

GIS particle impact source location

Chien-Yi Chen, Cheng-Chi Tai*, Ching-Chau Su, Ju-Chu Hsieh, Jiann-Fuh Chen

Department of Electrical Engineering, National Cheng Kung University

Abstract: This paper focuses on the artifact breaking-of-pencil-tips experiments in metal pipes to simulate particles impacts in gas insulation switchgear (GIS). The artifact acoustic signals are generated from the breaking of pencil tips. The signals are detected and measured by means of two acoustic emission (AE) sensors. According to the analysis, the AE signals include mainly two different frequencies. The velocities of sound waves with different frequencies differ from each other as the signals are delivered in the metal pipes. Since these two kinds of sound waves are produced at the same time as the breaking of pencil tips, we can calculate the acoustic wave velocities and amplitude attenuation of waves of different frequencies according to the arrival time of the sound waves. Also, we surely can locate the particle impact position from the transmission time and distance.

Keywords: particle impact; gas insulation switchgear (GIS); source location; acoustic emission (AE).

1. Introduction

GIS utilizes SF₆ gas as the insulation and seals the disconnecting switch, current breaker, potential transformer, current transformer, grounding switch in grounding metal cases. The advantages of GIS are as follows: being a certain kind indoor substation due to its demands for smaller space, having the longer maintenance period, keeping routine maintenance with ease, being suitable for all kinds of operating circumstances, being with no exposed electric conductor, systematic stability and safety [1, 2]. Because of the frequent operation and switching on/off the disconnecting switch in GIS, some dust and particles are generated. Under the influence of electric field effect inside the GIS, these particles will move up and down and even cause discharge. The spacer in GIS will worsen or the insulation worsening appears because the interval is affected by the particle impact or

discharge. With the particles impact on the pipe or the spacer inside the GIS, tip discharge may be occurred. The insufficiencies of air pressure in GIS and of insulation will also cause discharge.

Since the frequent operation and switching on the disconnecting switch usually appear in GIS, some dust and particles form and appear. As these particles are missed to be checked out, they will hit the spacer or the pipe in GIS under the influence of electric field effects. If the spacer is hit by the particles frequently, tips will form and cause tip discharge. In addition, the ingredient of the spacer is resin. It is also possible to cause discharge because of the insulation worsening after being used for a long time. The discharge inside GIS may endanger the whole power system. In order to keep the safe and steady operation of the electric power system, such kind of circum-

* Corresponding author; e-mail: cati666@gmail.com

Accepted for Publication: April 10, 2009

stances should be found in advance before the problems emerge. The condition of discharge inside GIS is complicated as the discharge may occur in the form of tip discharge or that caused by particle impact in GIS. Therefore, according to the styles and the positions of electricity, it would be helpful in keeping the maintenance of GIS.

2. Literature review

As for the ways to measure partial discharge of GIS, generally they are classified into two kinds: one is the electric method and the other is non-electric method [3]. The electric method, such as UHF and HFCT (High-frequency current transformer), could detect if there are PD events according to the change of electric signals. The UHF measurement method, its electromagnetic waves having frequencies are from 300 MHz to 3 GHz [4]. In general, the frequency of HFCT measurement is less than 20 MHz. Another kind of way to measure PD events is the non-electric method. One of the non-electric methods is AE measurement, which is able to measure the signals produced by PD in GIS. When particle impact occurs in GIS without the PD events, AE sensors could measure the signals of particle impact but the electric method fails to achieve it. In general, the frequency is less than 100 kHz [5, 6] as the PD events are measured by means of AE sensors. Since the AE method is utilized, the high frequency electromagnetic interference can be avoided [7]. The AE sensors applied in this research are VS30-V sensors, equipped with the low-frequency flat detector, with the frequency ranging from 20 to 80 kHz [8]. It will be able to show the condition of discharge or particle impact better than the general resonance detector. Since such facilities as current transformer, potential transformer, bus, con-

ductor, and switch are all sealed in GIS, the paths to deliver the signals of sound waves are very complicated in GIS when the PD or particle impacts occur [9]. So the sound waves deliver along the direction of GIS metal. The nearest distance from the origin of sound will be calculated according to the signals received directly.

3. Experiments

The metal pipes, which is with the length of 178 cm and the diameter of 23 cm and the thickness of 0.4 cm, are used with the breaking pencil tips to simulate particles impact in gas circuit breaker (GCB) and perform discharge experiments inside GCB. Due to the weight of the particles, they usually fall on the bottom part inside GIS. In this research we use two AE sensors which locate on the outer surface of the metal pipe to measure the signals. AE sensor1 is fixed at the position about 18 cm away from one end of the pipe spacer. AE sensor2 is located at the position about 6.5 cm away from another end of the pipe. The position of breaking the pencil tips keeps unchanged. The location of AE sensor2 is used as the start point and then AE sensor2 is moved 10 cm toward AE sensor1. Every time AE sensor2 is moved 10 cm, the simulation of particle impact will be done as it is moved. The circuit diagram of this research is shown as Figure 1.

The fixed location of breaking the pencil tips is inside of the pipe spacer, opposite to that of AE sensor1. AE sensor2 will detect the signals every time it moved 10 cm. The signals measured by AE sensor1 are shown in Figure 2. The signals measured by AE sensor2 at three different locations (50 cm, 100 cm, and 150 cm) are shown individually in Figures 3-4, and 5.

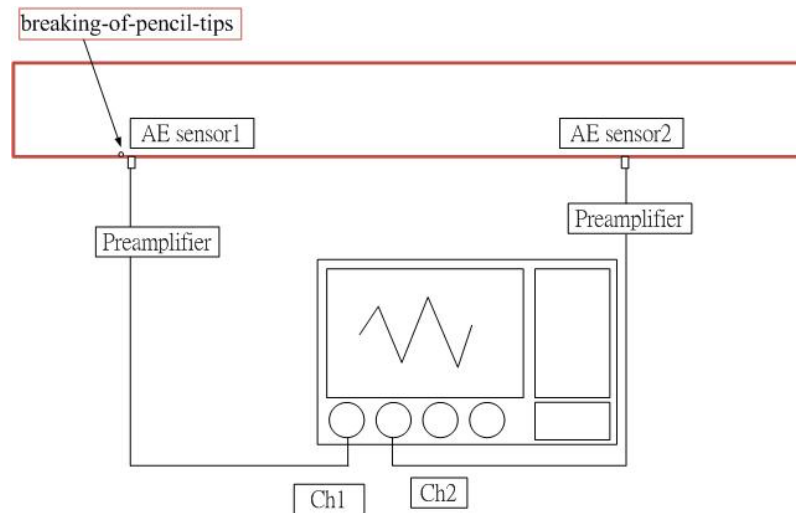


Figure 1. Measurement system.

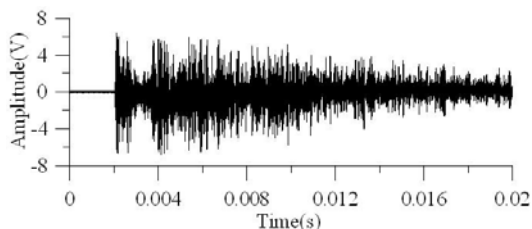


Figure 2. The signals measured by AE sensor1.

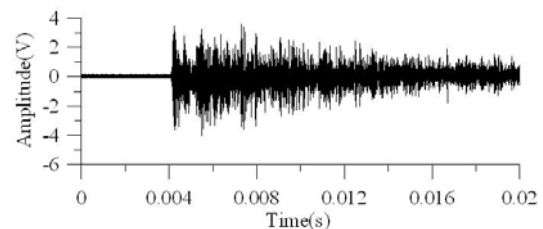


Figure 3. The signals measured by AE sensor2 at location 50 cm.

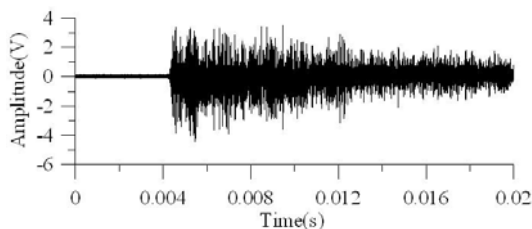


Figure 4. The signals measured by AE sensor2 at location 100 cm.

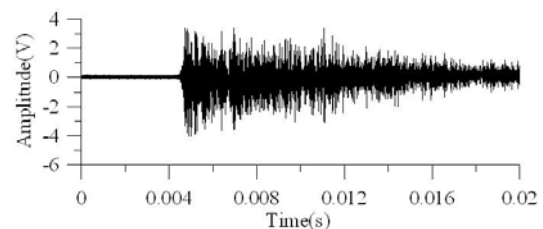


Figure 5. The signals measured by AE sensor2 at location 150 cm.

4. Signal analysis and source location

The wavelength of PD generated acoustic signals is much larger than the thickness of metal pipes. Thus it is mainly the lamb waves, which contain symmetric waves and anti-symmetric waves. The amplitude of anti-symmetric waves is smaller than that of symmetric waves. The first arriving signals are anti-symmetric waves. The waveforms of anti-symmetric waves detected are shown in Figure 6. As Figure 7 shows, the major frequency

of anti-symmetric waves, through the spectrum analysis, is about 115 kHz. The symmetric waves follow right after the anti-symmetric waves detected are shown in Figure 8. As Figure 9 shows, the major frequency of symmetric waves, through the spectrum analysis, is about 42 kHz.

Because sound waves process forward in the metal pipe spacer, there is acoustic resistance in metal. Therefore, as sound waves process from the point of breaking pencil tips to that of AE sensor2, the timing duration for deliv-

ering sound waves will be delayed and the amplitude attenuation will also appear. We can identify the position of sound origin from the timing delay and amplitude attenuation. Through the analysis of the spectrum, the signals of breaking pencil tips mainly contain different two major frequencies. The lower

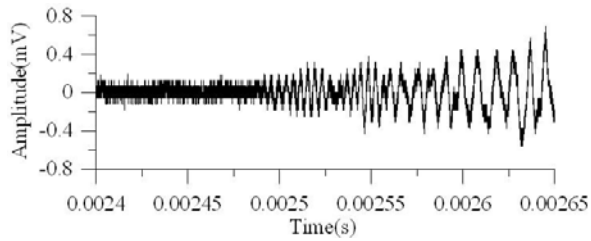


Figure 6. The waveforms of antisymmetric waves.

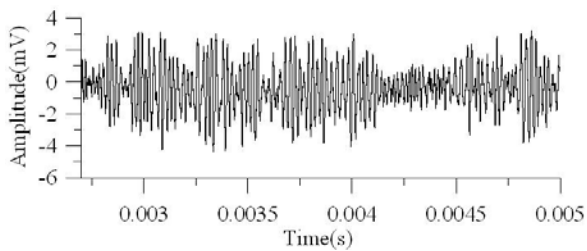


Figure 8. The waveforms of symmetric waves.

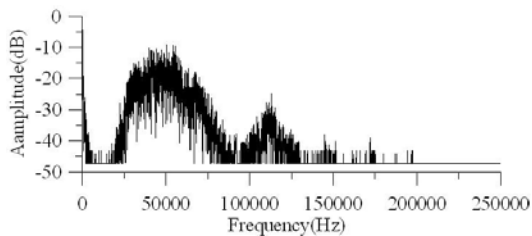


Figure 10. Spectrum analysis.

The velocity of sound waves in metal pipe is 2857 m/s. According to the sound origin produced by breaking pencil tips, the other sound waves are measured to process along the outer surface of the metal pipe process with faster speed, higher frequency, and shorter wavelength. The velocity of these sound waves is about 2123 m/s. From the different signals measured at different locations by the moving AE sensor2, we compared with the differ-

ences of arrival timing between these two sets of signals with different major frequencies. Then we get two different D-T curves of different frequencies, as Figure 12 shows. From Figure 11 it is concluded that the speeds of these sound waves differ, too. The timing that detected by AE sensors is also different. Figure 13 shows the timing for the signals detected under the frequency of 50 kHz. The velocity is referred as 2123 m/s.

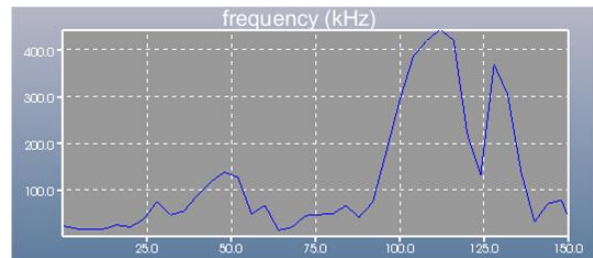


Figure 7. Spectrum analysis.

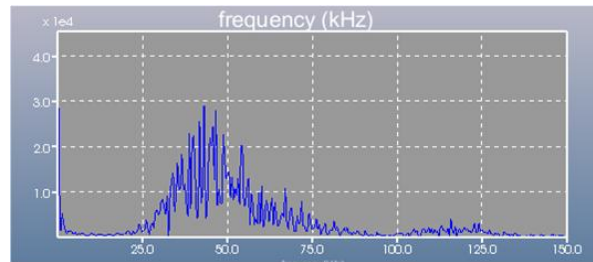


Figure 9. Spectrum analysis.

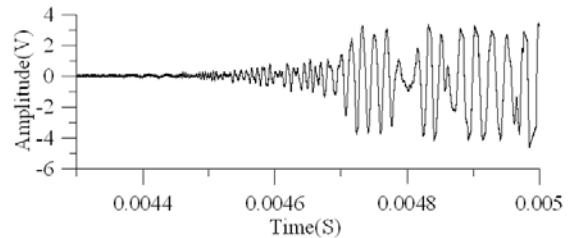


Figure 11. The signals of high frequency.

Figure 14 shows the timing for the signals detected under the frequency of 115 kHz. When with the timing differences and distances, the velocity of sound waves in metal pipe is 2857 m/s. D_a is referred as the distance from the sound origin to AE sensor1 or AE sensor2.

$$D_a = \frac{T_a}{(T_b - T_a)} D_b \quad (1)$$

where T_a is the timing difference between two sets of signals frequencies for AE sensor1, T_b is the timing difference between two sets of signals frequencies for AE sensor2, D_b is the distance between AE sensor 1 and AE sensor2, respectively. If the velocity of sound waves in metal pipe is smaller 2857 m/s. D_c is referred as the distance from the sound origin to AE sensor 1 or AE sensor 2.

$$D_c = D_b - D_a \quad (2)$$

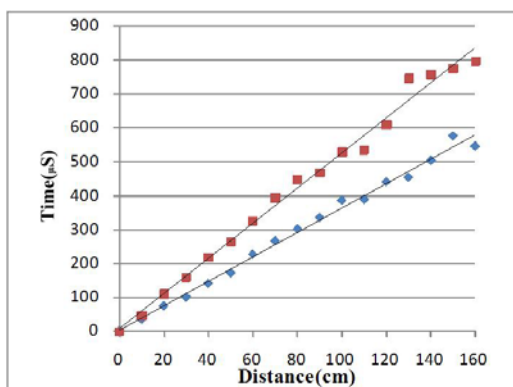


Figure 12. Distance vs. time curves of different frequencies.

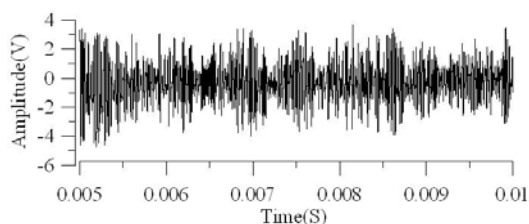


Figure 13. The signals of lower frequency

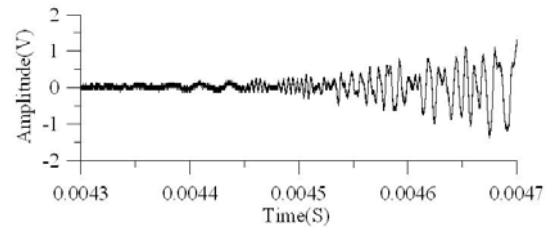


Figure 14. The signals of high frequency.

5. Results and discussion

The thickness of metal pipes is much smaller than the ultrasound wavelength. In general, it is almost impossible to fail to detect the longitudinal waves and the transverse waves. It is mainly the lamb waves that are detected by the sensors. If all the metal pipes are made up of the same material, the major frequencies of symmetric waves and antisymmetric waves in lamb waves keep steady with the slightest change. However, if the metal pipes are made up of various kinds of materials, the major frequency of ultrasound will surely change.

As AE sensor2 moves close to the location of breaking pencil tips, these signals detected by AE form a triangle. At the beginning the signals are strong and then drag long and become weaker and weaker. As AE sensor moves away from the location of breaking pencil tips, a set of sound waves with smaller amplitude and higher frequency is detected at the heading of the signals measured by AE sensor. Therefore, as AE sensor moves away from the location of breaking pencil tips, the heading signals with high frequency become more obvious. Since there's less acoustic resistance against sound waves in metal, the sound waves are able to process farther. There are many paths for sound waves to deliver from the sound origin to AE sensors, though. Even after the decline of sound waves through all paths, as long as their amplitudes of vibration are stronger than the white noises, these signals still can be seen. Thus the sets of signals drag long.

Because there is a wide range in AE frequencies caused by breaking the pencil tips, the velocities of sound waves also differ while processing along the metal pipe spacer since these sound waves are of different frequencies. Those of higher frequencies process faster. For the reason that we use the same AE sensors and amplifiers, in this research we can precisely calculate the locations of breaking pencil tips. The signals that we detect mainly contain different two major frequencies. The lower major frequency is about 50 kHz. And the higher major frequency is about 115 kHz.

In addition, as the velocity of sound waves and the timing curved line are both presented in simple equations and the location of sound origin is exactly the same one, we can figure out the location of sound waves is right on the intersect of these two different d-t curved lines.

6. Acknowledgements

This research was supported by the grant from National Science Council, Taiwan, ROC (NSC 95-2221-E-006-484). Also, this work made use of Shared Facilities supported by the Program of Top 100 Universities Advancement, Ministry of Education, Taiwan.

References

- [1] Sarathi, R., Dubey, V., and Sriivasat, Y. G. 2005. Identification of Incipient Discharges in Gas Insulated System using Acoustic Emission Technique, *Annual Report Conference on Electrical Insulation and Dielectric Phenomena*, Nashville, Tennessee, U. S. A: 91-94.
- [2] Sarathi, R., Dubey, V., and Srinivasa, Y. G. 2006. Partial Discharge Activity in Gas-insulated System Under Composite Voltage, *IEEE Transactions on Power Delivery*, 21, 1: 499-500.
- [3] Chen, L. J., Tsao, T. P., and Lin, Y.H. 2005. New Diagnosis Approach to Epoxy Resin Transformer Partial Discharge Using Acoustic Technology, *IEEE Transactions on Power Delivery*, 20, 4: 2501-2508.
- [4] Kurrer, R., Feser, K. 1998. The application of ultra-high-frequency partial discharge measurements to gas-insulated substations, *IEEE Transactions on Power Delivery*, 13, 3: 777-782.
- [5] Haque, E. Md., Darus, A. B., Yaacob, M. M., and Ahmed, F., 1997. Application of Acoustic Sensing and Signal Processing for PD Detection in GIS, *International Conference on Information, Communications and Signal Processing*, Singapore, 745-749.
- [6] Phil, S. Y., Fisher, C., and Eltom, A. H., 2002. The diagnostic analysis of partial discharge with acoustic monitoring in GIS equipment, *Presented at the IEEE Power Engineering Society Summer Meeting*, Chicago, U. S. A: 196-200.
- [7] Haque, E. Md., Darus, A. B., Yaacob, M. M., and Ahmed Feroz. 1997. Diagnosis of GIS Based on Acoustic Sensing Technique, *APSCOM-97 Proceedings of the 4th International Conference on Advances in Power System Control, Operation and Management*, Hong Kong, 556-558.
- [8] Vallen-systeme gmbh. 2000. "Acoustic Emissions sensor frequency responses", Lcking, Munich, Germany.
- [9] Hampton, B. F. 1993. Diagnostics for Gas insulated substations, *IEE 2nd International Conference on Advances in Power System Control, Operation and Management*, Hong Kong, 17-23.