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Test method about transient characteristics of Relay protection calibration apparatus

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Abstract

Relay protection calibration apparatus is used to detect whether the Relay protection instrument satisfy their performance index. This article introduces the high-speed data acquisition system based on ADS930, proposes the interpolation algorithm aims to improve test accuracy in signal processing. It describes the method of filter smoothing to remove interference. Results illustrate the technique is correct and practical.

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Keywords:high-speed data acquistion; interpolation algorithm; transient characteristics;

1. Introduction

Transient state is a process that the circuit change from a momentary state into a stable one due to a role changed. Transient characteristics involved in this paper is mainly about voltage, current rise and fall time, response rate and the synchronization test with analogy fault of Relay protection instrument. Recently, with the large-scale application of Relay protection system, it has become a very important job about prenatal or periodic verification to the system. However, most detection equipment can do conventional verification, such as voltage, current amplitude, phase, etc. But, relate to the transient parameters, especially that as criterion of transient protection components now gradually increased, needing to simulate or determine parameter values in the experiment is difficult, such as the voltage and current response rate. Other simple method has not been found except using High-speed digital storage

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oscilloscope for detection[1]. Therefore, it is urgent to research the method about measuring the transient characteristics so as to achieve the accurate and convenient detection of Relay protection instruments.

2. High-speed data acquisition

The system includes two major sections: data acquisition and data processing. To achieve the high-speed of data collection, TMS320F281x series DSP is selected as signal control processor. The series of DSP, which has the 32bits of precision and 150M processing capacity, are widely used in the digital signal processing and control field. ADS930 is a high-speed AD chip of TI Corporation. It is 3-5V operated, 8bits of resolution, sampling rate of 30MHz, strong anti-interference ability, which is suitable for superior sample rate. We sample 4000 points in a period, in other words, sample one point per $1\,us$. In view of the simple interface and widely used of RS232, data communication can be performed conveniently. The upper machine software is developed with Delphi, which is responsible for processing the collected data, completing display, preservation and other operations. The block diagram of system is shown in Fig 1. Combining with technical conditions of Relay protection calibration apparatus, we adopt common interpolation algorithm and filter smoothing method to disposing.

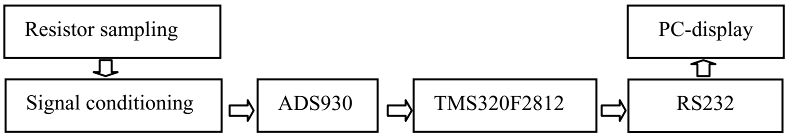

Fig. 1. Block diagram of system

3. Digital Interpolation Algorithm

Digital interpolation refers to adding some data between the discrete sampling points, aims to display the sampling waveform more clearly. It is the most usual way in function approximation theory[2]. We adopt it to increase the sample rate and improve the precision of calculation. Because the response of transient is quite fast, we need to capture sufficient number of points as much as possible in the transient process for accurately test. Rise time and the sampling interval graph shown in Fig 2:

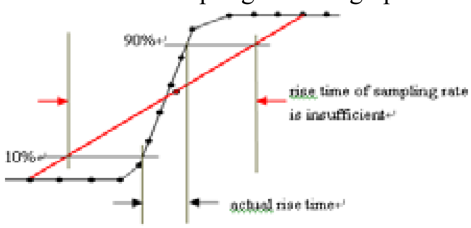

Fig. 2. Rise time and the sampling interval graph

3.1. Linear interpolation algorithm

Linear interpolation method is simple, fast and can be applied in signal reconstruction and recovery, such as square wave, triangle wave, etc. In polynomial interpolation, the most common way is the Lagrange interpolation[3]. Its expression is as follows:

Assume the function $y = f(x)$ is defined in the interval of [*m, n*], and known the function value $y_0, y_1, \cdots, y_n$ at the points of $m \le x_0 \le x_1 \le \cdots \le x_n \le n$. There is a simple function $L(x)$:

$$L(x) = \sum_{k=-\infty}^{n} y_k l_k(x) \tag{1}$$

Formula (1) is called the Lagrange interpolation polynomial, which:

$$l_k(x) = \frac{(x - x_0)\cdots(x - x_{k-1})(x - x_{k+1})\cdots(x - x_n)}{(x_k - x_0)\cdots(x_k - x_{k-1})(x_k - x_{k+1})\cdots(x_k - x_n)} \quad (k = 0,1,\cdots n) \tag{2}$$

When n= 1, (2) is called Linear interpolation. Linear interpolation is equidistant interpolation by way of arithmetic sequence. According to Linear interpolation formula, it is easy to get y_i of the interpolation:

$$y_i = m_0 + \frac{i}{k+1}(m_1 - m_0) \tag{3}$$

Formula (3), m_1, m_0 are two sample points, k is the number of interpolation point.

3.2. Sine interpolation algorithm

Sine interpolation $(\sin x/x)$ has been widely used in the field of signal processing. Based on the Sampling Theorem, the formula of sampling function interpolation has been derived from the time domain convolution principle:

$$y(t) = x_a(t) = \sum_{n=-\infty}^{\infty} x_a(nT) h_a(t - nT) \tag{4}$$

$$h_a(t - nT) = \frac{\sin[\pi(t - nT)/T]}{\pi(t - nT)/T} \tag{5}$$

Formula(5) is Sine interpolation function. $x_a(t)$ is continuous function, $x_a(nt)$ is the sample function.

Suppose $x(n)$ is a sampled sequence by interval of T, add M points between the two sampling sites to constitute a length of M sequence $k_1(nT), k_2(nT), \cdots k_m(nT)$. Formula(6) derived from is as follow:

$$c_m(nT) = \sum_{k=-\infty}^{\infty} x(kT) \frac{\sin[(n-k) + m/(M+1)T\pi]}{(n - k + m/(M+1))T\pi} \quad (M = 0,1,\cdots n) \tag{6}$$

4. Filter smoothing method

In order to eliminate interference generated in high-speed data acquisition or electronic circuit layout, we use filter smoothing technique to smooth the test curve. We calculate the data frequency in a small window of data smoothing through Fourier transform and filter out the frequency components greater than $1/(n\Delta t)$ to achieve a smoothed curve. Where, n is the number of points within the selected window, Δt is the time difference between adjacent points. We actually use a local low-pass filter to deal with the data window and realize data smoothing without changing the response curve.

5. Test principle

5.1. The measurement of rise time

Fig 3(a) shows a schematic diagram of waveform by measuring the inputted square-wave signal of Relay protection instrument. Adopting Modal method obtains the top value x_t and the bottom value x_b from rising curve of the wave. The rise and fall time refer to the time of circuit responding from the initial state to a steady one firstly. Therefore, the rise time is usually defined as the difference from steady-state 10% to 90%. Similarly, the fall time is 90% and 10%[4].

Rise amplitude of signal is the subtraction of x_t and x_b. Assume 10% of the amplitude is x_L, 90% is x_H .Their expressions are described as follows:

$$x_L = x_b + 0.1(x_t - x_b) = 0.9x_b + 0.1x_t \tag{7}$$

$$x_H = x_b + 0.9(x_t - x_b) = 0.1x_b + 0.9x_t \tag{8}$$

Using Linear interpolation or Sine interpolation in sampled data, find the corresponding measured value x_i by x_L, record i of x_i; find the corresponding measured value x_k by x_H, record k of x_k. Suppose the sampling interval is t *us*, rise time tr is calculated from the curve. Its expression is as follow:

$$tr = (k - i) * t \tag{9}$$

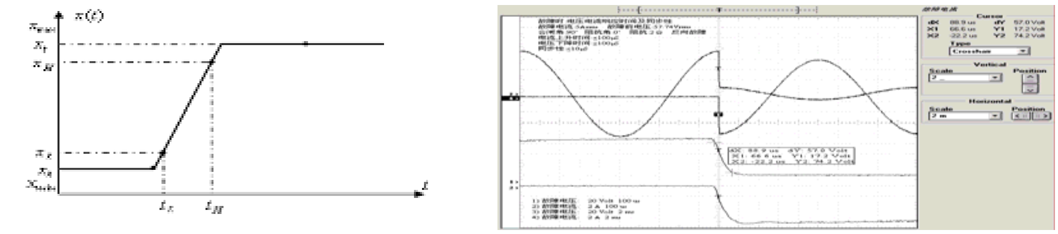

Fig. 3. (a) Schematic diagram of the square-wave; (b) Response curve of synchronous

5.2. Synchronization of voltage and current

Synchronization based on this system is used to determine whether the response of voltage and current change in the same rule and test their asynchronous time. Synchronization is defined as the response time of voltage and current when the simulated short-circuit failure occurs of Relay protection instrument. At this moment, amplitude of current increase immediately and voltage descend simultaneously. When starting the test, we set the phase of alternating voltage and current as 90° and -90° respectively at pre-fault moment. Next, operate the values of after-fault voltage and current, making sure pre-fault voltage is greater than the one of after-fault. Then, calculate rise time of current (here, the current rise in the opposite direction because of the phase) and fall time of voltage. Asynchronous time is the difference between voltage and current response. Fig 3(b) is the response curve of synchronous.

6. Analysis of test results

6.1. Voltage and current response rate test

Since some Relay protection instrument TEST-3330A that will be detected can not output square-wave signal, in our experiment, the standard square-wave voltage is outputted from function generator instead of TEST-3330A, which frequency is 50Hz, amplitude is 20 V_{PP}. We measure square-wave voltage rise and fall time as well as response rate in resistive load, and smooth the response curve with filter. The sampling data has been processed with Linear interpolation owing to the input signal is standard square wave. Response rate test curve of square wave voltage is shown in Fig 4(a). Test accuracy is improved through interpolating a data between the two samplings, as a result of AD sampling interval and the resolution. In this way, the interval changes from 1us to 0.5us. The rise and fall time of standard square-wave is 20ns. It is not difficult to find the rise time of voltage is accurately 0.5us by comparing the measured data in table 1. So the results attain the minimum resolution of AD, conforming to the rise and fall time of an ideal square-wave signal.

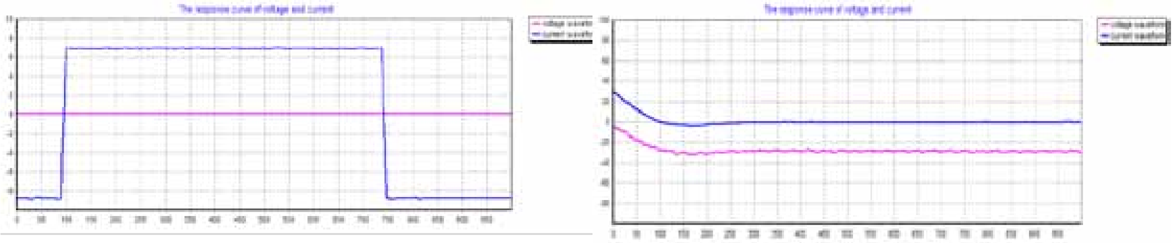

Fig. 4. (a) Response rate of square wave voltage; (b) Voltage and current synchronous

6.2. Synchronous test

While testing the synchronous of voltage and current of TEST-3330A, output alternating electrical parameters which frequency is 50Hz to the input port of calibration apparatus. We set the analogy fault current value is 1.5A, phase is -90 °; Pre-fault analogy voltage is 10V and after-fault value is 0V, phase is 90 °. We interpolate a sinusoidal data between the samplings. Fig 4(b) shows voltage and current synchronous test curve. According to the DL/T624-1997, asynchronous time should be no greater than 100 *us* [5]. Table2 shows the results are in the range of allowable error.

Table 1 Results of square-wave voltage

Interpolate	Rise time (*us*)	Rate of rise (V/ *us*)	Fall time (*us*)	Rate of fall (V/ *us*)
Before	1	20.791	1	20.791
After	0.5	42.009	0.5	42.009

Table 2 Results of synchronous test

Interpolate	Voltage fall time (*us*)	Current rise time (*us*)	Asynchronous time (*us*)
Before	46	128	82
After	68	121.5	53.5

7. Conclusion

In this paper, a method of transient characteristics on Relay protection calibration apparatus has been described. Test precision has been improved by using high-speed data acquisition system and interpolation algorithm. The use of filter smoothing method contributes to smooth the response curve and eliminates the interference caused by acquisition, which can more accurately test the transient parameters. The measured results show that the performance of the system is better than 0.5 index level.

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