A LabVIEW Based Instrument Current Transformer Calibrator

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ABSTRACT

The Virtual Instrument (VI) mainly refers to build all kinds of instruments by software such as LabVIEW, which likes a real instrument build in a computer. Its' main characteristics are flexibility, multi-functions, multiple uses for one PC computer, giving high performance, and is less costly. In this paper, the VI technology is applied to the test and measurement of instrument current transformer (TA). By using the LabVIEW, the TA accuracy calibrator was developed. This virtual TA calibrator can automatically measure the accuracy of TA and can indicate the ratio error and phase error curves. The tests and calibration for the TA show that the virtual TA calibrator can be used in place of the traditional calibrator and is much better than the traditional one.

Keywords: Instrument current transformer (TA), TA calibrator, Virtual Instruments, LabVIEW

I. INTRODUCTION

Since 1992 the VXIbus Rev.1.4 standard was established by the United States and LabVIEW was presented by the National Instruments co.(NI), the Virtual Instrument (VI) have lain the foundation for its commercial use. The main characteristic of Virtual Instrument is that it makes instruments by software. Most of the traditional instrument can be developed by VI. The VI is a real instrument made by the personal computer.[1]

The Instrument current transformer (TA) is widely used in all kinds of current measurement and it has the functions of protection, isolation and extending the measuring range. With the rapid development of computer measurement and control technology, and with the sequent emergence of current transformer and transducer, there is an increasing number of current transformers with high accuracy and low secondary current. The standard TA secondary current is usually 1A or 5A, some non-standard TA secondary current may be 0.1A or lower [2][3]. Although we have the technique to make this kind of calibrator by means of hardware such as single chip computer and electronic circuit, DSP and so on[4-8], it will cost too much money for these no-standard calibrator and will take too much time and the calibrator made by these hardware will not be satisfactory in both function and practicality for designing all kinds of new TA.

The calibrator that adopts VI technology not only can meet the requirements of the traditional one but also can satisfy customers with such advantages as multi-functions, convenience, and high ratio between performance and cost. The experiment results indicate that the virtual calibrator can provide excellent condition for TA measurement and design. The VI technology and personal computer must be widely used in the area of calibration on instrument transformer.

II. THE WORKING PRINCIPLE OF TA CALIBRATOR

The error of TA includes ratio error and phase error. The measuring of the error of TA or the calibration of the accuracy of TA usually applies differential measuring method. The method needs a standard TA except the measured TA and a TA calibrator. There is the same turn ratio between the standard and measured TA, and the standard TA's accuracy should be 2 levels higher than the measured one. The calibrator function lies in forming comparison circuits, measuring, and showing the error at all range. The comparison circuit, also referred to the difference measuring principle circuit, is showed in Fig. 1. By measuring the voltage on R_0 and R_d, calculate the corresponding current. Then the calibrator can indicate the errors.

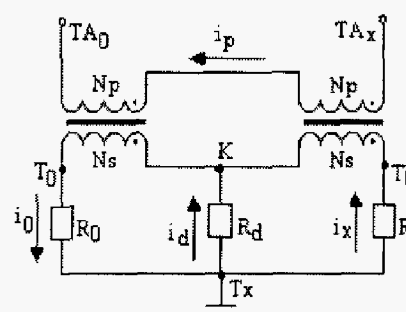

Fig.1 Schematic of TA comparison circuit

When a TA has the same turn ratio between the primary and secondary winding, the self-comparison circuit could be used and is shown in Fig.2. In the figures, TA_0 and TA_X are standard and TA being measured respectively. Np and Ns are primary and secondary winding turns. i_p and i_0, i_d, i_x are primary current, secondary standard current, secondary error current, secondary current of TA being measured respectively.

R_0 and R_d, R_b are secondary winding's resistance of standard TA, error current detecting resistance, burden resistance of TA being measured respectively. T_0 and K, T_b, T_x are voltage sampling points which can calculate the current. In this paper, only voltage between K and T_x, voltage between T_b and T_x are being measured and they represent the voltage on R_d and R_b respectively.

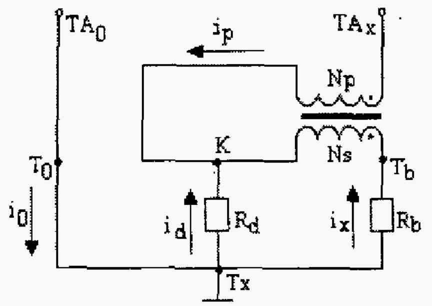

Fig.2 Schematic of TA self-comparison circuit

In general, the TA calibrator's principle of the sample resistance should be: 1) it can not affect the accuracy of the comparison circuit. In the ideal condition R_0 and R_d should be 0, but it can not be sampled. So there must be sample resistance, in this paper, R_d as shown in Fig.2 is used; 2) the magnitude of the sample resistance should make the sampled standard current and error current in pro rata and should not have too much difference. The sampled resistance is set by experiment: R_0 is the secondary standard current sampling resistance and can be 0.1~0.5Ω; R_d is the error current sampling resistance and can be 10~100Ω; R_b is the burden resistance and it depends on the TA being measured. By sampling the voltage u_0 and u_d on R_0 and R_d respectively, the ratio error and phase error are showed on the LED through some process and calculations.

According to the TA error's phase diagram [9], when i_0 is maximum, the value of i_d is the ratio error; when i_0 changes from negative to positive and equals to 0, the value of i_d is the phase error. For the same principle, the relationship is equal to the voltage signal u_0 and u_d, showed in Fig.3. **a** and **b** is represent the ratio error and phase error separately. The TA's real ratio error **f** and phase error **δ** can be found out through proper calculation.

$$f = \frac{a}{u_{0m}} \frac{R_0}{R_d} \times 100(\%) \qquad (1)$$

$$\delta = \frac{b}{u_{0m}} \frac{R_0}{R_d} \times 3438(') \qquad (2)$$

where u_{0m} is the amplitude of u_0.

The TA calibrator doesn't need very high accuracy. 1% to 3% error for the calibrator is enough. Because of the difference measuring principle, the error is the read error of calibrator, that is, the TA's error's error being measured. But the calibrator needs to have a suitable enlargement factor. The calibrator maximum enlargement factor through all channels should be 1000 times [10][11].

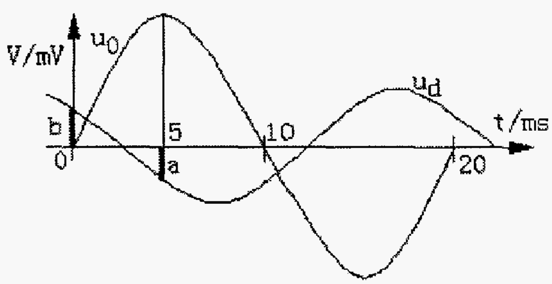

Fig.3 The Sketch map of ratio and phase error

III. THE PRINCIPLE OF VIRTUAL CALIBRATOR

The Virtual Instrument consists of three parts: the external comparison circuit (showed in Fig.1 or Fig.2), data acquisition card (PCI-6023) installed in the PC and the VI program by LabVIEW. Then, after the two channels' signal u_0 and u_d come into the PC through the ADC, the rest of the work is done by the software. In this paper we use voltage u_x on R_b substitute for u_0 approximatively. The virtual calibrator's work flow chart is shown as follow:

1) Set the essential initial values of the virtual calibrator;

2) Press the start button to start to work, adjusting the voltage regulator and changing the primary current, let the ratio between primary current and the rated current change from 10% to 120%;

3) The VI program will group the voltage signal u_x and u_d, then use the digital filter to eliminate the harmonic;

4) Calculate the root-mean-square (RMS) value of u_x and u_d, find out the amplitude of u_0;

5) Calculate the RMS valve of i_0 (substitute for i_x), i_d and the ratio between i_0 and it's rated current and show the results.

6) Find out the **a** and **b** showed in Fig. 3, calculate the ratio error and phase error and show the results.

7) Set the K times loop, record and show the errors acquired by every time;

8) Show and print all the results of calibration.

9) Stop.

The front panel of the virtual calibrator has the Controls, Indictor and Switch. The function of Controls is to set the initial value before it works; The function of the Indictor is to show all kinds of needed values, including digital, curve and diagram etc. . The switch decides the start and stop of the virtual calibrator.

Of course, to change the measuring range, the operator needs to adjust the voltage regulator and change the primary current. This operation is necessary like that of the traditional calibration, but the recording for the error in any range is done by the virtual calibration. This confirms the accuracy of recording and relieves the operator's work. The use of virtual calibrator is most interesting.

The controls of virtual calibrator include:

1) Setting the two sampling (analogue input) channels;

2) Setting the magnitude of sampling resistance in the comparison circuit;

3) Setting the secondary rated current of measured TA;

4) Setting the number of sampling of error curve;

The Indictor of virtual calibrator has:

1) Showing ratio and phase error, ratio between the primary current and the rated ones in digital;:

2) Showing ratio and phase error, ratio between the primary current and the rated ones in curves and diagram, where the curve include the active sampling points and function fitting curves.

3) Showing the error for the ratio between the primary current and the rated current from 10% to 120%;

4) Showing the waveform of standard and error current, digital value of amplitude;

5) Showing of digital RMS value the standard and error current;

6) Showing the pole of TA in the comparison circuit.

The above shows that the function of virtual calibrator is greatly expended that of the traditional ones. This kind of calibrator is not only convenient to use, but also makes the performance of the calibrator much better. From the function that shows the waveform, we can find out if there are some harmonics in the current, and confirm the accuracy for the calibrator.

IV. EXPERIMENT

The virtual calibrator is mainly characterized by the flexibility compared with the traditional ones. Although the front panel has many functions, they can be easily extended by the user. So the virtual calibrator is of important value for the non-standard TA calibration.

In the experiment, the primary current produce by a step-up current transformer and its' current controlled by a voltage regulator. Through fitting the comparison circuit, the measuring range of the virtual calibrator can be set in any value. This paper gives 5A and 0.1A two kinds of TA's calibration experiment. The parameter and method, results are presented below.

A. 5 A TA experiment

The parameter of TA being measured is:

Ratio of turn: $N_p : N_s$=100:100;

Ratio of current: $I_p : I_s$=5A:5A;

Winding resistance: 0.1Ω;

Core size: 70×110×40(mm);

Core material: silicon-steel sheet;

Burden: $R_b = 1\Omega$, cosφ=1.

Because of the 1:1 ratio of turn, the calibration for it doesn't need standard TA. The calibration circuit show in Fig.2. We can apply self calibration method to measure it's accuracy. The results are presented in the Fig.4 and Fig.5 and show that this TA's accuracy can be defined as 0.5 degree.

B. 0.1 A TA experiment

The parameter of standard TA:

Ratio of turns: 1:1000;

Ratio of current: $I_p : I_s$=100A:100mA;

Secondary winding resistance: 8.5Ω;

Core size: 29×46×25(mm);

Core material: permalloy;

Accuracy: 0.01 degree;

The parameter of TA being measured is:

Ratio of turn: $N_p : N_s$=1:1000;

Ratio of current: $I_p : I_s$=100A:100mA;

Secondary winding resistance: 30Ω;

Core size: 20×40×15(mm);

Core material: silicon-steel sheet;

Burden: R_b=35Ω, cosφ=1.

From the Fig.4 and 5, the accuracy of the TA being measured can be defined as 0.5 degree. In the experiment, the input signal of virtual calibrator should be properly grounded to avoid the disturbance. The sampling resistance in the comparison circuit should use precise ones and with no induction.

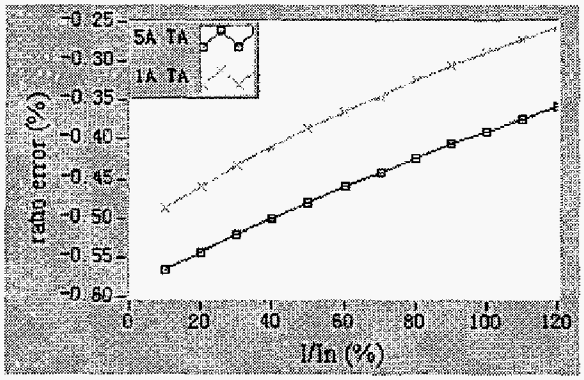

Fig.4 ratio error curves

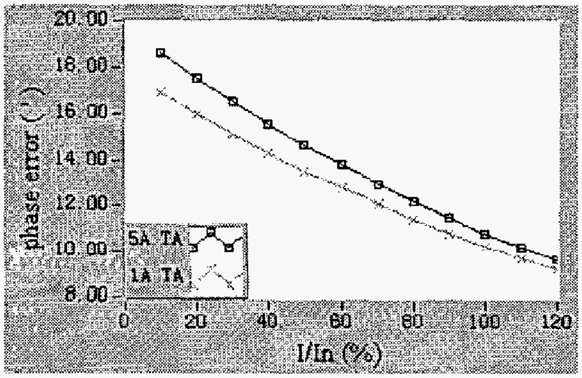

Fig.5 phase error curves

V. CONCLUSIONS

The VI technique is one of the new scientific and technique productions. The appearance of VI is called "Revolution of Measuring and Control Technology". According to the development of the software and hardware for computers, the VI technology will have more developing space. The VIs will replace most of the traditional ones in the 21th century.

With its flexibility, the virtual calibrator can measure any kind of TA including standard and non-standard ones. But the traditional calibrator can not measure most of the non-standard TA. It can record and save, display the data automatically. The method presented in this paper gives a new way to make the TA calibration.

The main characteristics of the virtual calibrator are:

1) Flexibility, virtual calibrator is mainly made of LabVIEW software and can be easily modified by rewrite some software;

2) Multi function, VI is designed on PC. It has waveform indictor, parameter controls and so on. At the time we calibrating a TA's accuracy, these functions can indicate many information such as waveform quality and so on;

3) Convenience to carry and use;

4) High efficiency and accuracy.;

5) High ratio between performance and cost;

6) For multiple use in one PC.

7) It can record and save, display the calibration data automatically.

VI. REFERENCE

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