# Research on GIS gas leak detection based on acoustic emission

Pengfei Ma[1,2,a], Tengfei Shi[1,2], Xinhui Duan[1] and Ximao Chang[1]

[1]*Department of automation,North China Electric Power University, Baoding 071003, Hebei, China*
[2]North China Electric Power University graduate student workstation of Yunnan Power Grid Corporation, kunming, *650217,*China;

**Abstract.** Because of the characteristics of the GIS equipment gas leakage, the paper used the acoustic emission technology to carry on the corresponding experiment to the GIS equipment. These tests included the detection of qualified GIS equipment, the detection of the leakage of simulated GIS equipment and the detection of the device when the device was in the opposite direction, and the corresponding experimental data were obtained. Based on the analysis of the experimental data, the advantages and disadvantages of the near distance probe and the long distance probe were analyzed and compared, the feasibility of using acoustic emission technique to detect GIS equipment were determined, and it was pointed out that the consistency of the direction of the set sound device should be kept in the testing process.

**Keywords:** GIS; acoustic emission technique; gas leakage.

## 1 Introduction

Now the power system has been continuously developed, the normal operation of the power system has been effectively protected because of the application of GIS equipment in power system. Six sulfur fluoride gas ($SF_6$) is a colorless inert gas, which has a strong insulation properties and arc extinguishing ability, it is widely used in the full closed combined electrical appliances (GIS), such as high voltage electrical equipment [1,2].

When the GIS device is produced or run, it may be defective or damaged,so when the GIS device is running, it sometimes happens that $SF_6$ gas leak problem. Gas density relay is the main monitoring tool for internal pressure change of GIS equipment. When the density relay is warning,it shows that the GIS device has a serious $SF_6$ gas leak, GIS equipment internal pressure reduction, The staff should immediately find the leak, or immediately added gas, otherwise it will threaten the safety operation of equipment[3].When the $SF_6$ gas leak, the insulation performance of GIS equipment will decline, it causes the equipment failure, and it will endanger the normal operation of the power grid. In 1996, the world's GIS device users received a Cigre survey, survey report shows that the insulation fault accounted for 20% of the total failure, in our country this kind of accident also has occurred[4].

$SF_6$ gas is also a kind of greenhouse gas, according to the "Kyoto Protocol", $SF_6$ gas has a strong greenhouse effect, the greenhouse effect is 23900 times the $CO_2$, so its leakage for atmospheric environment will cause great harm [5].When the $SF_6$ gas leak, HF, $SOF_2$, $SO_2$ and other substances

[a] Corresponding author: 1343422033@qq. com

 

will be produced, these substances will not only affect the life of the equipment, but also its toxicity will harm the health of the staff.

In order to reduce the harm caused by leakage of $SF_6$ gas, many kinds of detection methods are applied to monitor the leakage of GIS equipment $SF_6$ gas. Traditional detection methods are: Vacuum pumping method; Gas infrared imaging, $SF^6$ type UV ionization detector; Dressing method; Electrical breakdown technique, etc. Vacuum pumping method is generally used to measure the rate of decline in the manufacturing plant to determine the degree of leakage, but it is not able to determine the location of the leak point[6].Gas infrared imaging:$SF_6$ gas can absorb a certain band of infrared light, if the GIS equipment has the revelation, the infrared light shines the GIS equipment, the infrared light and the $SF_6$ gas meet, part of the incident light is absorbed and darker areas of the image will appear, leaks will be found[7-9].When the gas chamber containing $SF_6$ gas, UV ionization type $SF_6$ leak detector in ion will lag, the waveform of the output of the instrument will be distorted and delay, we can calculated the concentration of $SF_6$ gas using time delay[10,11]. Wrapping method: airtight packing cloth is made of flexible material, the GIS device can be wrapped by airtight packing cloth, then according to the extent of the drum up to determine the speed of leakage[12].Electrical breakdown: $SF_6$ gas with insulation, detection of the change in the voltage between the electrodes in the air can determine whether the gas containing $SF_6$[13].All of the above methods have great limitations, it is difficult to find the leak location quickly, simply and accurately.

The author studies the state of $SF_6$ gas leakage after GIS equipment, and the author carries on the experiment to the GIS equipment by means of detecting acoustic emission equipment. After the author analyzes the experimental data. Finally, the possibility of using acoustic emission technique to detect the $SF_6$ gas leakage of GIS equipment is obtained through the analysis of the experimental data.

# 2 Theoretical basis of acoustic emission technology

## 2.1 Detection principle of acoustic emission technology

Elastic wave is emitted by acoustic emission source, elastic waves propagate through the medium to reach the surface of the object being detected, and it causes the mechanical vibration of the surface, this vibration is converted into electrical signals by acoustic emission sensors. The acoustic emission signal is amplified and processed to form characteristic parameters, and is recorded and displayed. Finally, the characteristics of the acoustic emission source are evaluated through the interpretation of the data.

## 2.2 Gas leakage continuous sound source generation mechanism

Air flow from the nozzle to be ejected very fast, the noise generated in this process is called the jet noise. When the fluid is injected into the still air, the fully developed jet is divided into three parts: mixed zone, transition zone and fully developed area. When the nozzle diameter is D, a small amount of turbulence occurs in the gas mixture in the mixing zone, the center of the speed is constant, and it is equal to the exit velocity, the center length is about 4.5D; Behind the mixed area is the transition zone, the turbulent flow of a gas is full of transition zones, and the average velocity decreases with the increase of distance, the transition zone extends roughly to 10D; The last is the full development zone.

The jet noise belongs to the quadrupole sound source, the intensity of the sound source is mainly determined by the jet velocity field.The jet noise is the highest at the 4~5 times of the nozzle diameter. The spectrum of jet noise has the characteristic of wide band noise, if the nozzle diameter is a few millimeters or less, the noise spectrum will move to the high frequency part. The frequency spectrum of the jet noise power is basically a function of Straw's Hall number, but when the injection rate changes, the spectrum is not the same, especially when the speed difference is large, the difference is very large.

The spectrum of jet noise is expressed by the relative spectral level y.

$$y = \frac{1}{W}\frac{dW_f}{df}\frac{v}{5D}\frac{c_0}{c} \qquad (1)$$

W is the total sound power of jet noise, $W_f$ is sound power, D is the nozzle diameter, V is the flow rate, C is the local velocity of injection, $c_0$ is mbient sound speed. At low frequencies, the spectral density of the acoustic power is proportional to the square of the frequency; At high frequency, the spectral density is inversely proportional to the square of the frequency.

## 3 Experiment and data analysis

### 3.1 Laboratory equipment

Ultrasonic detector is SDT270 company's SDT, the other device is a long-distance detection of the disc type.SDT270 technical parameters as shown in Table 1, the field operation as shown in figure 1.

**Table 1.** Basic Technical Parameters of SDT270

| Type | parameter |
|---|---|
| display screen | 128X64 pixel with backlight LCD display screen |
| Built in probe | Ultrasonic scanning probe / infrared temperature probe / laser speed probe |
| External probe | Remote probe,Set probe,Contact probe,Magnetic probe |
| frequency range | 10kHz - 128kHz |
| Measuring range | -70°C~+380°C±0.5°C |
| Measurement limit | 0.0005 cc/sec |
| sensitivity | -65dB re 1V/ub @ 40kHz |
| working temperature | -15~+60°C |
| Battery | 4.8V 4400mAh NiMH , |
| Weight dimension | 0.83kg, 226x90x40 mm (LxWxH) |

**Figure 1.** Schematic Diagram of SDT270 Operation

### 3.2 Detection methods and cases

Test one:

In the preparation phase of the experiment, we labeled the GIS equipment, as shown in Figure 2. Test 2-3 times for each test point with a long distance probe and a close range probe, and record the data. When we use a long distance probe to test, to maintain the test point distance probe 2m, and each time the probe direction to maintain consistency. The relative pressure of the experimental gas chamber is 0.41MPa, When the distance is near, the range of noise environment for -7.5~ -7.2dB V, when the distance is far, the range of noise environment for -0.3~0.1dB V. Table 2 is the experimental data, figure 4 shows the experimental data was finishing line chart, which the abscissa said point detection, ordinate said measurement data, the unit is dBμV.

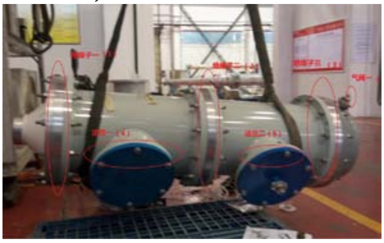

**Figure 2.** 252kV GIS Device Interval Icons

**Figure 3.** The Equipment of 252kV GIS

**Table 2.** Experimental Data List

| | Remote probe, environment:-0.3~0.1 | | | | | | Close range probe, environment:-7.5~ -7.2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measuring point | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | -0.2 | -0.3 | 0.2 | -0.3 | -0.2 | -0.2 | -7.4 | -7.5 | -7.5 | -7.4 | -7.7 | -7.2 |
| 2 | -0.2 | -0.2 | -0.1 | -0.2 | -0.4 | -0.1 | -7.5 | -7.3 | -7.3 | -7.5 | -7.6 | -7.4 |
| 3 | -0.3 | -0.2 | -0.3 | 0.1 | -0.1 | -0.3 | -7.3 | -7.5 | -7.4 | -7.5 | -7.2 | -7.5 |
| mean value | -0.23 | -0.23 | -0.20 | -0.13 | -0.23 | -0.20 | -7.40 | -7.37 | -7.40 | -7.47 | -7.50 | -7.3 |

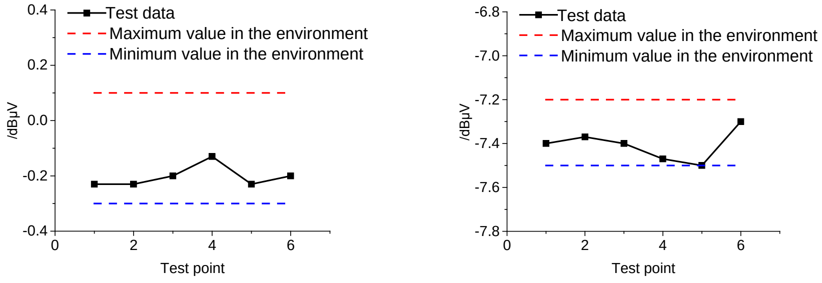


**Figure 4.** Detection Results of 252kV GIS Equipment in Good Condition

Test two:

The equipment is used to detect the two qualified GIS equipment in Figure 3.Test the first ten test points and record the data. To maintain the test point distance probe 2m, the probe direction of each test is consistent, the relative pressure of the experimental gas chamber is 0.4MPa.Table 3 is the measured experimental data, figure 5 is the data line chart, which the abscissa said of the measured point, ordinate said measurement data, the unit is dBμV. The scope of environmental stability region were 0.5~1.0dBμV and -0.5~0.1dBμV.

**Table 3.** Experimental Data List

| **Measuring point** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
|---|---|---|---|---|---|---|---|---|---|---|
| Gas chamber relative pressure: 0.40MPa environment:0.5~1.0 d=2m | | | | | | | | | | |
| mean value | 0.45 | 0.55 | 0.40 | 0.45 | 0.65 | 0.60 | 0.60 | 0.55 | 0.60 | 0.55 |
| Gas chamber relative pressure: 0.40MPa environment: -0.5~0.1 d=2m | | | | | | | | | | |
| mean value | 0.10 | 0.15 | 0.05 | 0 | 0.05 | -0.25 | -0.30 | -0.05 | -0.10 | -0.40 |

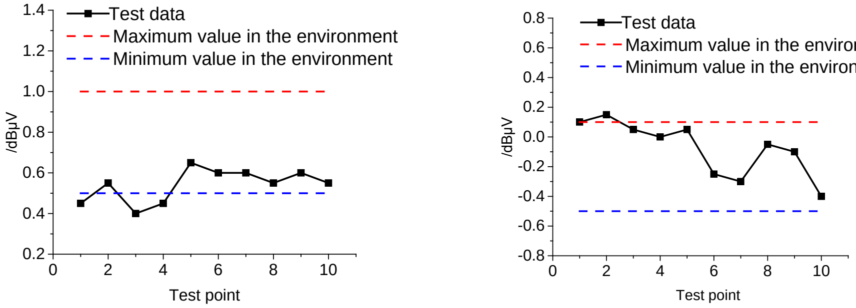


**Figure 5.** Diagram of Experimental Data

The experiment was conducted to simulate the air leakage in a gas chamber, control valve, and slow moving. The experimental personnel stand at a distance of 2 meters, they use a long distance probe to detect the leakage of the leak point, from the micro leak (close to the leak can't see the sound) to the micro significant (near the distance can be heard a small voice), to a significant leak (1m can be heard about a very small range of sound).Detection Figure 2 GIS equipment easy to leak point, and record the corresponding data. Data, such as in Table 4 shows, the line chart as shown in Figure 6, the abscissa of the said measure the extent of the leak, the ordinate said measurement data, the unit is dBμV, air chamber relative pressure 0.4MPa, environmental 1.2~1.9dBμV.

**Table 4.** Experimental Data List

| | Micro drain 1 | Micro drain 2 | Micro display | Leak 1 | Leak 2 |
|---|---|---|---|---|---|
| 1 | 0.9 | 1.2 | 1.3 | 6.3 | 5.6 |
| 2 | 1.4 | 1.1 | 1.2 | 9.1 | 6.2 |
| mean value | 1.15 | 1.15 | 1.25 | 7.70 | 5.90 |

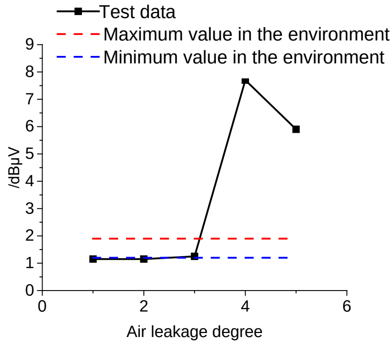


**Figure 6.** Diagram of Experimental Data

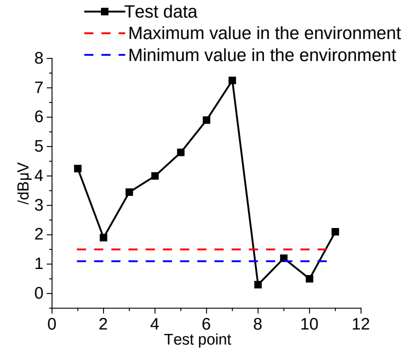


**Figure 7.** Diagram of Experimental Data

Test three:

The use of long distance probe and SDT270 to detect the GIS equipment in figure 2,distance probe 2m for each test point, and two sets of data were detected at each test point. When detecting the two sets of data, the device collects the sound in the opposite direction. The influence of external noise interference on the accuracy of measurement data is detected by this method. The relative gas chamber pressure 0.40MPa, range of environment is 1.1 ~1.5dB V. Data such as table 5 shows, a line chart as shown in Figure 7, the abscissa said of the measured point, ordinate said measurement data, unit is dBμV.

**Table 5.** Experimental Data List

| Measuring point | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.7 | 2.0 | 5.7 | 7.5 | 8.8 | 11.2 | 13.7 | - | - | - | - |
| 2 | 2.8 | 1.8 | 1.2 | 0.5 | 0.8 | 0.6 | 0.8 | 0.3 | 1.2 | 0.5 | 2.1 |
| mean value | 4.25 | 1.90 | 3.45 | 4.00 | 4.80 | 5.90 | 7.25 | 0.30 | 1.20 | 0.50 | 2.10 |

# 4 Data analysis and conclusion

## 4.1 Data analysis and results

From the experimental data it can be found that when the integrity of the GIS device is detected, the data of the entire tribe in the range of environmental noise, and the stability of the data measured by the close range probe is higher than that of the long distance probe, but the long distance probe is more suitable for large area and rapid test. In test 2, when a qualified GIS device is detected, most of the data is located in the range of environmental noise, a small number of parts in the external environment noise, and the error is very small; in the simulation of air leakage test, slight leakage can be detected obviously. Experiments show that when the leakage of GIS equipment is higher than that of the micro level, the air leakage can be detected by this method. In test 3, when the sound collector accepts the complete opposite noise, the data obtained completely have no law, and basically all outside the range of the ambient noise, the deviation is relatively large. The experimental results show that the same test point for multiple detection, the staff should keep the same direction of the sound collection device, in order to avoid the result of large data deviation.

## 4.1 Conclusion

Through the analysis, we can draw a conclusion, the leakage of GIS equipment can be well detected by acoustic emission technique when the air leakage is above medium;In the detection process, the direction of the probe should be kept consistent. This is a very important guiding significance for the operation of this method in the actual working conditions.

# References


1. Wu B T, Xiao D M, Yin Y. A New Optical Detection of SF6 Gas Leakage in GIS [J]. High Voltage Apparatus, 02:116-118, (2005).
2. Chen H K, Chen Y H, Cao K C. Research and Application for Portable SF6 Gas Leakage Detector [J]. Electric Power and Energy, 02:161-163+166, (2013).
3. Tian Y, YAN C S, SUN L S. On Locating and Check-up on the Leakage of SF6 Devices by the Technique of Laser Imaging [J]. Northeast Electric Power Technology, 12:35-37, (2005).
4. Zhang J, Zhang H. Research on Application of Negative Corona Discharge in SF6 Gas Leak Detection [J].Instrument Technique and Sensor. ,06:107-108(2010).
5. Yuan S Q,Dai Z,Chen F. Comparison of SF6 Leakage Detection Methods for High-Voltage Electrical Equipment. Southern Power Grid Technology, 02:54-58, (2013).
6. Lei F. The Detection of SF6 Gas Leakage Technology Using Laser Technology [J].Electric World, 08:11-13, (2012).
7. Gan D G.Study on the Method of SF6 Gas Leakage Leak Detection Technology Based on Infrared Imaging [J]. Electrical Applications, 30 (17): 56-58, (2011).
8. GARBER L, BONFIGLI G, MULLER S, et al. Improving SF6 Leakage Detection in Switchgear by Reducing the Influence of Solar Radiation on Density Measurement [C]//Conference Record

of the 2008 IEEE International Symposium on Electrical Insulation, June9-12,2008, Vancouver,BC,Canada:IEEE, (2008):441-444.

9. Gao S G, Zheng A Q, Geng J H, et al. Application of Laser Imaging Technology to Detect the Gas Leakage of SF6 Electrical Equipment [J]. High voltage electrical equipment, 46 (3): 103-105, (2010).
10. Jiang B L, Sun Ji Q, Xu L, et al. Ultraviolet Ionization Type SF6 Gas Leak Detector [J]. Modern Instruments, (4): 56-58, (2005).
11. Guo L M, Zhao H M, Lv Y P, et al.Design of Environment Online Intelligent Monitoring System on Leakage of SF6[J].Instrument Technique and Sensor,(8):76-78, (2011)
12. Zhou Z, Chen S Y, Gong S K, et al. Supervision and Fault Diagnosis for SF6 Electric Equipment[J].High Voltage Apparatus,47(2):104-107, (2011).
13. Wu Y Z. SF6 Gas Leak Detection Method and Alarm Technology [J]. Electrical engineering, , 04:19-20(2007).