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The Application of X-ray Digital Real-time Imaging Technology in GIS Defect Diagnosis

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Abstract

Gas insulated switchgear (GIS) is now a major product that is widely used by power system .The running state of GIS is very important for electric power systems because a power system failure will result in an enormous loss of life and property. X-ray imaging technique, which has been studied intensively for the past decades, can be very efficient tools for the application. X-ray digital real-time imaging technology is proposed for detecting GIS equipment. The internal defects of the equipment can be achieved by X-Ray digital real-time imaging technology in the case of without dismantling the device and electrification. Besides, the detection technology is a supplement and refinement to partial discharge detection methods. Moreover, it provides a basis for the condition-based maintenance and assistant decision-making of grid equipment.

Keywords: GIS ;X-ray; Digital Radiography(DR);defect; nondestructive detection.

1. Introduction

Gas insulated switchgear (GIS) at EHV levels was introduced in the 1970's. And it is now a major product that is widely used by power system. It has been proved that the safe and reliable operation of GIS equipment in power system plays a very important role in the security and stability of the grid. GIS is the metal packaging equipment that has advantages of smaller occupied area, compact structure and high reliability et al. If a variety of devices are sealed within the metal shell, there must be some defects. Such as by inspection these internal defects of the equipment are not easily found, thus positioning is even more difficult. The high conditions are required in maintenance, so field maintenance is more difficult. All kinds of devices are put together. If one device fails, other devices are easily spread. The running state of GIS equipment can not be eyed, thus its reliability is hastily reducing. Production field has many detectable and diagnostic methods such as pulse current, Ultra High Frequence (UHF) or Ultrasonic to

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ensure the reliability of GIS equipment, but rough judgment is only given by these methods. Meanwhile, a few parts can be only determined during the event of failure [1-3]. It can not be further to give its internal defects without removing the device such as type and position. In the paper, the detection method of X-Ray Digital real-time imaging technology is proposed. The development of X-ray imaging technique is from first taking X-ray film imaging to now using Computed Radiography (CR) and Digital Radiography (DR), adopting digital image to display ray fluoroscopy image. Ray digital image can not only use a variety of image processing techniques for processing image, improving image quality, but also simultaneously show acquired image by a variety of judging methods, referencing and complementing each other, as well as merging and processing, greatly enhancing judging information. Although CR and DR are superior to the traditional film imaging, but comparing with DR, CR is complicated to operate, not real-time, low efficiency and slightly inferior image quality. DR method does not replace imaging plate like CR during twice irradiation. Before data acquisition, a few seconds are only required by DR, simultaneously observing image. Compared with film imaging and CR, the production capacity of DR is hugely increased [4-6]. Therefore, the diagnosis method of X-Ray Digital real-time imaging technology is proposed by this paper, nondestructive detection the internal defects of GIS equipment. The type and position can be finally determined by the proposed means of this paper. If UHF and Ultrasonic detection method is combined with this technology, it can visually orientate the internal fault of GIS equipment to attain the purpose of rapid and accurate testing equipment. The reliable and accurate technical support is provided for the condition-based maintenance and assistant decision-making of grid equipment.

2. The priciple of X-Ray Digital Radiography technology

X-ray will interact with matter in penetrating an object, decreasing its intensity due to absorption and scattering. The attenuation coefficient and the penetrating ability of ray in the material is depended on by the level of decaying intensity, that is to say, it is different for different materials or different density of the same material to degrees of ray attenuation. After rays penetrate the object, the intensity change of rays is measured to obtain planar projection of discontinuities in the object, the changes in the material type or the changes in the geometry and so on, so as to achieve the purpose of understanding the internal situation of the object, such as the inside defect of the material, the structural condition of other substances inside closed object and so on [7-8]. X-ray DR consists of X-ray machine, flat panel detector and laptop mobile workstation and so on. Working in the field, laptop mobile workstation is connected with the flat panel detector. The image is receipted and transmitted by software, simultaneously achieving the functions of finding and viewing images. The type and location of the internal defects of GIS equipment can not be accurately determined by normal detection methods. And the detection of the internal defects of GIS equipment can be achieved by the proposed X-ray digital real-time imaging technology without dismantling the device and destroying the environment, or even no power to implement visual diagnosis.

3. The conventional defects of GIS equipment

The conventional defects of GIS equipment consist of defects of foreign body class, assembly class and material class. Foreign body class defects derive from defects of installation of the device, opening maintenance and operation et al. Assembly class defects origin from defects of incorrect installation, assembly scratch and running loosing by vibration et al. Material class defects originate from defects of device oneself. All kinds of defects can be simulated in the laboratory. X-ray digital real-time imaging technology is adopted by this paper to achieve the detection of these simulated defects. At the same time, the most typical and prone to happen defect, metal suspension defect, is chosen by this paper. It is proposed that X-ray digital real-time imaging technology combined with ultrasonic detection technology in this paper. It will be proved that X-ray digital real-time imaging technology is feasible and robust.

4. Exprimental Results of detection and Conslusions

In the first, the metal suspension defect is simulated. The ultrasonic detection technology is used to determine the presence of defects. The existing area of defects is gotten. X-ray digital real-time imaging technology is used to gain the clear picture of defects later. At the same time, defects of foreign body class, assembly class and material class are simulated. X-ray digital real-time imaging technology is used to achieve a variety of pictures.

4.1. Metal suspension defect

The ultrasonic detection technology can be used by the simulated metal suspension defect. In the lab, 20mm wide and 80mm long piece of iron is vertically suspended to simulate metal suspension defect. Its edge has visible spikes. It is 10mm from the ground electrode and 15mm from the high voltage electrodes. The simulated metal suspension is shown by the Fig.1(a)-(b).

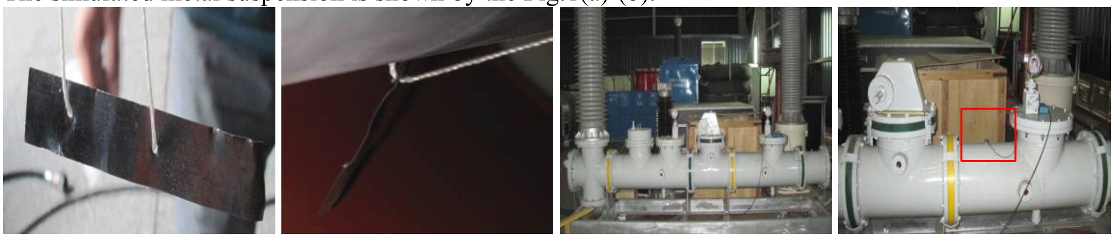

Fig.1.(a)the size and shape of simulated metal suspension;(b) the simulated metal suspension in conducting rod;

(c) 220 kV GIS test section;(d) the position of ultrasonic probe.

These tests in this paper are done in 220kV GIS test section. 220kV GIS test section is displayed by Fig.1(c). AIA-GIS ultrasonic PD tester is used by this test. And the ultrasonic probe is placed in different locations each chamber applying with different AC voltage levels to get different ultrasonic patterns. In this paper, the ultrasonic probe is only placed above the simulated metal suspension defect. It is given by Fig.1(d). During the experiment, three AC voltage levels are selected to obtain three groups of PD patterns. These patterns are shown by Fig.2and Fig.3.

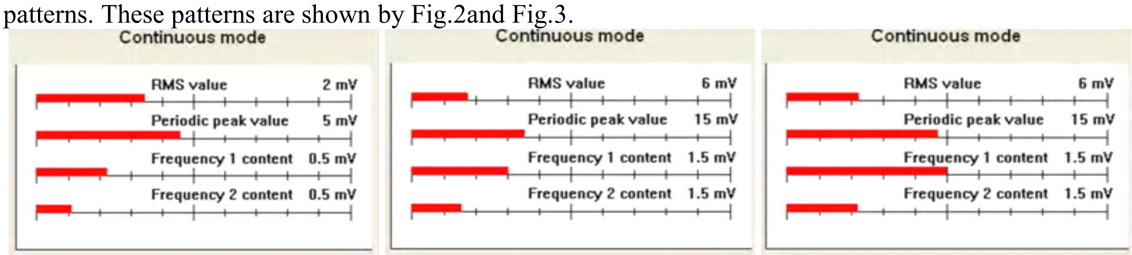

Fig.2. (a) continuous mode of 60kV AC voltage;(b) continuous mode of 64kV AC voltage;(c) continuous mode of 69kV AC voltage.

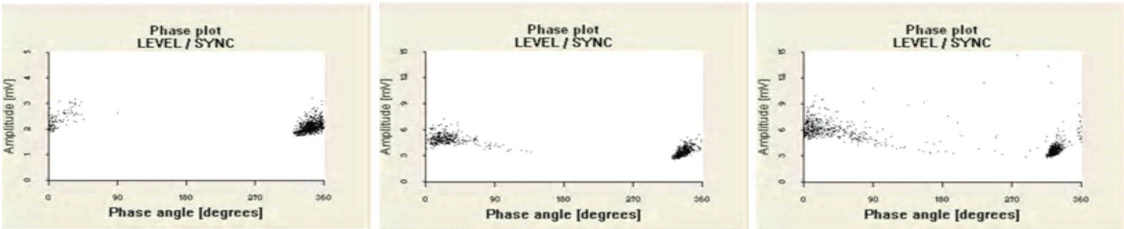

Fig.3. (a)phase plot of 60kV AC voltage;(b) phase plot of 64kV AC voltage;(c) phase plot of 69kV AC voltage.

By this way, Partial Discharge is identified. Furthermore, the existence of the defect is confirmed. Meanwhile, the probable position of the defect is fixed. In order to further determine the exact position and type of the defect, X-ray Digital Radiography system is built. It is shown by Fig.4(a). During the experiment, voltage, current or exposure time is changed, and the location of flat panel detector or X-ray machine is adjusted to ascertain the best parameter. The clear visual defect is given by Fig.4 (b)-(c).

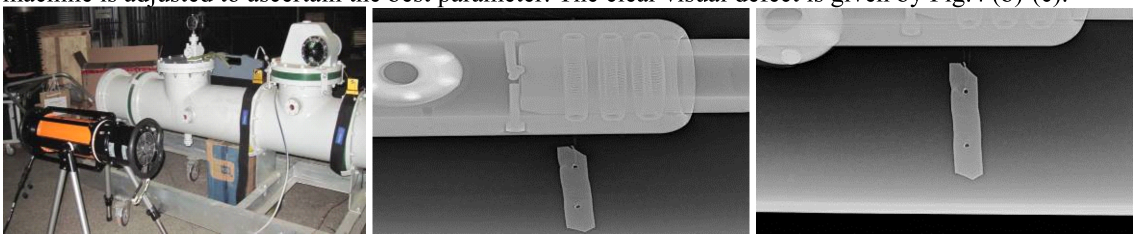

Fig.4. (a)The site layout of DR system;(b) The position one of metal suspension defect; (c) The position two of metal suspension defect.

Metal suspension defect is clearly discerned. The location of flat panel detector or X-ray machine is adjusted to obtain the exact position and type of the defect.Thus, X-ray Digital Radiography system is practical.

4.2. Foreign body class defects

The density of foreign body plays a very important role in these defects. If the density of foreign body is high, it will be easily identified. The density of the metal is much higher than others .In this way, the metal is prone to be identified. It is given by Fig.5.

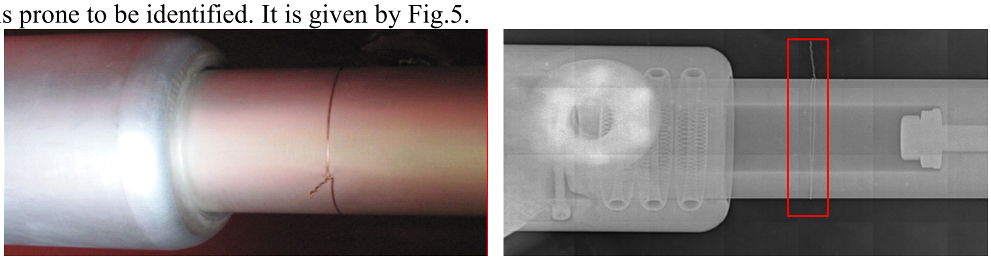

Fig.5.Tip defect of charged conductor (a)the original picture;(b)the picture after X-ray.

The original drawing of simulated tip defect can be seen as shown in Fig.5(a). The nondestructive detection image of simulated tip defect can be given in Fig.5(b).The tip defect of charged conductor can be clearly seen in Fig.5.

Fig.6.the simulated copper metal particles defect (a)the original picture;(b)the picture after X-ray. the simulated aluminium metal particles defect (c)the original picture;(d)the picture after X-ray.

The picture of material object about simulated copper metal particles defect can be seen by Fig.6(a).Some bright spots that scatter around the bottom of the shell in the GIS can be seen as shown in Fig.6(b).The graph of material object about simulated aluminium metal particles defect can be seen by Fig.6(c). But in the same position, some bright spots that scatter around the bottom of the shell in the GIS can not be seen as shown in Fig.6(d).As far as we known, the density of copper is higher than aluminium.

4.3. Assembly class defects

Assembly class defects origin from defects of incorrect installation, assembly scratch and running loosing by vibration et al. The correct original assembly picture is important to assembly class defects. The correct original assembly pictures of simulated several defects are given by Fig.10.Compared with the pictures of Fig.7, sub-gate not in place of earthing switch and closing not in place of earthing switch can be seen as shown in Fig.8.In Fig.9, The correct original assembly picture is on the left side, and no compressing of spring shim is on the right side. The comparison is very obvious.

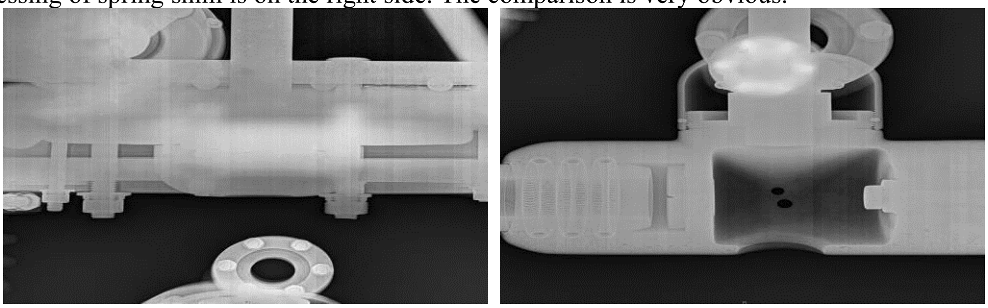

Fig.7. (a) sub-gate in place of earthing switch;(b)closing in place of earthing switch.

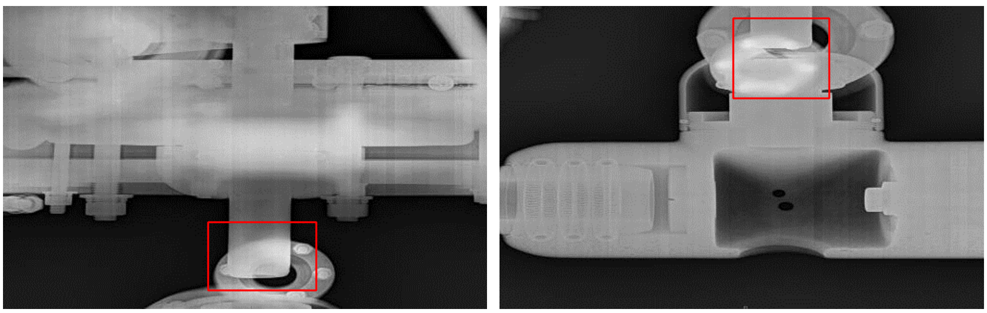

Fig.8. (a) sub-gate not in place of earthing switch;(b) closing not in place of earthing switch.

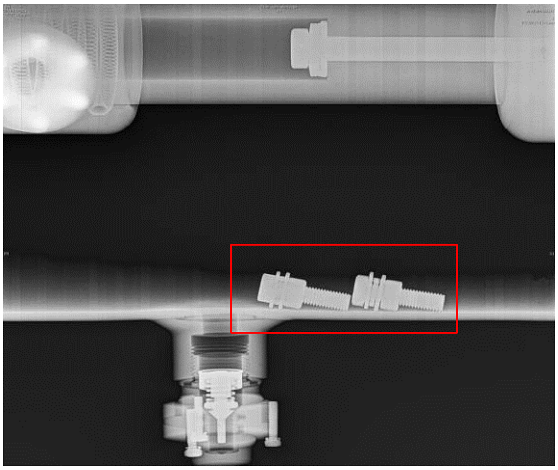

Fig.9.No compressing of spring shim.

For such defects, before the equipment access to the power grid, the test is necessary. Compared with the original picture, it is of great help to determine the defect.

4.4. Material class defects

Material class defects originate from defects of device oneself. The crackle and bubble is found in operation insulation rod due to the installation, operation and maintenance and so on. The result of nondestructive examination is that the bubble is seen by Fig.10 (b) and the crackle is not seen by Fig.10(b).

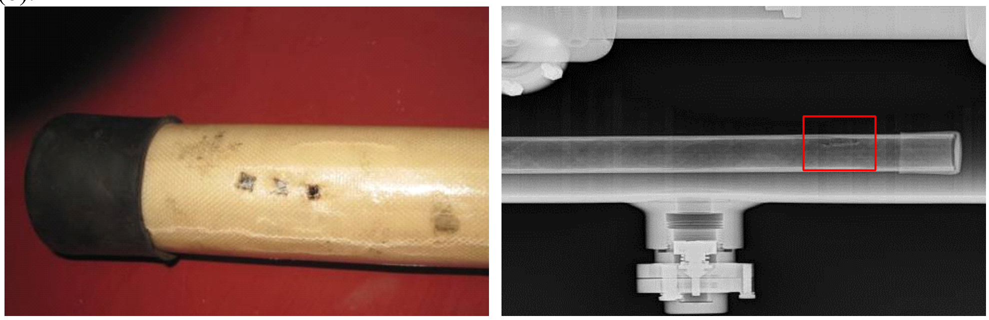

Fig.10. the defect of bubble about operation insulation rod (a) the original picture; (b) the picture after X-ray

The experimental results demonstrate that these defects of foreign body class, assembly class and material class of the GIS can be easily identified. Thus, in this paper, the proposed approach has the more practical value. Compared with the ultrasonic detection technology, the exact position and type of the defect can be further determined by X-Ray Digital real-time imaging technology. At the same time, the internal defects of the equipment can be achieved by X-Ray digital real-time imaging technology in the case of without dismantling the device and electrification. Besides, the detection technology is a supplement and refinement to partial discharge detection methods. Moreover, it provides a basis for the condition-based maintenance and assistant decision-making of grid equipment.

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