The Image Study of Partial Discharge Location by Acoustic Measurement

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***Abstract*—In this paper, we introduced a new type of partial discharge on-line monitoring by ultrasonic visualization system, which is based on ultrasonic diffusing technology. The system uses ultrasonic positioning and image processing method to achieve the partial discharge ultrasonic position visualization. System uses the array type of ultrasonic sensor and a corresponding signal processing device of ultrasonic signal, processes the synchronization acquisition signals of 32 calculation ultrasonic sensor, gets the partial discharge power plane coordinates, establish a mapping relationship between image coordinate data of partial discharge and the actual equipment through image processing technique and finally achieves the visualization of partial discharge intensity and location. The system can intuitively show the discharge location in the image and its status in the development and changes, timely find power equipment's failure and has extensive application value.**

Keywords—Partial discharge; Acoustic measurement; Image composition;

I. INTRODUCTION

PD(Partial Discharge) is one of the major causes of power equipment insulation degradation/aging. It will accelerate aging of power insulation system and affect the service life of the equipment when the system is under partial discharge for a long time. Therefore, it is necessary to detect the partial discharge problems on power electrical equipment [1]. As an important content of partial discharge detection, partial discharge positioning and judgement of fault type for electric power fault directly determines the effect and efficiency of equipment insulation diagnosis. In order to achieve effective positioning of partial discharge detection, there is a new diagnosis method coming out in recent years which is based on ultra-high frequency localization by electromagnetic wave, ultrasonic localization by acoustic signal and acoustic positioning [2-6].

Ultrasonic localization method also uses the difference between the duration of the spreading of ultrasonic wave to each sensor to calculate the address the source of the ultrasonic [7-10]. Using UHF sensor to a positioning analysis of GIS is the basic idea of acoustoelectric combined positioning method, which scopes the insulation defects roughly at the first time and then at the same time uses UHF sensor and ultrasonic sensor to secondary positioning analysis. Finally, it realizes the accurate positioning of insulation defect.

However, the application of both ultrasonic positioning and UHF positioning are relatively narrow range and lack of intuition. They all achieve positioning by measuring the time difference of the signal and require a higher ability of stuffs, which makes it difficult to achieve fast direct evaluation and localization of partial discharge for a lot of power equipment. From medical ultrasound imaging detection technology in the application, this paper puts forward a new kind of visualization of partial discharge detection technology and systems with the sensor design and image information processing method. This paper describes the design method of the ultrasonic sensor array and then the signal pre-processing methods and system building are analyzed and finally to artificial corona type defect as a local power supply test verification of the ultrasonic visualization detection system.

II. ULTRASONIC VISUALIZATION OF PARTIAL DISCHARGE TECHNOLOGY

A. Partial discharge rectangular ultrasonic sensor array

Ultrasonic wave refers to more than 20 kHz frequency sound wave which it has a good directivity, strong penetrating power and easy to obtain the characteristics of relatively concentrated sound energy. Therefore, applying ultrasound to partial discharge detection has a lot of advantages such as the bigger detection distance, which is more adapt to the requirement of engineering application of on-line monitoring device.

At present, ultrasonic testing technology mainly adopts two methods including single channel testing and multi-channel testing technology. Single channel testing technology is mainly used in distance measurement and the ultrasonic signal strength measurement. Multi-channel technology can make use of multiple sensors' signal to analyze the delay of each ultrasonic signal source to make localization. Therefore, it is mainly used in ultrasonic positioning. This article uses the multi-channel technology of ultrasonic testing. In this paper, we use 32 SPU0410LR5H-QB sensors of piezoelectric ultrasonic array and ultrasonic sensor frequency response curve is shown in figure 1.

32 SPU0410LR5H-QB ultrasonic sensors used in this article have a frequency response range between 10kHz~40kHz, which is near the peak frequency of a ultrasonic partial discharge signal. Therefore, we can collect the complete ultrasonic signals generated by partial discharge.

Ultrasonic arrays mentioned in last paragraph are built by multiple piezoelectric sensors in order and the array element spacing for ultrasonic signal frequency corresponds to the half

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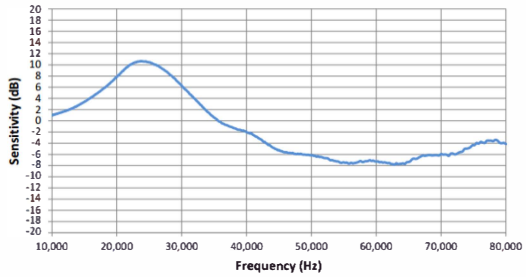


Fig.1. The frequency response curve of ultrasonic sensor

wave [11-15]. Partial discharge detection of ultrasonic sensor array has good positioning effect, small volume, manufacturing easy and high measurement accuracy. Ultrasonic array used for localization of partial discharge detection includes plane square array, circle array, L array and cross array, etc. This paper combined the advantages of each kind of sensor arrays. As shown in figure 2, this array structure is established. The new array can greatly increase the signal analysis, so as to facilitate the late on the positioning calculation by the software. In addition, it can also avoid the malfunction or the shortcoming of inaccurate measurement signal from single-channel sensor array by using rectangular sensor.

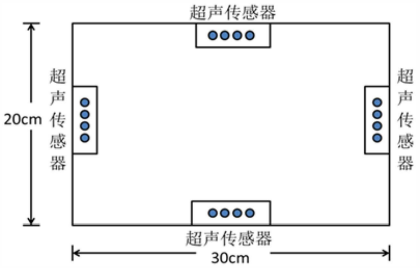


Fig.2. Ultrasonic sensor array

B. Image synthesis of partial discharge of ultrasonic signal

In this paper, image synthesis needs a computer to calculate the signal delay and the geometric relationships of every ultrasonic sensors in order to get the specific coordinates of partial discharge in the space [16-17]. By using the image processing technology and combined it with visible image from the camera, we could transmit them in the form of video streaming transmission to the computer. We could also superimposed them together under the computer processing and adjust the transparency to achieve in a visible image calibration with mist markers of partial discharge location.

III. ULTRASONIC IMAGING SYSTEM

The ultrasonic imaging system designed by this paper can be divided into a number of different function modules. The system operation process can be summarized as: First, the system collects plane rectangular array configuration of 32 ultrasonic sensor signal acquisition; Secondly, the amplifying signal acquisition and preprocessing filter device; Thirdly, AD card and computer connection with specific software; Lastly, the image synthesis of 32 ultrasonic sensor signal processing and logitech C270 high-definition camera. The structure of ultrasonic imaging system module diagram is shown in figure 3 below.

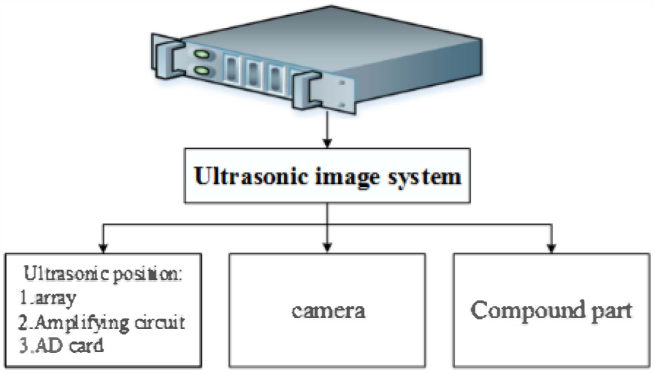


Fig. 3 Ultrasonic imaging system schematic diagram

Ultrasonic positioning module is composed of three parts: ultrasonic sensor matrix, amplification filter circuit and AD card. Ultrasonic sensor array used a new 32 channel matrix structure as shown in figure 2. The type of single channel sensor model is SPU0410LR5H-QB. The amplifier circuit is a two-stage AD620 discharge filter module and each level uses negative feedback amplifier circuit with magnification of 20dB. Adopting the capacitance between two levels of DC component, cascade amplifier gain can be achieved after 40dB. The op-amp chip has a high precision, low power consumption, low noise, high input resistance, high common mode rejection ratio, simple to use, etc. AD collection module uses data acquisition card signal sampling frequency for each channel 100kHz and channel number is 32. System adopts RBH8362 type USB data acquisition card and the type of data acquisition card supports 32 channels parallel sampling. Each channel sampling rate is 200 kHz and 16 bit sampling precision.

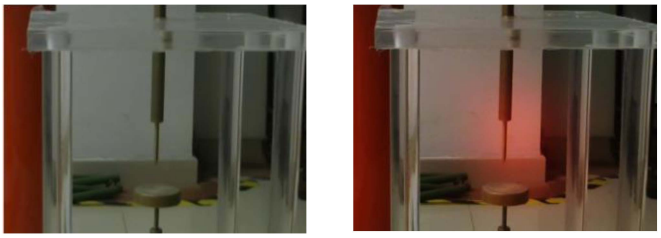
In ultrasonic visualization synthesis module, we make the application of computer internal software to process the signal of transmission video with coding data as a background, 32 ultrasonic sensor acquisition signal as data analysis. Finally, we obtain the position of the density of the partial discharge signals coordinates and the mist with red mark in the background of video, so as to realize the accurate location of partial discharge.

IV. TESR RESULT AND DISCUSSION

In order to test and calibrate partial discharge ultrasonic sensor unit, this paper uses the pulse current method based on IEC60270 standard. The experimental equipment include an tank(experiment tank make of 1cr18ni9ti stainless steel material) as well as the open wide tank. Take partial discharge in the air for ultrasonic signal source, needle-plate electrode in different distance for different partial discharge signals. The final test results under different voltage and distance are show in the data and figure below.

Ultrasonic orientation imaging laboratory is shown in figure4. In this paper, the experimental model of electrode is under high electrical voltage. Therefore, the test system should keep a safe distance from with partial discharge model. This paper design test distance starting from 1.2m. Some relationship between different electrical parameters are studied respectively by ultrasonic positioning system such as: the partial discharge quantity(Q), measurable maximum distance

(d), the strength of ultrasonic signal made by partial discharge(dB) and magnitude of applied voltage(kV), etc.



(a) (b)

Fig.4. Orientation imaging results

During experiments, all the partial discharges are made by the needle-plate model. The needle-plate distance is controlled in 20mm~30mm. Partial discharge experiments were respectively moved under the environment of inside tank and outside tank in order to get the contrast test between the influence of tank environment. Under different voltage, inside tank and outside tank needle-plate distance of 20mm and 30mm results are respectively shown in figure5, and 6.

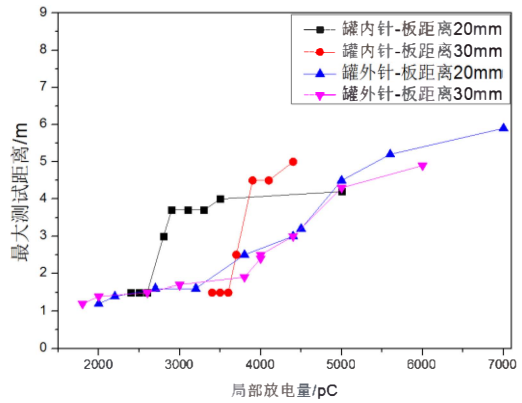


Fig.5. The relationship between discharge quantity and test distance

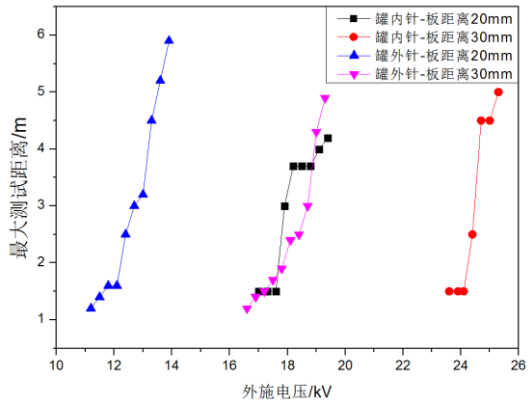


Fig.6. The relationship between the applied voltage and test distance

The test results in figure5 shows that this system in the tank, the maximum detectable range increases with the increase of partial discharge in the discharge. In the initial stages of partial discharge, the system response is relatively limited distance. When the partial discharge gets more severe as the voltage rising, the system can detect maximum distance. During the corona stabilization to breakdown, the maximum measurable distance increases with partial discharge slowly. As corona occurs outside the tank, the system of the maximum detectable range along with the severity of partial discharge is linear upward trend. The results is related to the corona discharge of ultrasonic signal radiation mode and the system response threshold.

According to the test results in figure 6, applied voltage and maximum test range have a nearly linear relationship. Inside the tank, there is still a linear relationship of applied voltage and maximum test range from the corona stabilization to breakdown while in the middle of a small section, the maximum test distance stays stable.

We statistic analyze the minimum ultrasonic signal strength of partial discharge that ultrasonic positioning system can response. The sensitivity of the results are shown in figure7. The figure shows that system can response above 24dB intensity ultrasonic signals of partial discharge.

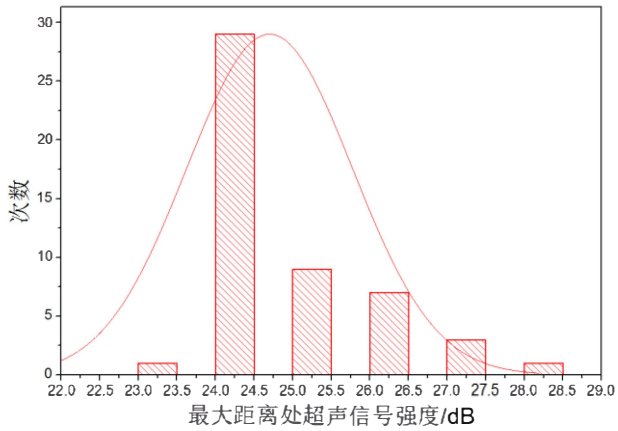


Fig.7. The statistics of the ultrasonic signal intensity at the largest distance

V. CONCLUSION

This paper put forward and designed a new kind of visualization detection of partial discharge device. In the paper, we explained how to constitute sensors array. The system of signal processing method and visual realization method are studied. Finally, we can distinguish artificial corona type defect and achieve the ultrasonic visualization testing system for the test. The ultrasonic localization of partial discharge matrix was achieved in this paper and has high resolution in partial discharge signals; Through image fusion image registration techniques, we can achieve the purpose of the positioning accuracy of partial discharge detection and visualization; The system can also reflect intensity of partial discharge; In addition, the ultrasonic imaging system designed in this paper has the advantages of high positioning accuracy, short response time, small volume and easy to carry, etc.

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