Study on the method of measuring direction and positioning with the sparse linear array sensor on the Partial discharge（PD）source

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Abstract. We propose a method based on MUSIC and Chaotic Monkey algorithm for measuring direction and positioning with the sparse linear array sensor on the discharge source. First, we de-noise and focus on the linear array signals. Then, we get the angle of the incoming signal by MUSIC algorithm. Finally, we find PD source localization by ultrasonic array Chaotic Monkey algorithm. At last, the results from some experiments show that the errors are about 3.5cm, which indicates that this estimation method is with a good accuracy.

1. Introduction

Ultrasonic array partial charge location method is a new method for detecting partial discharge. [1-4] Its basic principle is to use ultrasonic sensor array signal gathering electric equipment partial discharge, and then be processed by the method of estimation array signal processing theory DOA give partial charge location source of azimuth and elevation information. This method has a flexible beam control, a higher signal gain, strong interference rejection capability and high spatial resolution and so on. Currently, the electricity has been researchers.

Sparse linear array ultrasound transducer PD source is detected, the sensor array developed can save costs and improve its economy. Due to engineering practice, it will inevitably encounter some situations picket array sensor fails. Therefore, it is necessary to study the sparse linear array transducer.

This paper studies the partial discharge ultrasonic detection sparse linear array transducer. First, we de-noise and focus on the linear array signals. Then, we get the angle of the incoming signal by MUSIC algorithm. Finally, we find PD source localization by ultrasonic array Chaotic Monkey algorithm. The correctness of the method is verified through experimental study.

2. Linear ultrasonic array signal direction finding method based on MUSIC algorithm

After de-noising and focusing on the linear array signals, the direction finding method is used to estimate the direction of the linear array:

1) By $\tilde{X}(t)$ of the line 1~K and line K+1~M to construct the subspace matrix:

$$R_Z = E[\tilde{X}_d(t)\,\tilde{X}_u^H(t)]$$

In the formula：$\tilde{X}_u(t)$ matrix is composed of in line 1~K; $\tilde{X}_d(t)$ matrix is composed of in line K+1~M.

2) Column vector standard orthogonal subspace matrixR_z, get the U_1 matrix.

3) Based on the column vector matrix U_1 structure spectral peak function:

$$P(\theta) = 1/[a_k^H(1-U_1U_1^H)a_k$$

Genetic algorithm is used to search spectrum peak on the function, can obtain the azimuth estimation angle θ, in which a_k is $\tilde{X}(t)$ column vector array manifold before K elements.

3. PD ultrasonic array positioning principle based on Chaotic Monkey algorithm.

3.1 Multi-platform PD Lateral positioning principle.

The principle of Lateral positioning is shown in Figure 1（Take the three platform as an example） The coordinates of the 3 groups of array sensors are $A(x_1, y_1, z_1)$、$B(x_2, y_2, z_2)$、$C(x_3, y_3, z_3)$。The orientation angle and pitch angle of the array sensor can be obtained by the lateral algorithm .Based on the direction finding and the position of the array sensor, the equation of the line in the direction finding lineS1is determined.

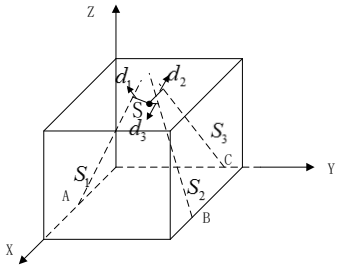

Figure 1

Direction vector S is$\vec{S}_t(m_1, n_1, p_1)$, suppose the electrical equipment partial discharge location is$S(x, y, z)$.For different positions DOA straight lines without any error situations that intersect at PD source$S(x, y, z)$. However, due to experimental research and engineering measurements error influence, the n lines is iso-surfaces , You can get straight to the PD source finding pieces of line where the minimum distance and functions: $d = \sum_{t=1}^{3} d_t = d_1 + d_2 + d_3$ .Then we search for global optimization in the condition of boundary space .Looking for a point $S'(x', y', z')$makes the space of a point to the direction of the distance is minimum .And this point is the local source space coordinates.

3.2Introduction to Chaotic Monkey Algorithm Theory

Chaotic Monkey algorithm is used to solve the problem of low efficiency of traditional genetic algorithm. It is a new global optimization algorithm, which is especially suitable for multi variable and multi valued functions. Chaotic is a kind of behavior of nonlinear dynamical systems, and there is a very complicated attractor in nonlinear dynamical systems. Therefore, the combination of chaos search method and monkey algorithm, will greatly improve the search speed and accuracy of the monkey algorithm, which can effectively prevent the convergence to local optimal solution.

4. Experimental study

In order to further verify the correctness of the method proposed in this paper, we set up a bureau in the laboratory to test the Partial discharge detection system, including the Nine element linear sparse ultrasonic array sensor, fuel tank model, needle plate discharge model, multi-channel synchronous data acquisition system and computer, etc.。

During the experiment, the SNR is at about 10dB, the sampling data length is 8000, the signal amplification is 256 times, the sampling frequency is 10MHz, the filtering range is 60~300kHz. Then we put the discharge model in (40 cm, 80 cm, 50 cm) position, the partial discharge ultrasonic sensor array is respectively coupled on the outer wall of the tank: Position1 (50 cm, 0 cm, 0 cm), Position2 (0 cm, 50 cm, 0cm), Position3 (0 cm, 100 cm 0, cm). During the experiment, the voltage is gradually increased until the pin plate model has a stable discharge signal, the waveform of the ultrasonic array signal is shown in Figure 2.

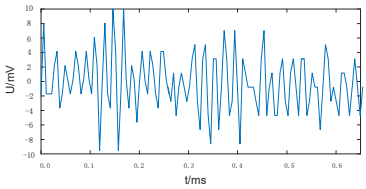

Figure 2

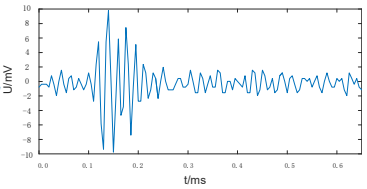

Figure3

Using the method mentioned in this paper to process the signal we get the waveform as shown in Figure 3, get the azimuth angle and pitching angle of 3 positions respectively (99.5°，33.7°) 、(51.0°，47.5°) 、(119.2°，46.6°). The map of the measurement is shown in Figure 4. Then we use targeting techniques of Chaotic Monkey algorithm to locate the partial discharge source and the result is (41.9 cm, 81.5 cm, 51.9cm), the spatial distance error is 3.1cm.

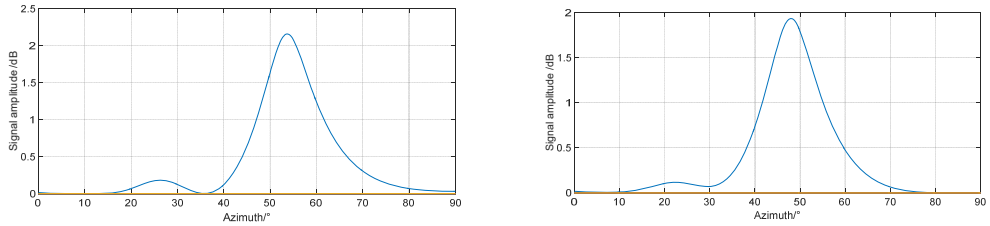

Figure 4

We changed the location of the PD source location and the Ultrasonic array sensor, carried out five other experiments by following the same steps mentioned above. The results are shown in the table below:

Times	Location of PD/cm	Location of sensor/cm	Direction angle /(°)	Location results by chaotic monkey /cm	error/cm
1	(25,70,90)	(50,0,0)	(106.3,48.5)	(22.4,67.9,91.4)	3.6
		(0,50,0)	(52.2,70.9)		
		(0,100,0)	(142.1,64.9)		
2	(80,80,50)	(75,0,50)	(88.4,0)	(77.7,78.8,50.7)	2.7
		(50, 0,0)	(71.6,29.3)		
		(0,50,0)	(68.0,29.4)		
3	(60,40,30)	(50,0,0)	(74.5,37.3)	(62.5,42.4,28.6)	3.7
		(0,50,0)	(102.1,24.9)		
		(0,100,0)	(133.1,17.2)		
4	(40,80,20)	(25,0,0)	(81.0,15.2)	(37.7,78.3,18.0)	3.5
		(65,0,0)	(109.9,15.2)		
		(0,45,0)	(46.8,22.5)		
5	(70,40,80)	(0,20,50)	(72.8,24.3)	(71.5,37.9,77.4)	3.7
		(60,0,60)	(74.4,27.8)		
		(25,0,0)	(39.7,50.9)		

5. Summary

1) We propose a method based on FASTDOA and Chaotic Monkey algorithm for measuring direction and positioning with the sparse linear array sensor on the discharge source.

2) We have studied the application of the method for measuring direction and positioning in the field of partial discharge detection of electrical equipment, and verified the feasibility of the method by experiment.

Reference

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