Live Detection Technology of SF6 Equipment Based on Computer Aided Laser Imaging Technology

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Abstract. To overcome the limitations of traditional methods for detecting gas leakage for SF6 equipment, such as staff safety being endangered and poor reliability of power supply, this paper introduces the laser imaging technology for gas live detection of SF6 equipment. Through discussing an example of SF6 gas leakage detection, it is shown that the SF6 gas leakage detection method based on computer aided laser imaging technology can be long-distance live detection, and can determine the SF6 gas leakage point safely, quickly and efficiently[1]. It guarantees the safety of personnel, improves the efficiency of maintenance, reduces the time of power failure, and improves the reliability of power supply.

Keywords: SF6 Gas, Laser Imaging Technology, Leakage Detection, Live Detection, Computer Aided

1. Introduction

SF6 gas with excellent insulating, arc-quenching performance and stable chemical thermal properties has been widely used in ultra-high voltage electrical equipment. For example, circuit breaker, disconnecting switch and mutual inductor that adopt SF6 gas-insulated and gas insulated switchgear (GIS) and so on. But following the SF6 gas insulated switchgear and so on. However, with the extensive use of SF6 gas insulated equipment in high-voltage electrical devices, due to SF6 electrical equipment manufacturing, installation and other quality factors as well as components aging and external force damage and other factors[1]. The problem of SF6 gas leakage has also been revealed. The occurrence of SF6 gas leakage not only reduces the arc extinguishing capacity and insulation performance of the SF6 switch arc extinguishing chamber of electrical equipment, but also brings a serious hidden danger to the safe operation of equipment. At the same time, the leakage of SF6 gas through the arc, voltage discharge, temperature and other factors, can form strong decomposable substances with strong corrosive and toxic properties, which may endanger the operation, maintenance personnel safety. Moreover, SF6 is a strong greenhouse gas, if it can emit or leak into the atmosphere; it will aggravate the greenhouse effect of the atmospheric environment[2]. At the same time, because of the high price of SF6 gas, a large number of gas supplements will increase the cost of equipment maintenance, so it is very meaningful to strengthen the leakage detection of SF6 equipment[3].
For a long time, there is no good leak detection method for the problem of SF6 electrical equipment leakage. Common methods to detect leakage and locate leakage points of SF6 equipment are: dressing method, soap-water method, handheld leak detector, etc. These methods have limitations such as long operation time, low detection sensitivity, gas poisoning and power failure, which affect the reliability of power supply. Finding a way to deal with the traditional leakage detection obviously, ensuring the safe use of equipment and ensuring the normal operation, and ensuring the safety and health of the inspection staff are a problem that can be dealt with in a timely manner now. The emergence of laser imaging technology provides a method for fast and safe on-line live detection of SF6 gas leakage. This paper introduces the method of SF6 gas leakage detection based on laser imaging technology, and through the analysis of an example of gas leakage detection, shows that this method can be long-distance live detection, can quickly and efficiently determine the leakage point of SF6 gas equipment, to ensure the safety of personnel, improve the efficiency of maintenance, reduce the time of power failure of the equipment. It can improve the reliability of power supply\textsuperscript{[4-5]}. 

2. Traditional methods and imitations of SF6 gas leak detection

SF6 is a kind of odorless and colorless gas. This gas cannot be the same as insulating oil, which can directly detect the leakage point and see the leakage gas through the eyes. At present, in the process of changing electrical operation and inspection, the gas density is the priority to continue to check the changing environment of pressure in the equipment to determine whether there is SF6 gas leakage in the equipment. If the gas density relay decreases rapidly in electrical power, it can be explained that the equipment produced SF6 gas leakage, gas testing should be carried out immediately to determine whether the leakage is possible\textsuperscript{[6]}. The traditional methods of leakage detection include dressing method, soap-water method, handheld leak detector, etc. The common practice is to cut off the equipment when SF6 gas leak is found, and test the leakage point at the porcelain bushing and flange of the equipment with soap water or handheld leak detector. The porcelain bushing and flange of the equipment are sealed and wrapped in plastic film for the new equipment, and then tested by SF6 leak detector section after 24 hours. Problems can be found after these methods reach a certain level, but more obvious limitations can still be seen: 1. The working time is relatively long, and the sensitivity of the inspection is relatively low. Only about range of leakage location can be known, which cannot be accurately positioned. 2. The power leakage finding of large equipment such as GIS and gas insulation transformer has high working intensity, heavy workload, no obvious effect, and it is often difficult to find the leakage point. Power equipment needs to be cut off in the process of searching; 3. It needs to be close to the equipment, and there is danger of electric shock and gas poisoning. Therefore, it is of great significance to carry out SF6 gas leakage detection with live line fast and safely.

3. Principle of SF6 laser imaging leak detector

Because SF6 gas has a strong infrared reception characteristic, if the laser touches SF6 gas, will be received by SF6 gas, so the laser will obviously weaken. The SF6 laser imaging leak detector mainly controls the characteristics of SF6 gas and its reception theory\textsuperscript{[2]}, The principle of SF6 laser imaging leak detector is that through the laser ejector deliver incident laser is aimed at the range of the equipment to be inspected, and the back-scattering laser is injected into the imaging system of the laser photography equipment by the background reflection. If there is no gas leakage, the reverse scattered laser and the backscattered laser occur in the same image. In the case of gas leakage, when the incident laser generated encounters the gas leaked by SF6, the energy will be absorbed accordingly, and reversely return to the laser imaging system. Laser intensity can be weakened by the reception of gas smoke, resulting in two leaking conditions, one of which is no leakage. The other thing is that there's leakage. The two cases are obviously different, and the final laser imaging is different. SF6 gas laser imaging is related to the concentration of the gas, the higher the concentration, the greater the absorption, the relativity degree also increases\textsuperscript{[3]}. In such cases, gas that is not normally visible can be seen in the video, so the location of the leak and the direction of the gas leak can be
determined. This type of technology can see the gas leakage of SF6 that is invisible to the naked eye in the display of video. The inspection staff can check the SF6 gas in monitoring video. Therefore, it can be found whether there is the leakage of SF6 gas, and you can see this principle in Figure 1. According to this principle, the SF6 laser imaging leak detector can be studied. This instrument is mainly composed of the following parts: laser reception system, amplification imaging and data processing system, laser emission system, recording system and display system, as shown in Figure 2.

![Figure 1. Working principle of SF6 laser imaging leak detector](image1)

![Figure 2. The composition of SF6 laser imaging leak detector](image2)

4. Example application

In this paper, RLI-07 SF6 gas leakage laser imaging leak detector produced by Nanjing Shantai Company is adopted. It is a product of a collection of infrared laser spectrum technology, laser scanning imaging technology, infrared image and visible light image fusion technology. It is the most popular and powerful SF6 gas leakage laser imaging product in China.

4.1. First case
Since September 26, 2008, the operators of a 110-kV GIS in a 110-kV substation found that the alarm of low pressure of the gas density relay in the chamber of the lightning arrester, and the maintenance personnel had to make up the air in the chamber once a month. On November 2, 2008, maintenance personnel used SF6 laser imaging leak detector to detect the leakage of the air chamber, and found the gas leakage at the bottom of the gas density relay. In this test, the maintenance personnel are at a distance of 9m from the leak point, and it takes only 20 minutes. Thus, the SF6 laser inspection imaging technology can detect and determine the leak point safely and efficiently in a long distance without affecting the power production, to visualize the leak situation and ensure the maintenance personnel and it also ensures that the maintenance personnel are free from the danger of electric shock and gas poisoning[4].

4.2. Second case

Since April 15, 2009, a 220 kV GIS in a 220-kV substation which is found that the gas density relay pressure indicator alarm of the bus barrel connected to the transformer and the maintenance personnel repaired the gas. Since then, the gas will be repaired every two months. It seriously threatens the safety of equipment operation[5]. At present, it was urgent to deal with the peak summer. On July 9, 2009, maintenance personnel used SF6 laser imaging leak detector to detect the leak of the bus barrel. After nearly 40 minutes of detection of the bus barrel, it was found that there was a leak point in the pipe connected with phase A in phase B. This inspection costs relatively little time. Under the long-distance live detection, it can be explained that the SF6 laser inspection imaging technology has relatively high sensitivity and accurate location, which can achieve live detection, reduce the time of power failure and improve the accuracy of power supply[6].

5. Conclusion

SF6 equipment live detection based on laser imaging technology can live detect SF6 gas leakage situation from a long distance. The colorless and odorless SF6 gas of dynamic cloud smoke can be seen on video display. This can quickly, accurately and directly see the location of the leakage gas. According to the laser imaging technology to detect the method of gas leakage, compared with the usual method used before, this method does not need power cut. Finally, it can carry out inspection on the leakage area at a long distance within the safety range, ensuring that the normal use and inspection staff will not be exposed to harmful gas and electric shock. It reduces the time of power failure and correspondingly improves the reliability of equipment power supply. The application of SF6 gas leakage laser imaging has greatly improved the accuracy of finding leakage points and achieved better conditions for SF6 gas equipment status detection.

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