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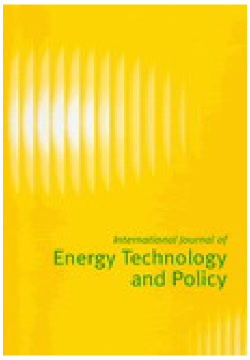


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# Partial discharge detection method for power equipment based on UHF method

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**Abstract:** In order to avoid the impact of noise on the performance of partial discharge detection and improve the accuracy of detection results, a partial discharge detection method for power equipment based on ultra-high frequency method is proposed. Firstly, use a conical antenna sensor to collect ultra-high frequency signals during partial discharge of power equipment. Then, wavelet entropy is used to denoise the collected ultra-high frequency partial discharge signal, removing the noise components contained in the signal and retaining the effective information components of the signal. Extract features such as signal skewness, steepness, discharge level, phase, and cross correlation, and use chicken swarm algorithm to detect partial discharge of power equipment based on the extracted features. The experimental results show that the detection result of this method is the most accurate, and the number of false samples for partial discharge signal type is 0, indicating that its detection effect is good.

**Keywords:** UHF; power equipment; partial discharge; antenna sensor; wavelet entropy; feature extraction.

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**Biographical notes:** Shengchun Liu graduated with a North China Electric Power University electrical engineering degree in 2005. He obtained his Master's degree in Electrical Engineering from Xi'an University of Technology in 2017. In recent years, he has completed 42 projects. He published 28 papers. He applied for eight patents and obtain authorisation. During the work period, a series of research on partial discharge of power equipment have been carried out. It has made a positive contribution to promoting power grid construction and technological progress.

Jie Zhang has a long-term commitment to power line loss analysis and reactive power and voltage professional fields. Outstanding achievements have been made in scientific and technological support for major construction projects, research on key technologies at high altitude and technological research in the field of new energy. It has made outstanding contribution to the popularisation and application of new technology in Qinghai power grid and the improvement of scientific and technological management level.

## 1 Introduction

With the continuous expansion of power system and equipment scale, partial discharge has become one of the main reasons for equipment failures and accidents. Therefore, it is extremely urgent to carry out research and technical development on partial discharge detection of power equipment (Raichura et al., 2021; Musso et al., 2021; Kurabayev et al., 2022). The research on partial discharge detection method is committed to developing high-precision and high-sensitivity detection technology, providing early warning and maintenance means by real-time monitoring and diagnosis of partial discharge defects in equipment, so as to ensure the reliable operation of power system and provide important support for the improvement and innovation of partial discharge detection technology of power equipment (Taehyun and Jaehyun, 2021; Meitei et al., 2021; Zhou et al., 2021; Yanpeng et al., 2021).

Xu et al. (2021) proposed a fast detection method for partial discharge pulses based on random matrix theory, which utilises the PD time series received by ultra-high frequency sensors to construct a high-dimensional random matrix. Based on the empirical spectral distribution theory of the time series model under random matrix theory, a fast detection method for partial discharge pulses based on sliding time windows is proposed. The simulation and laboratory testing results show that this method can quickly identify PD pulses in time window data, but there is a problem of low detection accuracy. Cai et al. (2021) proposed a transformer partial discharge detection method based on UHF self-sensing. The transformer core, high-voltage winding, and high-voltage bushing end screen were selected as UHF antennas to model and conduct simulation research on UHF self-sensing detection. The test results have verified the feasibility of this method, which can achieve high sensitivity and safety detection of on-site partial discharge in transformers. However, its anti-interference performance to electromagnetic interference is poor, and the detection accuracy is limited by the quality of the detection environment. Duan et al. (2022) proposed a partial discharge detection method for converter transformers based on high-frequency and ultrasonic joint detection, discussed the principle of ultrasonic high-frequency current joint detection, introduced the hardware and software system of the ultrasonic high-frequency current partial discharge detection system for converter transformers, established an augmented matrix constraint method for ultrasonic signal estimation, conducted experimental research on partial discharge of converter transformers, and verified the correctness of the scheme. However, due to the lack of noise processing in this method, the accuracy of the detection results is not high.

Aiming at the problem of low detection accuracy of the existing methods mentioned above, a partial discharge detection method for power equipment based on UHF method is proposed. The main contents of this paper are as follows:

1 The UHF method is used to obtain partial discharge signals of power equipment for discharge signal analysis. This method can accurately detect whether there is partial discharge in the insulation of power equipment, and the sensitivity is significant.

2 The wavelet entropy method is used to denoise the collected UHF partial discharge signal, complete the filtering of UHF partial discharge signal noise components, and adjust the ratio of effective information and noise information of UHF partial discharge signal to reduce noise signal interference.

3 The chicken swarm algorithm is used to process the partial discharge signal, extract the features in the partial discharge signal, obtain the signal skew feature, steep feature, discharge capacity feature, phase feature, and cross correlation feature, and realise accurate partial discharge detection of power equipment based on the above features.

## 2 Partial discharge detection method for power equipment

### *2.1 Partial discharge signal acquisition based on UHF method*

In the collection of partial discharge signals, the expected goal of signal collection is to detect and monitor partial discharge phenomena in electrical equipment or systems, in order to detect potential faults in advance and avoid equipment damage (Jiang et al., 2021; Ning et al., 2021; Jia et al., 2021). Partial discharge signals are usually very weak and embedded in other background noise, such as electromagnetic interference, device noise, etc. Therefore, how to accurately extract and analyse local discharge signals from complex background noise has become a key issue. The ultra-high frequency method has the characteristics of high sensitivity, high resolution, and broadband response. It can capture weak partial discharge signals and provide highly sensitive detection even at low discharge energy. Moreover, due to the rapid variation of ultra-high frequency signals, the use of ultra-high frequency methods can provide high-resolution partial discharge detection results. In addition, the ultra-high frequency method has response over a wide frequency range and can detect partial discharge signals of different frequencies and shapes, which is beneficial for improving signal acquisition accuracy.

The application of UHF method to partial discharge signal acquisition requires careful selection of sensors and reasonable arrangement of sensor positions. The reasonable implementation of these steps can help to accurately obtain partial discharge signals in power equipment. The specific steps of using UHF method to collect partial discharge signals are as follows:

1 Sensor preparation: to ensure accurate collection of ultra-high frequency partial discharge signals and improve the anti-interference ability of the collection system, signal sensors with high sensitivity and wide frequency response range, such as antennas or sensor arrays, can be selected for receiving and recording partial discharge signals. This article selects a conical antenna sensor, which has high sensitivity and broadband response ability, and can capture ultra-high frequency signals generated by partial discharge. Then, design and arrange the signal transmission line reasonably to prevent signal distortion and external interference.

2 Sensor arrangement: arrange the sensor at the appropriate position of the power equipment to receive the partial discharge signal optimally. In this paper, sensors are arranged near key components of power equipment, such as insulation joints, insulators, etc. These areas are usually hot spots where partial discharge occurs, and the collected signals can better reflect the health status of equipment.

3 Signal acquisition: UHF sensors are used to collect signals from power equipment. The sensors will convert UHF signals caused by partial discharge into electrical signals and input them to data acquisition equipment, including recording waveform, amplitude, spectrum and other information of partial discharge signals. Start the data acquisition equipment to collect partial discharge signals.

**Figure 1** Schematic diagram of cone antenna sensor structure

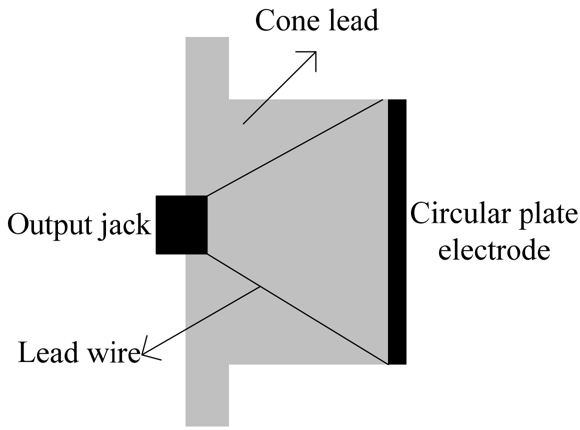
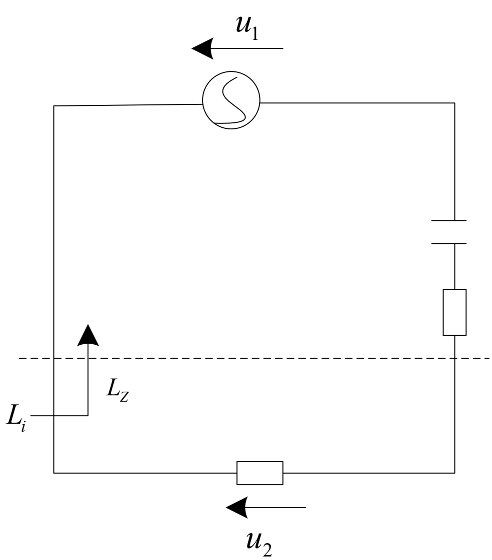



**Figure 2** Equivalent circuit of conical antenna sensor




When using UHF method to collect partial discharge signal, cone antenna sensor is introduced to capture UHF electromagnetic wave signal, hereinafter referred to as partial discharge signal. The structural diagram of the cone antenna sensor is shown in Figure 1, and the equivalent circuit of the cone antenna sensor is shown in Figure 2.

When partial discharge current pulse occurs in power equipment, the partial discharge signal is collected at this time, and the acquisition result is shown in equation (1):

$$dA = \left|\frac{u_2}{u_1}\right| = \frac{L_z}{L_z + L_i} \tag{1}$$

Among them, $u_1$, $u_2$ represents the partial discharge signal voltage appearing in the power equipment, and the partial discharge signal voltage sensed and output by the cone antenna sensor; $L_z$, $L_i$ represents the impedance of the measuring power equipment and the entrance impedance of the cone antenna sensor.

## *2.2 Partial discharge signal denoising based on wavelet entropy*

The partial discharge signal acquisition results are obtained through Section 2.1, but the obtained partial discharge signals carry noise components with different intensities, which will lead to large partial discharge type detection errors. Therefore, in order to ensure the detection accuracy of partial discharge, this paper uses the wavelet entropy algorithm to remove the signal noise component after obtaining the partial discharge signal of power equipment using the ultra-high frequency method, and completes the screening processing of the noise component of the ultra-high frequency partial discharge signal. The wavelet entropy algorithm can set the noise energy threshold. Combining this threshold, the ratio of effective information and noise information of UHF partial discharge signal can be adjusted to achieve signal denoising (Cheng et al., 2021).

In this process, it is necessary to reasonably set wavelet entropy, quantify and calculate the UHF partial discharge signal collected in Section 2.1, and use equation (2) to calculate the total wavelet entropy energy of the partial discharge signal of power equipment:

$$F_i = \sum\nolimits_{m=1}^{M} \left|g(i,m)\right|^2 \tag{2}$$

Among them, $g(i, m)$ represents the $i$-layer wavelet coefficients of the partial discharge signal; $m \in M$, represents the number of wavelet coefficients.

The high-frequency information in each decomposition scale of partial discharge signal is set as a single signal source, and the high-frequency wavelet coefficients of each layer are divided into multiple sub-bands using the equal division processing method, and the wavelet entropy of each sub-band is calculated. The energy of the $j^{\text{th}}$ sub-band in the high-frequency wavelet coefficients is:

$$F_j = \sum\nolimits_{n=1)}^{N} \left|g(i,m)\right|^2 = \sum\nolimits_{m=n}^{N} F_i \tag{3}$$

Among them, $n$, $N$ are the range point of wavelet coefficient sub-band.

In the total energy of wavelet entropy of partial discharge signal of Super high frequency power equipment, the calculation method of the energy ratio $q_{i,j}$ and wavelet entropy $R_j$ of wavelet coefficient of sub-band $j$ is as follows:

$$q_{i,j} = \frac{F_j}{F_i} \tag{4}$$

$$R_j = -\sum_i q_{i,j} ln q_{i,j} \tag{5}$$

The partial discharge signal of UHF power equipment is divided into low frequency and high frequency components (Escurra et al., 2021). The low frequency component is wavelet coefficient, and the high frequency component is noise information. If all information components in this high-frequency area belong to noise, then the noise threshold is:

$$k(i) = \sqrt{\frac{u^2}{M-1}} \tag{6}$$

Among them, $u^2$ is the periodic change of voltage caused by partial discharge.

In practical applications, there are also effective signals in the high-frequency area, so in order to ensure that the UHF partial discharge signal is not distorted, the wavelet entropy value is used to represent the information distribution state (Li et al., 2021). If the wavelet entropy is large, the noise content is large. Using wavelet entropy $k(i)$ and its specific operation steps for noise reduction of partial discharge signal are as follows:

1 Extract the wavelet basis function most similar to the original UHF partial discharge signal, set the decomposition scale of UHF partial discharge signal, and extract the signal noise information component and effective information component under multi-scale conditions (Yanpeng et al., 2021).

2 Set the noise variance $\mu_i$ as the $i^{th}$ scale, and calculate the wavelet threshold of the $i^{th}$ scale for denoising

$$k(i) = k(i)\ \mu_i \sqrt{2lnM_i} \tag{7}$$

Among them, $M_i$ represents multi-scale sampling points.

3 Perform threshold quantisation on the noise information component of the $i^{th}$ scale, discard the wavelet coefficients with absolute values lower than the threshold of equation (7), and obtain the approximate high-frequency wavelet coefficients of the $i^{th}$ scale.

4 Since noise can appear in multiple frequency bands of signal wavelet domain, the wavelet coefficients of multi-scale noise are also diversified. When the decomposition scale becomes larger, the wavelet coefficients of noise are smaller (Yang and Ren, 2022). In combination with the distribution law of noise signal, set wavelet thresholds of different scales through equation (7), and then threshold the high-frequency coefficient components of each scale.

5 Due to the significant noise in the partial discharge signal, only one wavelet transform cannot fully extract the effective signal. Therefore, after the second wavelet transform is performed, wavelet entropy thresholds can be performed to obtain the approximate second high-frequency wavelet coefficients of the partial discharge signal.

6 Low frequency coefficient obtained by using one time wavelet transform $q_m$ approximate quadratic high-frequency wavelet coefficient $\mu_m$ perform signal reconstruction to complete partial discharge signal noise reduction processing:

$$u_m = \sum_m q_m + \sum_m \mu_m \tag{8}$$

### *2.3 Implementation of partial discharge detection of power equipment based on chicken swarm algorithm*

According to the structural characteristics of power equipment, the type of partial discharge is not single. Different types of discharge behaviours indicate different operating states of equipment (Wang et al., 2021; Sonia et al., 2021). In order to accurately detect partial discharge signals of power equipment $u_m$ type, the characteristic information of the discharge type needs to be set. Set the discharge signal after noise removal in the partial discharge statistical parameters $u_m$ its characteristics of deflection, steepness, discharge, phase and cross-correlation are *S, H, P, φ, D*. Then:

$$S = u_m \sum_{j=1}^{m} \left(y_j - \gamma\right) \cdot z_j \Delta y / \varsigma \tag{9}$$

$$H = \left[u_m \sum_{j=1}^{m} \left(y_j - \gamma\right) \cdot z_j \Delta y / \varsigma\right]^2 \tag{10}$$

Among them, $y_j$ and $\Delta y$ are the phase and width of the $j^{\text{th}}$ phase window of $u_m$ in sequence; $z_j$, $\gamma$ is the probability and mean value of events in the phase window; $\varsigma$ is $u_m$'s standard deviation of events appears in the phase window. Relative to the discharge signal with normal distribution, *S*, *H* represent partial discharge signal of power equipment respectively $u_m$ whether there are deflection and bulge patterns during the change.

$$D = \frac{u_m \sum_{j}^{m} \delta_j^+ \delta_j^- - \left(\sum_{j=1}^{m} \delta_j^+ \sum_{j=1}^{m} \delta_j^-\right)}{\sqrt{u_m \sum_{j=1}^{m} (\delta_j^+)^2 - \left(\sum_{j=1}^{m} \delta_j^+\right)^2 - u_m \sum_{j=1}^{m} (\delta_j^-)^2 - \left(\sum_{j=1}^{m} \delta_j^-\right)^2}} \tag{11}$$

Among them, $\delta_j^+$ and $\delta_j^-$ represent the average discharge of the $j^{\text{th}}$ phase window of $u_m$ in sequence; '+' and '–' indicate positive and negative half cycle; *D* reflect the positive and negative half cycle shape similarity of the discharge signal spectrum.

$$P = \frac{\sum_{j=1}^{m} c_j^- \delta_j^-}{\sum_{j=1}^{m} c_j^-} \Bigg/ \sum_{j=1}^{m} c_j^+ \delta_j^+ \tag{12}$$

Among them, $c_j^-$ and $c_j^+$ are the discharge repetition rates of the $j^{\text{th}}$ phase window of $u_m$ in sequence; *P* reflect the difference of discharge capacity.

$$\varphi = \frac{\varphi_{in}^-}{\varphi_{in}^+} \tag{13}$$

Among them, $\varphi_{in}^{+}$, $\varphi_{in}^{-}$ is $u_m$'s initial phase angle of discharge; $\varphi$ reflect initial phase difference of $u_m$'s discharge.

Based on the extracted partial discharge signal features of power equipment, the chicken swarm algorithm is used for partial discharge detection of power equipment. Compared with traditional algorithms, the chicken swarm algorithm can help determine the optimal sensor layout scheme in partial discharge detection of power equipment, maximising the coverage of potential discharge areas. Moreover, this algorithm is easy to implement parallel computing and can handle multiple search paths simultaneously, improving processing efficiency and speed. For partial discharge detection of large-scale power equipment, the chicken swarm algorithm can quickly search for the optimal solution and support real-time data processing and analysis. In addition, the chicken swarm algorithm has non-local search ability, which can jump out of the local optimal solution and find a better global optimal solution. For complex power equipment or systems, partial discharge may occur in different positions and forms. The chicken swarm algorithm can comprehensively detect and locate potential partial discharge sources through global search.

To avoid the chicken swarm algorithm falling into local minima, multiple strategies can be adopted. Firstly, diversify the initial solution set and use different random initial solutions through multiple iterations to start the algorithm, increasing the search space. Secondly, by increasing randomness, introducing random perturbations or adjusting the randomness of algorithm parameters, the algorithm has a greater chance of jumping out of local minima. Next, an adaptive strategy is adopted to adjust algorithm parameters and update rules based on feedback information. At the same time, a local search strategy is introduced, combining global and local search strategies to fully utilise the ability of local search to optimise the local neighbourhood of the current solution. Finally, it is possible to consider combining multiple optimisation algorithms to comprehensively utilise the advantages of different algorithms and improve global search capabilities. The comprehensive application of these strategies can effectively improve the global search performance of the chicken swarm algorithm and avoid falling into local minima.

The specific steps of using chicken colony algorithm to detect partial discharge of power equipment are as follows:

1 Set the initial values of the parameters such as the size of the chicken flock, the number of iterations, the update frequency of the individual position, and the dimension of the individual position.

2 The flocks were initialised, and the individuals in the flocks were arranged according to their own fitness. The males were divided into m groups. After the females were randomly divided into each group, the females and males were set as a partnership. m females were arbitrarily extracted to manage the chicks, and the mother-child relationship between females and chicks was set.

3 At the beginning of foraging, analyse whether to update the group position and chicken herd relationship, and use the position update method to update the position of the male, female and young chickens.

The position of the cock will be disturbed by the position of the companion cock, so its position needs to be updated:

$$\varrho_{i,j}^{t+1} = \varrho_{i,j}^{t} \times \left[1 + rand(0, \pi^2)\right] \tag{14}$$

Among them, $\pi^2$ is variance; $\varrho_{i,j}^{t}$ t is the position of the $j^{th}$ rooster in dimension $i$ during the $t^{th}$ iteration of support vector machine parameter optimisation; $E$ is the position of the $j^{th}$ rooster in dimension $i$ during the $t^{th}$ iteration, representing the position update result; rand is a random number.

The hens will feed under the leadership of the male, and the position update status is also disturbed by the male. Because the female chicken has the stealing behaviour, the method of its position update is:

$$\varrho_{i,j}^{t+1} = \varrho_{i,j}^{t} + b_1 \times rand\left(\varrho_{s1,j}^{t} - \varrho_{i,j}^{t}\right) + b_2 \times rand\left(\varrho_{s2,j}^{t} - \varrho_{i,j}^{t}\right) \tag{15}$$

Among them, $\varrho_{s1,j}^{t}$, $\varrho_{s2,j}^{t}$ is male followed by the female, and the position of the male in other populations; $b_1$, $b_2$ is the weight of foraging.

The feeding range of young chickens is limited by their female chickens, and the location update method is:

$$\varrho_{i,j}^{t+1} = \varrho_{i,j}^{t} + \psi \times \left(\varrho_{n,j}^{t} - \varrho_{i,j}^{t}\right) \tag{16}$$

Among them, female chickens' position i dimension values is $\varrho_{n,j}^{t}$, $\psi$ is the influence factor of female chickens on the position of young chickens, with the minimum value of 0 and the maximum value of 2.

4 Calculate the fitness value of the individual position of the support vector machine parameter solution, replace the chicken with larger fitness value with the male, female and young chicken with smaller fitness, and complete the iterative optimisation of the partial discharge detection problem solution of power equipment.

5 Analyse whether the number of iterations is the maximum. When the iteration conditions are met, output the chicken with the minimum fitness at this time to obtain the partial discharge detection results of power equipment:

$$f(v) = sgn\left\{\left(\sum_{j=1}^{m} \eta_j \left(\rho_j \cdot \rho_i\right)\right) + \varrho_{i,j}^{t+1}\right\} \tag{17}$$

Among them, $\eta_j$, $\rho_j$, $\rho_i$ indicates the location, type and scale information of partial discharge defects.

## 3 Experimental analysis

### *3.1 Experimental plan design*

1 Experimental objective: To verify the effectiveness and accuracy of the proposed partial discharge detection method.

2 Experimental sample data collection:

   a Select appropriate power equipment samples (such as transformers, generators, etc.) for partial discharge detection.

   b Generate a series of simulated partial discharge events on the sample and record the corresponding partial discharge signals.
   c As needed, use different discharge voltages and frequencies, as well as local discharge sources at different positions and sizes, to simulate different discharge situations.

3 Experimental environment settings:
   a Ensure that the laboratory environment meets safety standards and avoids other electromagnetic interference and noise from introducing experimental results.
   b According to the requirements of partial discharge detection methods, select appropriate discharge detection systems and equipment, and calibrate and debug them.

4 Comparison method settings:

   In order to verify the effectiveness of the proposed method, Xu et al. (2021 method, Cai et al. (2021) method, and Duan et al. (2022) method were used as comparative methods to compare the effectiveness of partial discharge detection in power equipment.

## *3.2 Analysis of experimental results*

Partial discharge will lead to the discharge fault of gas insulated metal enclosed switchgear. According to the practical application, there are many types of partial discharge of gas insulated metal enclosed switchgear. This paper takes three kinds of sharp plate discharge, air gap discharge and surface discharge as examples to test the detection effect of different methods on three kinds of partial discharge problems. The time-domain waveform states of tip discharge, air gap discharge and surface discharge are shown in Figure 3.

Taking the sharp plate discharge signal in Figure 3(a) as an example, this method uses a cone antenna sensor to collect the partial discharge signal of power equipment, and there is noise in the signal, which seriously affects the signal characteristics. For this reason, before and after denoising, the discharge signal time domain changes are shown in Figure 4 and Figure 5.

Combined with the time domain waveform information of the standard cusp discharge signal in Figure 3(a), and compared with Figure 4 and Figure 5, it can be seen that the noise components seriously cover the effective information of the original partial discharge signal. After the noise reduction processing in this method, the noise components are basically filtered, the effective components are retained, and the denoising ability is qualified.

Compared with Xu et al. (2021) method, Cai et al. (2021) method, and Duan et al. (2022) method, analyse whether this method has advantages in the use of similar methods. The test results are shown in Figure 6, Figure 7, Figure 8 and Figure 9.

According to the experimental data in Figure 6, Figure 7, Figure 8 and Figure 9, compared with the methods in Xu et al. (2021), Cai et al. (2021) and Duan et al. (2022), the accurate sample number in the detection results of the three partial discharge signals in this method is consistent with the actual sample number. There are 5, 10 and 5 wrong samples in the detection results of Xu et al. (2021), Cai et al. (2021) and Duan et al.

(2022), respectively. In contrast, the detection result of this method is the most accurate, and the number of false samples is 0. Therefore, this method is more suitable for partial discharge detection of power equipment. This is because the proposed method uses the chicken swarm algorithm for partial discharge detection, which has non-local search ability and can jump out of the local optimal solution to find a better global optimal solution. For complex power equipment or systems, partial discharge may occur in different positions and forms. The chicken swarm algorithm can comprehensively detect and locate potential partial discharge sources through global search, which can improve the accuracy of detection results.

**Figure 3** Partial discharge types of gas insulated metal enclosed switchgear, (a) tip discharge, (b) air-gap discharge, (c) creeping discharge

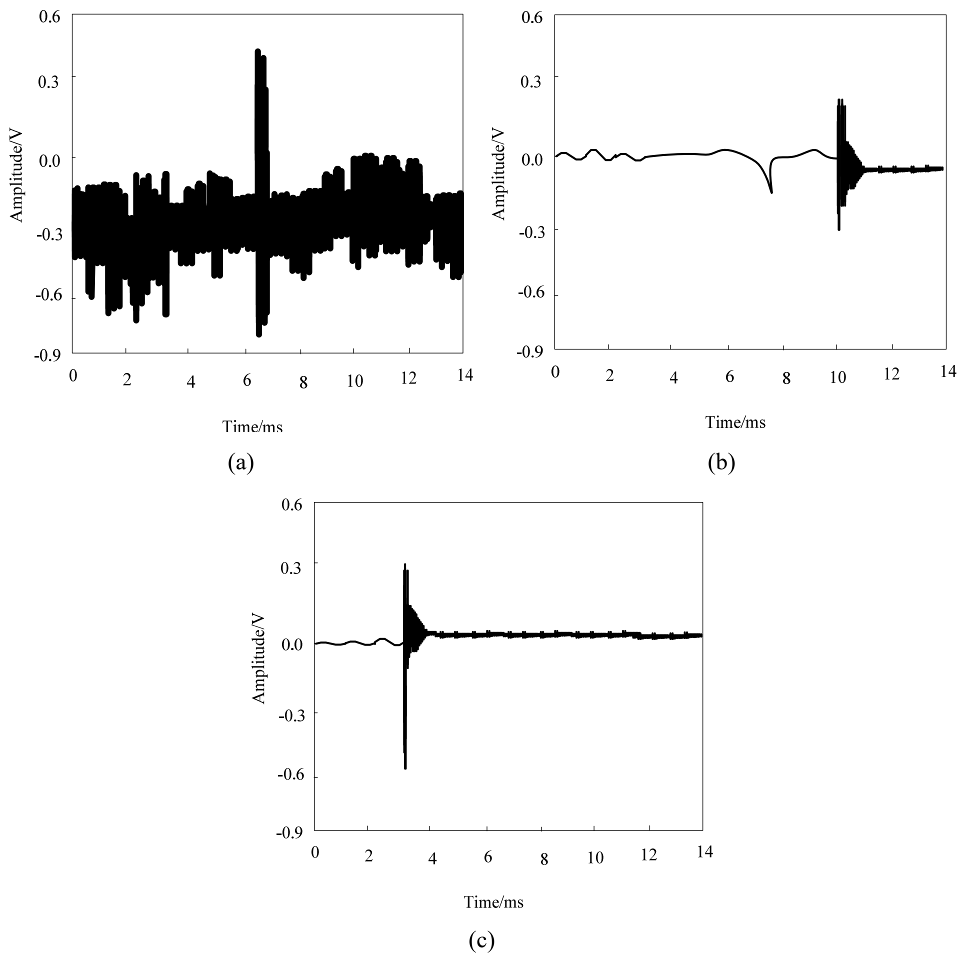


**Figure 4** Time domain waveform of partial discharge signal before denoising

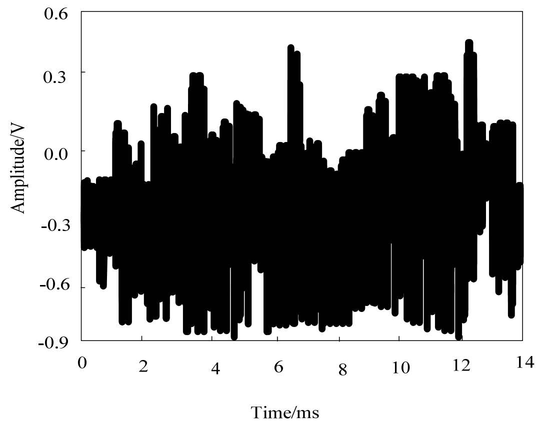



**Figure 5** Time domain waveform of partial discharge signal after denoising

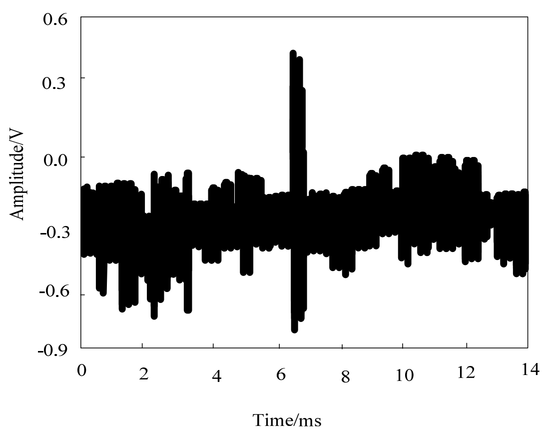



**Figure 6** The detection results of three types of partial discharge signals using this method

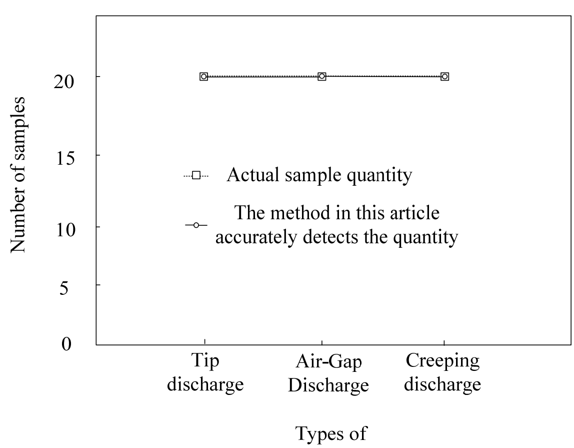


**Figure 7** Detection results of three partial discharge signals using Xu et al. (2021) method

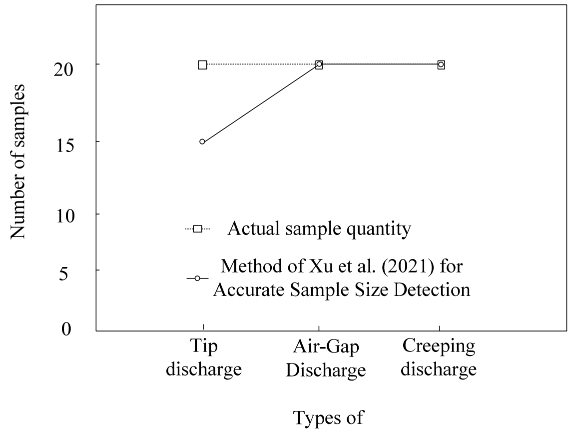



**Figure 8** Detection results of three partial discharge signals using Cai et al. (2021) method

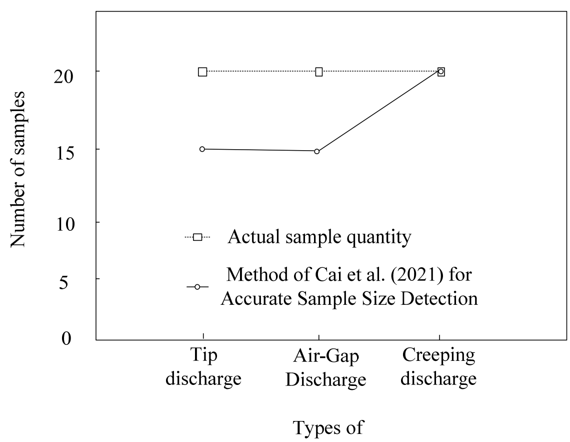
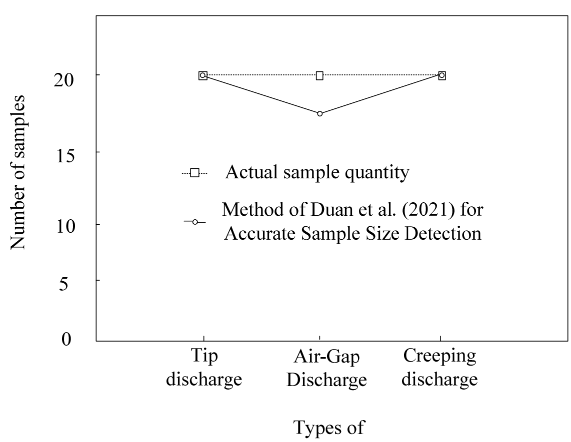



**Figure 9** Detection results of three partial discharge signals using Duan et al. (2022) method



## 4 Conclusions

According to the current grid operation situation, there are many large-scale power outages due to insulation aging of power equipment, and partial discharge is the source of insulation aging. Therefore, the research on partial discharge detection is of great significance to identify the type of partial discharge and quickly remove the fault of power equipment. Aiming at the problem of partial discharge detection of power equipment, this paper proposes a method of partial discharge detection of power equipment based on ultra-high frequency method. The main use value of this method is reflected in the following two points:

1. In this paper, after the partial discharge signal with noise is denoised, the noise component is basically filtered out, and the effective component is retained
2. The chicken colony algorithm is used to process the signal characteristics, and accurate partial discharge signal detection results are obtained. It can be seen from the experimental results that the detection results of the method in this paper are the most accurate, and the number of false detection samples of partial discharge signal type is 0. However, there are 5, 10 and 5 false detection samples in the detection results of the methods in Xu et al. (2021), Cai et al. (2021) and Duan et al. (2022), respectively. It can be seen that the method in this paper can improve the detection accuracy of partial discharge of power equipment.

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