Research on the application of phased array detection in Power transmission and transformation metal equipment

Liming Xiea, Yanfei Zhang, Tao Zhang, Xuechao Zhang, Lei Lv
Inner Mongolia Power Research Institute Hohhot, Inner Mongolia
*a#xieliming@impd.com.cn
489296683@qq.com

Abstract—This paper analyzes and compares the characteristics of conventional nondestructive testing method and ultrasonic phased array testing method, and introduces several ultrasonic phased array testing methods of power grid equipment. Ultrasonic phased array technology is a high-efficiency, intuitive and reliable new nondestructive testing technology. It is of great significance to apply ultrasonic phased array technology to the nondestructive testing of power industry equipment and explore the adaptability of its testing technology to ensure the reliable operation of equipment and the security of power grid.

1. INTRODUCTION
With the sustainable development of economy and society, electric power industry, as a relatively intensive industry in equipment, technology, capital and other aspects, has also achieved rapid development. With the continuous popularization and expansion of China's power grid, a large number of high parameter, large capacity and complex structure equipment are used in power transmission and transformation projects. The reliability of these equipment is directly related to the safe and stable operation of the power grid. Power transmission and transformation equipment in power grid often has the characteristics of complex structure, difficult to disassemble and short maintenance period, which brings difficulties to the detection of equipment defects. Therefore, it is very important to explore a reliable and efficient new non-destructive detection method to ensure the safe and stable operation of power grid equipment.

Ultrasonic phased array technology has many advantages, such as multi angle scanning, variable focusing mode, and intuitive A-scan, C-scan and fan scan imaging forms. It can effectively detect various surface and volume defects in welded joints. The test results are displayed in the form of images, which provide rich information for defect location, quantitative and qualitative rating. It is a new recordable NDT method. Ultrasonic phased array testing technology has the advantages that traditional ultrasound can't compare. According to the inspected workpiece, the reasonable and effective testing technology can greatly improve the detection efficiency and defect detection rate. Because of its unique advantages, ultrasonic phased array detection technology has been widely used in many industries. At the same time, the research depth of this technology is deepening and the research scope is expanding. Ultrasonic phased array technology has the following technical characteristics: the incidence angle, focal length position,
focus size and position are continuously and dynamically adjustable within a certain range. At the same time, the probe beam of the detection method can be controlled by software to achieve rapid translation. With the above advantages, ultrasonic phased array can realize the detection of many complex structure welds.

Compared with the ordinary pulse ultrasonic technology, phased array ultrasonic technology has obvious advantages.

1) It can control the synthesis, deflection and focusing of the ultrasonic beam, and solve the problem of poor accessibility of the ultrasonic beam in the detection of the workpiece in the confined space and complex structure.

2) The focus depth, focus mode, focus size and direction of the beam are controlled and optimized by software. So then to improve the resolution, sensitivity and Signal to Noise Ratio.

3) The quantitative and qualitative detection of defects is more accurate than that of ordinary pulse ultrasonic detection.

4) The probe used in ultrasonic phased array technology is not a single probe, but an array chip, which is equivalent to scanning multiple probes at the same time. The size of the probe is small, and it can realize multi angle scanning.

5) The graphical display interface can display the test results in the form of A, B, C, S scanning, and use special software to analyze the test data.

2. INSPECTION AND EVALUATION OF WELDING OF GIS TANK

The GIS fully enclosed switchgear is an important equipment of substation, which is composed of breaker, disconnector and other high-voltage electrical appliances. One of the important factors affecting the operation of GIS is the leakage of SF6 gas. If the welding quality of GIS tank butt weld is unqualified, the tank cracking will cause SF6 gas leakage, which will not only affect the reliable operation of GIS and even the power system, but also cause environmental pollution and endanger the health and life safety of the staff. With the continuous improvement of the voltage level of the substation, the thickness of GIS aluminum alloy tank is also increasing. For thickness aluminum alloy, the welding quality problem is more serious. Therefore, it is of great significance to inspect the welding quality and evaluate the safety of GIS tank butt weld.

GIS tank body is generally made of 5083 aluminum plate and rolled plate by butt welding. There are several hand holes on the tank body, and the head of hand hole is connected with the cylinder body by fillet weld. The general welding methods are MIG (inert gas welding), TIG (tungsten inert gas welding) or MIG + TIG. Due to the large thermal conductivity of aluminum and the large thickness of the cylinder, a large amount of heat energy is transmitted rapidly during the welding process, which is easy to form non fusion defects on the groove side of the tank weld. When the root of the weld is not cleaned or the root gap setting is unreasonable, it is easy to form root incomplete penetration defects. Due to the unique physical and chemical properties of aluminum alloy, the weld of thickness aluminum alloy tank may also have defects such as porosity and hot crack. Before leaving the factory, GIS tank welds are mainly subject to X-ray inspection. After the equipment is in service, it is difficult to disassemble the GIS, so it is impossible to carry out ray detection. Ultrasonic phased array provides the possibility for in-service NDT of this kind of equipment.
Ultrasonic phased array inspection was carried out on the girth weld of GIS equipment tank in a 110kV substation. The detector adopts dopoule PHASCAN phased array detector, the probe adopts dopoule 10S16-0.5×10 chip self focusing linear array phased array probe, and the wedge adopts dopoule SD10-N60S-IH wedge. Before the detection, the aluminum alloy standard test block was used to calibrate the instrument sound speed, delay, probe front and system sensitivity. Through the detection of GIS longitudinal and circumferential weld artificial defect simulation test block, the GIS weld phased array detection process was developed. The wall thickness of the GIS tank is 8mm and the weld reinforcement is 2mm. In order to eliminate the influence of weld reinforcement on ultrasonic multiple reflection, according to the actual echo, the wall thickness correction is set to 8.2mm. According to the weld design drawing, the groove form is V-shaped, the weld width is 12mm, the blunt edge height is 2mm, and the groove angle is 35°. The weld model is established in the instrument, and the function of "weld diagram" is enabled. The butt girth weld of aluminum alloy tank body was scanned and inspected by Sector covering of 40°-70°. Through inspection, it is found that the whole circle of the weld is incomplete. We can see the defect waveform display from Figure 1. It can be seen that the real-time and intuitive ultrasonic phased array detection technology provides a reliable means for in-service GIS tank weld nondestructive testing.

3. INSPECTION AND EVALUATION OF TUBE BUS WELD

Tube bus is one of the important equipment in the power transmission and transformation system, which is mainly used in the conductor connection between the transmission line and the transformer, the conductor in the transmission line and the connecting conductor in the power equipment. The tube bus is generally made of pure aluminum or aluminum alloy, and TIG (inert gas welding) and MIG (melt inert gas welding) are mostly used for welding. The tube bus is generally made of pure aluminum or aluminum alloy, and TIG (inert gas welding) and MIG (melt inert gas welding) are mostly used for welding. Welding method and quality inspection shall be in accordance with DL / T 754-2013. Ultrasonic phased array detection technology can replace the traditional ray detection, making the detection work more efficient and environmental protection.
A 220kV power transmission and transformation project of a substation is made of 6063 material, with specification of Ф250 / 230mm. Ultrasonic phased array testing was carried out on the bus. The detector adopts dopoule PHASCAN phased array detector, the probe adopts dopoule 10S16-0.5×10 chip self focusing linear array phased array probe, and the wedge adopts dopoule SD10-N60S-IH wedge. The thickness of the tube bus bottom is 10 mm, and the weld reinforcement is 4 mm. Due to the influence of weld reinforcement on ultrasonic multiple reflection, the plate thickness correction is set to 10.4mm according to the actual echo in the instrument. And set the weld size, open the "weld diagram" function. Through ultrasonic phased array inspection, it is found that the weld has lack of penetration defect, with a length of 1/2 circle. See Figure 2 for the detection process. Dissect and destroy the bus bar of the pipe, and the internal weld appearance is shown in Figure 2. It can be seen that the root of the weld is not fully penetrated. See Figure 2-3 for defect waveform display. According to the requirements of the procedure, the quality of the weld is evaluated as IV, unqualified.

4. DETECTION AND EVALUATION OF GIS LINEAR CONDUCTOR
GIS high-voltage linear conductor is an important equipment of substation. In recent years, there have been many failures caused by weld cracking in power grid companies. The structure of welding seam of GIS high voltage linear conductor is complex, and the thickness of welding is thin. See Figure 3. When conventional ultrasonic testing is used, the echo at the thread, the echo at the edge of the weld and the defect wave appear at the same time, which is difficult to distinguish. It will have serious interference and influence on the determination of the test results, making the defect difficult to detect or the defect echo difficult to distinguish. Due to the long length of the workpiece, which is often outdoors, the radiographic testing can not be effectively protected, and the testing is extremely inconvenient.
By analyzing the structure of this kind of equipment, when the ultrasonic phased array method is used for detection, the phased array probe can be installed reversely to realize the girth weld detection from the side of the payment table, as shown in Figure 3. In the ultrasonic phased array inspection of GIS high-voltage linear conductor welds, due to the serious diffusion of the circular tube acoustic beam, the special curvature wedge is customized by the wafer self focusing phased array probe, which can effectively detect the GIS linear conductor welds. See Figure 3 for the detection method.

5. CONCLUSIONS
The aluminum equipment clamp of power grid is an important hardware for connecting wires and electrical equipment, which is composed of fastening wires and connecting electrical equipment. The former is a tube structure, and the latter is a terminal board structure. The forming method of aluminum equipment clamp is usually welding or integral casting. The connection between tube structure and terminal board is a weak link. If there are defects, it is easy to expand until failure in the operation process, and then endanger the safety of power grid equipment.

There are many irregular arc surfaces in the aluminum clamp of power grid, which can not be detected by conventional ultrasonic probe and phased array probe. The array chip of the flexible phased array probe can bend arbitrarily and change the curvature with the shape of the workpiece surface. The thickness of the probe is only 3mm, and it can enter the narrow area with limited detection space for detection, which provides a new method for non-destructive detection of aluminum clamp in power grid. See Figure 4.

![Figure 4. Phased array detection of aluminum clamp in power grid](image)

6. CONCLUSIONS
As a new, efficient, intuitive and reliable nondestructive testing technology, ultrasonic phased array technology has incomparable advantages over other nondestructive testing methods. Its successful application in the supervision and inspection of GIS welding line, large-diameter aluminum tube bus, GIS linear conductor and aluminum clamp and other power transmission and transformation equipment has great significance for improving the level of technical supervision and ensuring the safe and stable operation of power transmission and transformation equipment. Although ultrasonic phased array testing technology has many advantages, but in practical application, there are still many problems to be solved urgently in the detection of power transmission and transformation equipment due to the limitations of the complex structure of the inspected workpiece, the imperfect standard and the difficulty of the analysis and quality evaluation of the detection results. With the progress of phased array technology and the deepening of the research in the detection of equipment and substation, phased array detection technology will be more widely used.
ACKNOWLEDGMENT
I really thank the help and encouragement from my colleagues in my laboratory, thank you for my family’s encouragement, and appreciate Inner Mongolia Electric Power Research Institute for supporting my project fund. (Research on Key Technologies of turbine blade inspection based on phased array technology, 510241190010).

REFERENCES
[1] Liu, X.R, “Study on the detection and evaluation method of ultrasonic phased array technology”, Nanchang University of Aeronautics press. vol.1, 2012, pp.4-13.
[2] C.Z.Q, C.B.F, X.F. “Application of ultrasonic phased array in circumferential welding of linear conductor”, Yunnan electric power, vol.6, 2016, pp.25.
[3] L.Y, “Comparison between conventional method and phased array method”, Nondestructive flaw detection, vol.39(5), 2015, pp.1-4.
[4] L.C.X, Yi.H, J.R, “Current situation and development trend of metal technology supervision in power grid”, Hunan electric power, vol.3, 2016, pp.39-42.
[5] W.M, D.H, “Application of ultrasonic phased array technology in nondestructive testing of power industry”, Guangdong electric power, vol.12, 2009, pp.50-52.