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RESEARCH ON IMPROVED POSITIONING ALGORITHM BASED ON UWB

[1,3]MINGJUN WANG, [2]SHUXIAN DENG
[1]Zhengzhou University, 450007, ZHENGZHOU, CHINA
2Henan Engineering Institute, 450007, ZHENGZHOU CHINA
[3]Zhejiang Business College, 310053, HANGZHOU, CHINA
E-mail: [1]mingjun_w@163.com , [2]dshuxian@163.com

ABSTRACT

Ultra Wide Band Radio (UWB) is also known as the impulse radio (IR). It will become one of the most competitive technologies, especially in the high speed data transmission, high precision positioning, tracking and other fields; it has broad application prospects in the future. The main function of the high-voltage circuit breaker in the power grid is breaking, closing and carrying run normal current; it can carry, close and break a predetermined abnormal current within a predetermined time. The most primary and fundamental requirement for the high voltage circuit breaker is to ensure that there is a high degree of reliability. The conditions and defects of the insulation can be found by partial discharge detection. It has important scientific significance and value of engineering applications for us to study the precision positioning method to the circuit breaker.

Keywords: *Impulse Radio (IR), Positioning Algorithm (PA)*

1. INTRODUCTION

The main function of the high-voltage circuit breaker in the power grid is: breaking, closing and carrying normal current; bearing, closing and breaking the prescribed abnormal current within a specified time. High reliability is the first and most basic request for high voltage circuit breakers. Once the circuit breaker failure occurs, it may cause damage to other electrical equipments and power system blackout, so losses will be much higher than the value of circuit breakers themselves. Partial discharge is the main reason that causes insulation deterioration, and it is also the main symptom and manifestation of insulation deterioration. We can understand that insulating status of the breaker through the partial discharge detection, and can detect insulation defect of the equipment. We can determine the source of partial discharge (SPD) using local discharge positioning method. In this way, the operators can repair equipments more accurately and satisfy the high demand in the economy and reliability for high voltage circuit breakers, which not only reduces the costs but also saves the time, and prevents the occurrence of potential and sudden accident to a large extent. It has important scientific significance and application value for us to research on accurate positioning methods for the circuit breaker' SPD.

Ultra wide band radio (UWB) is also known as impulse radio (IR), it will become one of the most competitive technologies, and it has broad application prospects in the high speed data transmission, high precision positioning, tracking and other fields. (1) High concealment is the most prominent characteristics compared with conventional wireless communication. UWB's duty ratio is very low in the narrow pulse signal, pulse width is at the level of nanosecond or sub-nanosecond, the average power is very small, which makes the UWB signal easily concealed in the environmental noise and other signals, so the UWB itself has very high concealment, and does not to interference other communication system. (2) UWB has strong discernibility about time and space. The pulse that UWB launches lasts short time, and the duty ratio is extremely low, at the receiving end, the multipath signal can achieve effective separation, so UWB technology has great advantage relative in the conventional serial transmission signal or duration time far outweigh the multipath propagation time of the communication system of the multipath resolution. (3) UWB has stronger penetration ability, more accyrate positioning. Ultra wideband wireless communication has a strong penetrating ability, can realize partition imaging. Because of the narrow pulse width, we can get the arrival time in a small scale, thus reach positioning accuracy in a centimeter level, but also locate in the interior and

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underground. (4) Higher information rate. According to the Shannon formula, channel capacity can be increased by increasing bandwidth, UWB can obtain very high communication rate with its very wide bandwidth, and the influence of signal-to-noise is not very big increasing the bandwidth.

2. PDS LOCATION ALGORITHM

The measured UHF signals in different locations exist time differences. According to this feature, choose a high sampling rate of data acquisition system to gather UHF signal, then locate the discharge source according to the sensors position. There are four ways to achieve: the signal amplitude comparison method, bisector surface method, the signal order comparative law, time difference calculation method. We can use signal time difference calculation method to locate the SPD of circuit breaker, that is, by means of measuring the time difference between two sensors, we can locate the SPD's place .This is the main content of this paper.

Compared with other methods, positioning principle of time difference method is relatively simple, but the drawback is that the velocity of electromagnetic waves can reach 0.3 m / ns, even if only a small time gap will lead to a very large error. To solve this problem, the paper puts forward a unit impulse response method based on waveform similar and energy-based ratio method based on the energy change detection waveform to get the time difference, good results were obtained.

2.1 Square Integral Method Based on The Time Differences [2]

The signal will occur more serious distortion and attenuation when two sensors' positions are far from each other or the signal experiences a more complex structure in the transmission process , and the correlation peak can not be recognized clearly. signal delay can be determined by using energy detection approach when this condition occurs.

The approach squaring to the signals has two advantages: the first is we can simplify the form of signals, the second is we can keep delay information effectively retention, in fact, it is the energy detection.

Since the average noise usually can not be zero, we still need average law before the square, this method can make the waveform clearer, easier to identify, specific method is subtracting the noise average value from each sample before square arithmetic. Then do integral square to the discharge signal sequence [6].

$$x_i' = \frac{1}{N}\sum_{j=1}^{i+n} x_j^2, \qquad i=0,1,\cdots,n-N \ (N>0) \quad (1)$$

Take N = 10 after removing the noise average of the partial discharge signal, via a square integral, the curve is shown in Figure 1 and Figure 2.

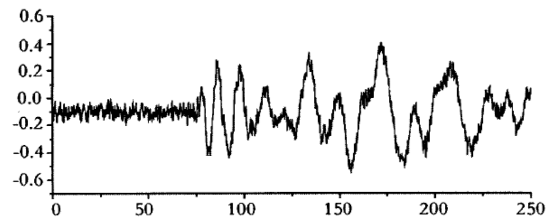

Figure 1: Original Waveform

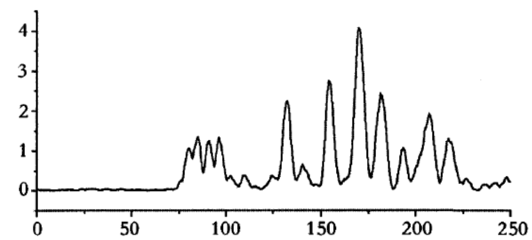

Figure 2: Waveform After Square Integral Method

It can be seen that the SNR increases and the background noise is smoothed after square integral, and it is easy to judge the specific moments generated by the discharge , because the starting position of the signal also becomes clearer. The waveform in the above figure is very suitable for determining delay through program. Indeed, when using the square integral method to calculate the leading edge of the signal, the leading edge is not the real time delay of the signal relative to the sampling point; however, more accurate delay estimation is very critical. So, the next step is to improve the criterion of waveform edge

2.2 Improved Square Integral Method(Energy Ratio Method)

Its principle is to detect the arrival time of useful signal through the construction of energy ratio function. This article will use the method to calculate the PD's delay within circuit breaker, subject to the signals received at each sensor, first, calculate the moment that the signal reaches, and then to estimate the relative time delay among the signals.

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Definition 1: the valid values x_{RMS} of the signal $x(t)$ in the time period $[0,t]$ are:

$$x_{RMS} = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt} \qquad (2)$$

The received signal $x(t)$ though A sensor can be expressed as:

$$x(t) = \begin{cases} n(t), & t \le t_0 \\ n(t)+s(t), & t \ge t_0 \end{cases} \qquad (3)$$

In which $n(t)$ is the noise. The signal from sensors only includes $n(t)$ before t_0, until the useful signal $s(t)$ arrives, after all these, the signal not only includes $n(t)$, but also $s(t)$. Time domain initial zero crossing method is to find the channel t_0 to estimate the time delay between each channel signal. It is because of the noise interference and distortion, which makes the possibility very low to precisely locate the time t_0 on the basis of the threshold value solely. If the average value of the noise is not zero, we still need to remove it from each sample. After the noise is removed and the signal $s(t)$ arrives, the energy of the received signal $s(t)$ will appear mutations at the moment t_0. x_{RMS} is a measure of the average energy of the signal in a time slot, according to formula (2), we can obtain energy ratio before and after the time t_0. Plus a sliding rectangular window $U(r)$ on the $x(t)$, the window's width is $2t$.

$$U(t) = \begin{cases} 1, & t \le 2T \\ 0, & \text{others} \end{cases} \qquad (4)$$

Dividing the window into w1, and W2 in half as a dividing line in the center of it, seek the valid values of x (t) in w1, w2 respectively:

$$[x_{RMS}]_{W_1} = \sqrt{\frac{1}{T}\int_0^T \left[x(\tau)h(t-\tau)\right]^2 d\tau} \qquad (5)$$

$$[x_{RMS}]_{W_2} = \sqrt{\frac{1}{T}\int_0^T \left[x(\tau)h(t+\tau)\right]^2 d\tau} \qquad (6)$$

The energy ratio on both sides of the window center is defined as:

$$Test(t) = \ln\left[\frac{[x_{RMS}]_{W_2}}{[x_{RMS}]_{W_1}}\right]$$

$$= \ln\left[\frac{\sqrt{\frac{1}{T}\int_0^T \left[x(\tau)h(t+\tau)\right]^2 d\tau}}{\sqrt{\frac{1}{T}\int_0^T \left[x(\tau)h(t-\tau)\right]^2 d\tau}}\right] \qquad (7)$$

Energy ratio Function $Test(t)$ is a function of sliding rectangular window center, and when $t = t_0$, the formula (7) can be written as:

$$Test(t_0) = \ln\left[\frac{\sqrt{\frac{1}{T}\int_0^T \left[n(t)+s(\tau)\right]^2 d\tau}}{\sqrt{\frac{1}{T}\int_0^T n^2(\tau)d\tau}}\right]$$

$$= \ln\left[\frac{x_{RMS} \text{ with signal}}{x_{RMS} \text{ of Background}}\right] \qquad (8)$$

The numerator in formula (8) obtains maximum value when $t = t_0$, the denominator is the RMS noise, therefore we can see that $Test(t)$ is maximum when $t = t_0$.

We should repeat comparisons to select the most suitable value in the window width T, because T plays a very important role in the location determination, and the value of T should be greater than the cycle time of an oscillation waveform, and less than the continuous oscillation time, so it can effectively converge to the signal edge. Within this range, T is the less, the judgment is more accurate.

It depends on the signal edge amplitude that the peak of Energy ratio function is significant or not. In some experimental data of partial discharge signal, the amplitude arrived at first is less than the follow-up wave and noise, some are even too small to observe and distinguish signal's real frontier directly, and only existence strong follow-up wave [3],In this case, the treatment effect is poor, there may even occur misjudgment. We should pay attention to this point in practical application.

2.3 UWB Positioning Algorithm Based on Improved Integral Square Law

The common localization algorithm based on the UWB has TOA, TDOA, RSS and AOA etc [5]. By means of measuring the arrival time differences among two different known point and unknown point, we can obtain the distance difference, this is TDOA positioning principle. A set of TDOA value

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is corresponding to a pair of hyperbola whose focuses are just the two known points, the intersection of multiple hyperbolas is just the unknown point. The positioning principle is as shown in figure3 [4].

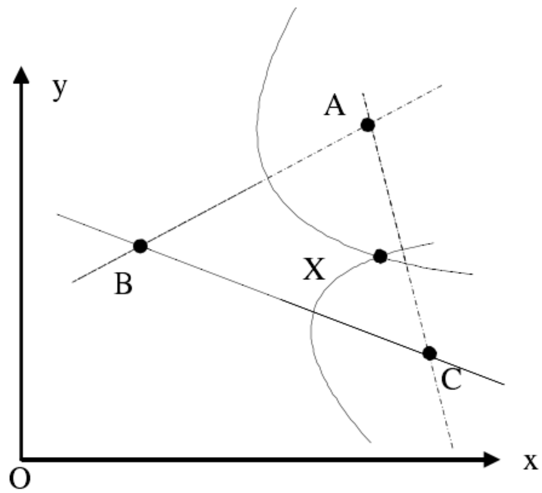

Figure 3: TDOA Positioning Principle

Suppose that the coordinates of a, b, c are known, respectively written as (x_A, y_A),(x_B, y_B) , (x_C, y_C) , the unknown point's coordinates are (x, y) , by the distance difference values $r_{CA} = r_C - r_A$, $r_{CB} = r_C - r_B$, solving the following equations, we can obtain the target point coordinates (x, y).

$$r_{CA} = \sqrt{(x_C - x)^2 + (y_C - y)^2} - \sqrt{(x_A - x)^2 + (y_A - y)^2}$$
$$r_{CB} = \sqrt{(x_C - x)^2 + (y_C - y)^2} - \sqrt{(x_B - x)^2 + (y_B - y)^2}$$
……………………………………(9)

The unreasonable solutions in the equations can be excluded through a prior knowledge of the measured values based on TDOA. The way does not need the synchronization between reference stations and the target point, only needs the synchronization between reference stations. theoretical measurement error is smaller than TOA, and it is easy to implement ,so TDOA is widely used in positioning scheme.

In the simulation process, we also added an improved square integral method to determine the leading edge of signal waveform. Simulation process is shown in the following figure 4.

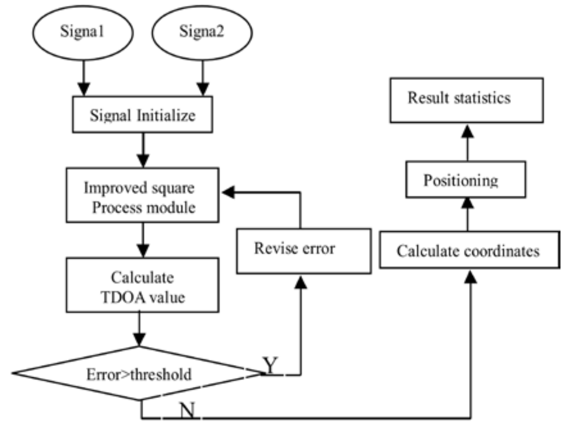

Figure 4: Simulation of Flow Chart

3. SIMULATION AND EXPERIMENTAL RESULTS

As Shown in Figure 5, the two circles' radiuses are all r, A and B are the sensor points respectively, C and D are the positions of target points in the two arcs.

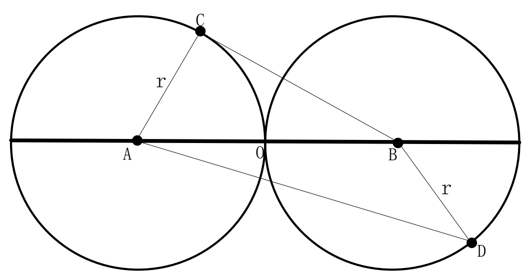

Figure 5: Positioning Simulation Figure

As C and D move, their distance relative to the sensor A and B also changes accordingly. Let radius $C_A = r$, then the distance between C and B is as follows:

$$CB^2 = CA^2 + (2r)^2 - 2 * 2r * CA \cos \angle CAB \quad (10)$$

Let electromagnetic velocity be v, and discharge point C is near to A and far from B, then A receives the signal earlier than B, the time difference is Δt . Using oscilloscope to measure two channel signal relative time delay Δt , and the distance of CB can be drown through (11):

$$L_{CB} = CA + v \cdot \Delta t \quad (11)$$

Generally, the electromagnetic wave that the discharge source emitted is mainly distributed in the 40-200M frequency range, it belongs to the TEM wave [6-7], it propagates along a straight line,

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its speed can be considered as the speed of light, approximately 3 x 10^8 m/s. let AB=3M, r=1.5 M. For each positioning point, make five repetitive discharge tests, let Δt be the average of the five times. First, different discharge test results are calculated and then use time difference method to determine the position of discharge resource. Location results are as follows:

Table 1: Location Algorithm of Measurement Results Table

Arithmetic	Δt (ns)	L_{CB}-L_{CA} (m)	∠CAB	CB-CA (m)	CB (m)	Error (m)
Improved TDOA	8.17	2.451	2*PI/3	2.469	3.969	0.018
	6.11	1.833	PI/2	1.854	3.354	0.021
	3.58	1.074	PI/3	1.098	2.598	0.024
TDOA	8.42	2.526	2*PI/3	2.469	3.969	0.057
	6.39	1.917	PI/2	1.854	3.354	0.063
	3.89	1.167	PI/3	1.098	2.598	0.069

As can be seen from Table 1， it is practicable for us to locate the partial discharge source using the improved method of this thesis. To some extend, the absolute error is small, positioning accuracy is improved compared to TDOA, and the positioning requirements are satisfied.

4. CONCLUSION

It is the key of positioning PDS that the time differences between signals are calculated accurately. In this article, the positioning model is established by using the time differences between two signals, and the positioning results are discussed as the PDS is at different places.

The final simulation results show that we can improve positioning precision of TDOA using the improved square integral method after the positioning signal is processed.

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