in Fig. 5.

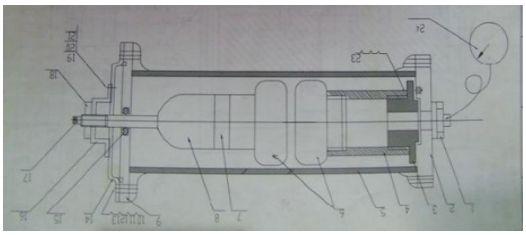

Figure 3. Test device drawings

Figure 4. Plate electrode photograph

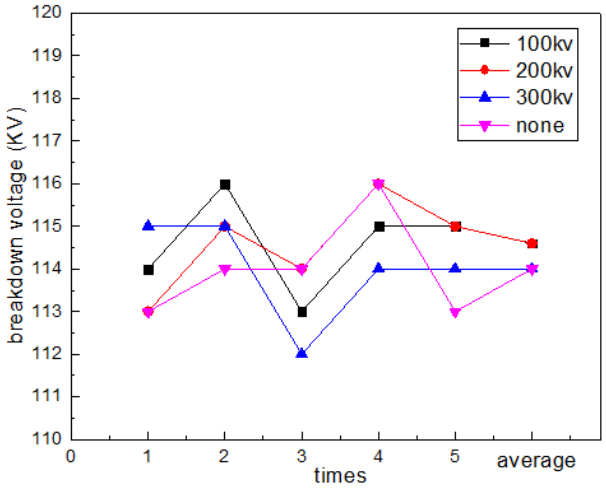

Figure 5. Breakdown voltage line diagram under different conditions

The results show that the breakdown voltage fluctuates little after X-ray irradiation, and the average breakdown voltage of the test equipment is maintained at 114 kV. Considering the causal factors itself, it can be concluded that the breakdown voltage of SF_6 gas does not decrease or increase after 15 minutes of irradiation. In fact, when digital X-ray imaging of GIS equipment is carried out on the spot, the breakdown voltage of SF_6 gas does not decrease or increase. In general, the process of X-ray irradiation spends not more than 3 minutes each time, so it can be concluded that X-ray irradiation has no effect on the withstand voltage of SF_6 gas.

B. SF_6 gas dissociation test after X-ray irradiation

In order to avoid the decomposition of SF_6 gas during the digital X-ray imaging of GIS in the field, the effect of X-ray exerting on the SF_6 gas under different tube voltage levels was studied. The experimental equipment is the SF_6 decomposition product detector with accuracy of ±0.1 μ L/L made in Canada. In order to facilitate the comparison of several situations expediently, for each voltage level (100kV, 200kV, 300kV), the irradiation time is 3, 5, and 7 minutes, respectively. The composition of the gas is measured with a spectrometer and the data is recorded before and after irradiation. In addition, the gas need to replace between two experiments. The result is shown

in Table I to Table III

TABLE I
RESULT OF SF_6 GAS DISSOCIATION TEST UNDER 100kV

SF_6 gas component	New gas	3min	5min	7min
CF_4（μL/L）	21.2	21.4	21.3	21.2
H_2S（μL/L）	0	0	0	0
SO_2（μL/L）	0	0	0	0
SF_6（%）	99.99	99.99	99.99	99.99

TABLE II
RESULT OF SF_6 GAS DISSOCIATION TEST UNDER 200kV

SF_6 gas component	New gas	3min	5min	7min
CF_4（μL/L）	21.3	21.4	21.2	21.3
H_2S（μL/L）	0	0	0	0
SO_2（μL/L）	0	0	0	0
SF_6（%）	99.99	99.99	99.99	99.99

TABLE III
RESULT OF SF_6 GAS DISSOCIATION TEST UNDER 300kV

SF_6 gas component	New gas	3min	5min	7min
CF_4（μL/L）	21.2	21.3	21.3	21.2
H_2S（μL/L）	0	0	0	0
SO_2（μL/L）	0	0	0	0
SF_6（%）	99.99	99.99	99.99	99.99

By comparing the test results, it can be found that CF_4 is an inherent component of the new gas and its content is close to zero. Its concentration does not increase with the length of time and the voltage level of the X-ray irradiation. In addition, H_2S and SO_2 did not appear during multiple X-ray emission. From this experiment, we can see that there is no dissociation of gas under 300 kV tube voltage after 5 min.

IV. CASE ANALYSIS & DEFECT BANK ESTABLISHMENT

It can be seen from the above that X-ray irradiation has no effect on the decomposition characteristics and withstand voltage of SF_6 gas. In this paper, taking the defects of the grading shield as an example, case one is that there is a short metal tip in the grading shield. Case two is that there is a long metal tip in the grading shield without partial discharge and case three is that the metal screw is loosened obviously with partial discharge. Three picture of above defects were obtained, which further proves the practicability and validity of the method. Based on this, the typical defect library of different defect grades is constructed.

A. Case of metal tip defects in the grading shield

Defect identification norm: In X-ray digital imaging, it can be judged as general defects if bolts are slightly loosened(Less than two). If the amount of loose bolt or screw is less than two and the bolt or screw is still in the hood without partial discharge, it is recommended that it be evaluated as a state of care. Further, the screws were obviously loosened without partial discharge could be found to be a serious defect. If the bolts and screws are obviously loosened (more than two) and the partial discharge characteristics are found, it is recommended that it be evaluated as a state of hazard. X-ray detection atlas based on three defects is shown in Fig. 7 to Fig. 9.

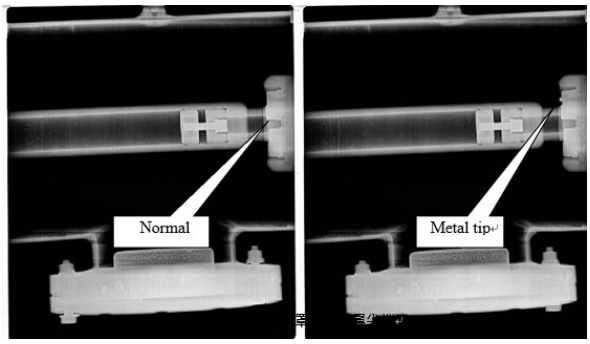

Figure 7. There is a metal tip in the grading shield

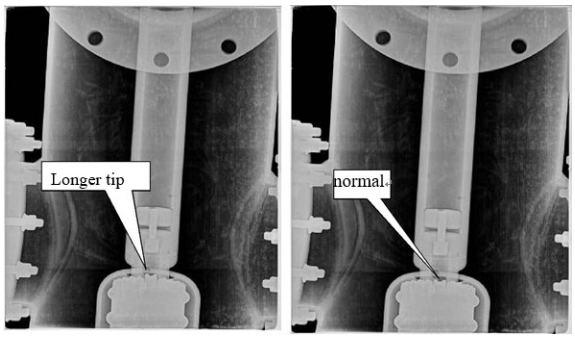

Figure 8. The metal tip in the grading shield is longer but without partial discharge

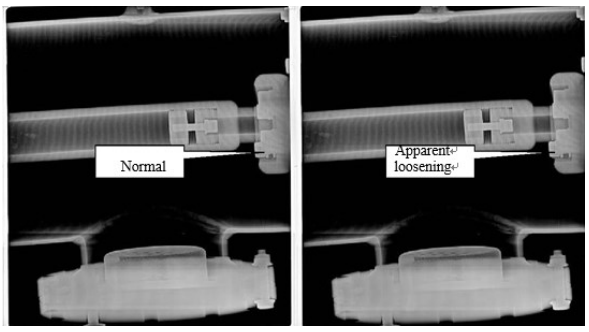

Figure 9. The metal screws in the grading shield are obviously loosened with partial discharge

B. Typical defect library of X-ray visualization

In order to establish a scientific reference for the identification and judgment of typical defects in GIS equipment, the different types of defects are divided into three grades: general, severe and critical. (A represents general grade, B represents serious grade, C represents critical grade, see Table IV)

TABLE IV
TYPICAL DEFECT TYPES OF GIS

Defect grade			A	B	C
Typical defect	Grading shield	Metal tip	subsistent and air tight	longer without PD	subsistent foreign bodies
		Metal screw	Slight loosening	Apparent loosening without PD	Apparent loosening with PD
	Adsorption cover		rigid plastics	General material plastic	Breakage
Other defects	Component loss		————	Spring of disconnector	Conductive pole or other key parts
	Tank moisture value		————	Not overproof	Overproof

V. CONCLUSION

In this paper, the principle of X-ray digital imaging theory is introduced, and the experimental platform composed of CR imaging system and GIS model is established. The test tooling filled with SF_6 gas under certain pressure is designed. The withstand voltage and gas dissociation tests of SF_6 gas after X-ray irradiation under different tube voltages were launched. The results shows that X-ray irradiation has no effect on the withstand voltage and dissociation of SF_6 gas. It can be used to detect the insulation of GIS. As the pictures were obtained in defect recognition test of the grading shield, the potential defects can be found effectively before the accident. The defect library, including general, serious and critical defects, is established, which provides reference for the further fault pattern recognition.

REFERENCES

[1] Asiegbu G O, Haidar A M A, Hawari K. A Review of Defect Detection on Electrical Components Using Image Processing Technology[M]// Proceedings of the Fourth International Conference on Signal and Image Processing 2012 (ICSIP 2012). Springer India, 2013:247-255.

[2] Guo T, Hong Y U, Liu Z. Research on Fault Diagnosis Method of GIS Based on Partial Discharge Recognition of BP Network and X-ray Detection[J]. Yunnan Electric Power, 2015. (in chinese)

[3] Huanqing X, Junpeng M, et al. Study on digital X-ray imaging technology for detecting typical defects in GIS equipment [J]. Journal of Grid technology, 2017(41).1697-1702. (in chinese)

[4] Naiyong L， Meiling Z，Xin W，et al．A new bus protection principle of GIS fault accurate isolation and automatic restoration of power supply[J]．Power System Technology，2015，39(10)：2965-2971(in Chinese).

[5] Guoyao H，Xiying Z，Bing C. Research and development of the optimized & miniaturization GIS[J]. High Voltage Apparatus，2012，48(10)：78-82. (in chinese)

[6] Xin L. Modern high voltage switchgear technology[M].2nd ed. Beijing：China Machine Press，2011. (in chinese)

[7] Haitao Z, Xiaohua L, Ming L, Haibo L, Zhengting W, Yong F. Detection and diagnostic analysis of internal partial discharge in 750 kV GIS disconnector. Journal of high voltage apparatus. 2010(8): 6-9. (in chinese)

[8] Xie Q, Wang Y, Li T, et al. Application of signal sparse decomposition in the detection of partial discharge by ultrasonic array method. IEEE Transactions on Dielectrics & Electrical Insulation, 2015, 22(4): 2031-2040. (in chinese)

[9] Qing F, Weidong L, Wei D and Xin T. A new ultrasonic diagnosis technology for internal default of GIS equipment. Journal of High voltage apparatus. 2008(6): 589-595. (in chinese)

[10] Deun L, Wei S and Zhiqiang G. Application comparison between conventional and ultrasonic detection methods for GIS partial discharge. Journal of High voltage apparatus, 2009:99-103. (in chinese)

[11] Xianhai P, Hao J, et al. Application of X-ray Digital Imaging Technology in GIS Equipment Adsorbent Cover Material Identification[J]. Hebei Electric Power, 2014(6):4-6. (in chinese)

[12] Ximei H, Zhihui W, et al. Typical application of cr technology in electrical equipment detection [C]// High Voltage Apparatus, 2014:124-127. (in chinese)

[13] Yan B, He X M, Wang Z H, et al. Application of X-ray digital imaging defect detection system in GIS equipment[J]. High Voltage Apparatus, 2010. (in chinese)

[14] Hong Y, Jie W, Xianping Z, Yi M and Lei C. The perspective detection of the X-ray digital radiography for the electrical equipment. International Conference on High Voltage Engineering and Application, Shanghai, 2012, pp. 591-599. (in chinese)