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# THE ROLE AND IMPORTANCE OF SOFTWARE APPLICATION IN INSTRUMENT TRANSFORMERS ACCURACY TESTING

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Abstract: The application of modern electronic solutions and microprocessor technologies has significantly improved measuring methods and devices for instrument transformers accuracy testing. PC hardware and software application options in this filed of measuring techniques significantly increase reliability, efficiency and accuracy. This paper presents the role and importance of software application in instrument transformer accuracy testing that have been developed by the Electrical Engineering Institute "Nikola Tesla"**.**

**Keywords:** instrument transformer, accuracy testing, software.

## 1. INTRODUCTION

From the metrological standpoint, modern devices for testing measurement transformer accuracy are characterized by high precision and direct reading and printing of the amplitude and phase errors; on the technological level, they use electronic components and microcomputers with adequate software support. Development of mentioned measuring devices has been moved from hardware to software, as a global tendency in measuring technique.

The Electrical Engineering Institute "Nikola Tesla", has been testing instrument transformers accuracy continuously for more than 40 years. During this period, several measurement methods and dozens of different devices have been developed in this field. Significant results have been achieved, especially in the development and application of current comparators, so that the Institute is among the leading manufacturers of measurement equipment in this field. Modern scientific and technological trends are applied to the development and improvement of measurement devices.

The Institute has developed several types of electronic apparatus for instrument transformer accuracy testing, whose operation is supported and improved through the use of microcomputers. Application of particularly developed software had significant role in upgrading them.

This paper presents a review of these new devices for measurement transformer accuracy testing:

- Computer controlled device for automatic testing of current transformer accuracy;
- Computer aided device for standard instrument transformers calibration;
- Virtual instrument for instrument transformers accuracy testing.

## 2. DEVICE FOR AUTOMATIC TESTING

The mass production of low voltage current instrument transformers requires accuracy measurements during manufacture and final product control. As this is a relatively cheap mass produced article, the classical measurement methods are impractical from both the technical and economical standpoints. A significant advance was made by automating the accuracy testing of current transformers. Thus, a computer based device has been developed for the Serbinan transformer manufacturer MINEL-Zrenjanin, for automatic testing of current transformers (ASK-2) [1].

The composition of this device is shown in Fig.1.

The basic components of this measurement system are: a voltage controlled current source (VCCS), compensated current comparator (CCC), the tested transformer ($T_X$), test load (B), reference transformer ($T_R$), analog (AE) and digital (DE) electronic blocks, computer (PC) and printer.

This system is valuable because it uses an original concept for applying the compensated current comparator, static current controller and computer control and measurements. The operator inputs the data on the tested transformer, chooses the test options and the manner and form of registration. The accuracy testing of a single current measurement transformer lasts under ten seconds. CCC performs the current comparison and simultaneously supplies electrical energy to the circuit through the secondary winding of the comparator. The current in the detection winding $N_d$, i.e. the voltage $U_d$, after passing through the current-voltage converter (A) corresponds to the error current $I_g$ of the tested transformer:

$$\underline{U}_d = K \cdot N_d \cdot \frac{N_2}{N_k} \cdot R \cdot \underline{I}_g \qquad (1)$$

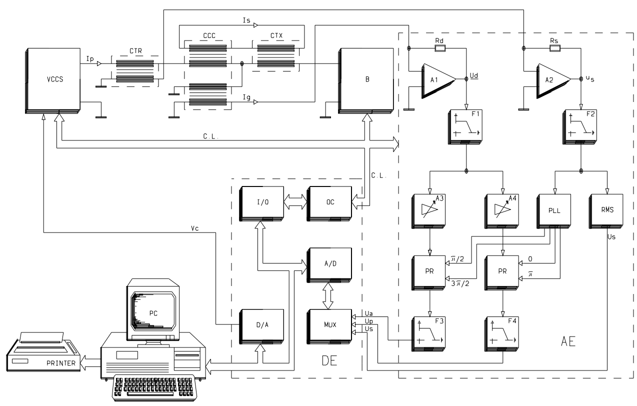


**Fig. 1. Block diagram of automatic testing device, ASK-2**

This hardware is supported by specially developed dedicated software used for mathematical calculations with signals, the visual presentation of measured errors on digital displays and the graphical printing of measurement results on a digital printer. The mathematical processing of measured signals includes zero corrections, calibration, division of two digital signals, averaging and round off measurement results. In order to increase reliability, the most important elements of the device are monitored and the device is additionally protected against operation in irregular conditions (inverted terminals of the tested transformer, operation outside the measurement range, ect.).

All significant parts of the device are under constant software monitoring. Both the correct and irregular operation is indicated by corresponding signal lights. The graphical and numerical presentation of measurement results has been adapted to the ergonometric requirements of efficient and comfortable operation. The final results of measurement transformer accuracy tests are printed in the form of a report which, apart from the results themselves, contains also all the other relevant test data. The report is both printed and stored in the data base.

The ASK-2 has been subjected to a detailed analysis and testing in order to verify the accuracy and the efficiency of measurements and reliability of operation. Individual elements were tested as well as the device as a whole. The results of tests can be summarized as follows:

- error of CCC in the whole range of rated primary and secondary currents does not exceed $10^{-5}$ % and 0.02’,
- the reference current can be adjusted with an error below 1 % and a harmonic factor under 2 %,
- the influence of temperature on the accuracy of measurements is felt only in the analog part of the device and is less than 0.02 % / 10 $^{o}$C,
- the total estimated, declared error of the device is under $\pm$ 0.5 % of the measured amplitude error and $\pm$ 0.02 % and $\pm$ 0.5 % of the measured phase error and $\pm$ 0.5’, and
- the effective accuracy testing time of a current measurement transformer, for the standard set of test points is 9.5 s.

Due to good metrological characteristics, this device can be used to test current instrument transformers with accuracy classes from 0.1 to 3. Its testing speed places this device among the most efficient of its kind. Finally, and very importantly, this has been achieved without sacrificing the accuracy of measurement.

## 3. DEVICE FOR STANDARD TRANSFORMERS CALIBRATION - INST-2A

Standard instrument transformers calibration is a very complex and delicate metrological task given that the required measurement accuracy in this case is ten times greater than in the accuracy testing of instrument transformers class 0.1. Such a device is developed for the standard instrument transformer calibration needs of the National Metrology Institute of Serbia and Montenegro. The composition of INST-2A can be seen from block diagram in Fig.2.

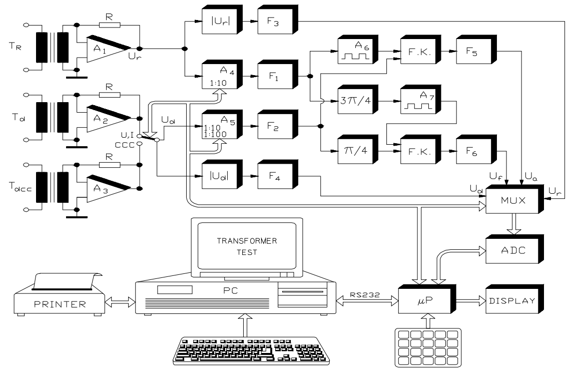


**Fig. 2. Block diagram of device INST-2A**

### *3.1. Principle of operation*

INST-2 electronically processes two voltages, the reference voltage $U_R$ and the differential voltage $U_d$. The first voltage $U_R$ corresponds to the secondary current or voltage of the reference transformer, while the differential voltage $U_d$ corresponds to the complex error of the measurement transformer. The vector diagram of these voltages is given in Fig.3, which shows their basic harmonics with a defined amplitude and phase error.

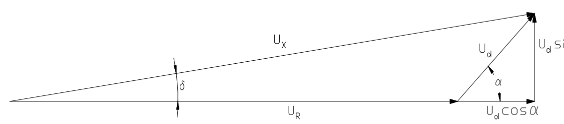


**Fig. 3. Voltage vector diagram for the differential method.**

Equations which describe the ratios of these voltages and their relation to the complex error $\underline{G}$, amplitude error $g_a$ and phase error $g_f$ of the measurement transformer are:

$$\underline{G} = g_a + g_f \tag{2}$$

$$\underline{G} = \frac{U_x - U_R}{U_R} = \frac{U_d}{U_R} \tag{3}$$

$$g_a = \frac{U_d \cdot \cos\alpha}{U_R} \tag{4}$$

$$g_f = \delta \approx tg\delta = \frac{U_d \cdot \sin\alpha}{U_R + U_d \cdot \cos\alpha} \tag{5}$$

### *3.2. Description of hardware*

INST-2 has several interconnected modules on PCBs (Europa format). This approach was dictated by the complexity of the device, ease of adjustment, testing and servicing. The analog part is technologically based on low offset and low noise integrated circuits OP77 and OP37, made by PMI. The digital part uses “Intel” chips, SAB8031. For a 14-bit A/D converter, type 7135 by Intersill is used. The 13 mm high digital 7-segment LED displays type HDN 1033 permit easy and clear reading of measured error.

### 3.3. *Description of software*

Special care was paid on the development of the software. The result is a custom made program for the precise testing of measurement transformer accuracy. It contains several software blocks: operational, measurement, mathematical-logical, data base, control-signalizing block and block for the graphical and numerical presentation of measurement results.

The operational block initializes the device, chooses functions and the rated values of the tested transformer. The measurement block automatically selects the gain and controls the analog multiplexer and A/D converter. The mathematical-logical part processes the results, performs calibration, averaging, elimination, roundoff and indication of measurement results. The elimination of coarse errors is a subprogram in the algorithm for finding the mean value of measurements, performed in order to decrease chance errors. For the deviation of individual results from the mean value Schoven's criterion is used. This turned out to be a good approach which increases the accuracy of measurement results. All significant parts of the device are under constant software monitoring. Both the correct and irregular operation are indicated by corresponding signal lights. The graphical and numerical presentation of measurement results has been adapted to the ergonometrical requirements of efficient and comfortable operation. The final results of measurement transformer accuracy tests are printed in the form of a report which, apart from the results themselves, contains also all the other relevant test data. The report is both printed and stored in the data base.

The technical characteristics of INST-2A are presented in table 1.

Device INST-2A is a modern measurement device with good metrological characteristics. Strong software support of the measurement, mathematical processing, visual graphical presentation and the printing of results enables an accurate and reliable, efficient and comfortable operation.

**Table 1. Technical characteristics of INST-2A**

| | Amplitude error | Phase error |
|---|---|---|
| Measurement ranges | ± 0.2 % and<br>± 2 % | ± 10′ and ± 100′ |
| Max. resolution of reading | 0.0001 % | 0.0001′ |
| Estimated accuracy | 0.1 % of the measured value and ± 0.0002 % | ± 0.1 of the measured value and ± 0.0001' |
| Rated voltages | 100 V, 110 V, 120 V, 100/√3 V, 110/√3 V, 120/√3 V, 200/√3 V | |
| Rated currents | 1 A and 5 A | |

## 4. VIRTUAL DEVICES

A wider meaning of this term relates to the modern concept of a flexible, multipurpose, universal hardware and specific, custom made software in powerful program packages for measurement and acquisition, usually based on object programming. The use of this concept in the manufacture of the virtual devices for testing instrument transformer accuracy by non-conventional and non-linear mathematical models (non standard transformers ratio method [2], two-phase conversion method [3] or DFT method [4] is not more fashion, but a realistic possibility and optimum solution. The structure of virtual instrument for accuracy testing by DFT method, developed in the Institute, is presented in fig.3.

The differential method assumes that there is a reference transformer $T_N$ with a transformer ratio $n_N$ equal to the rated ratio $n_X$ of current transformer $T_X$ being retified. The voltage $u_N$ coresponds to the secondary current $i''_N$ of the reference transformer $T_N$, while the diferential voltage $u_d$ corespodents to the complex error of the current transformer $T_X$.

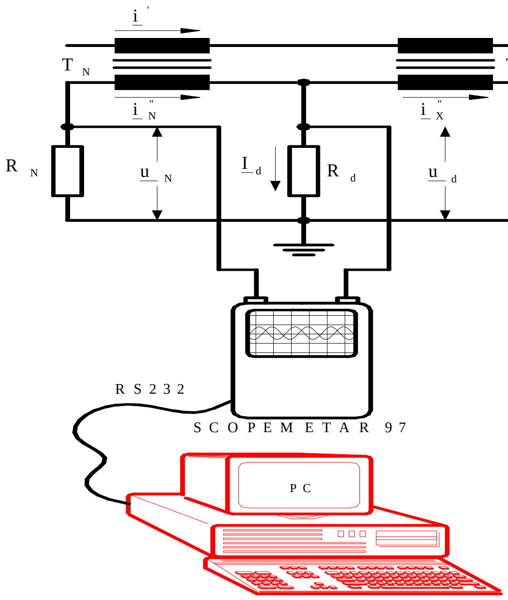


**Fig. 3. The virtual instrument structure**

The method based on integration of DFT virtual instrument concept, composed of standard hardware (osciloscope, PC) and specific software is outlinned. The voltages $u_n$ and $u_d$ are acquierd by dual-channel digital osciloskop. Through serial interface RS232 they are input into PC and, by the DFT method both voltages $U_{1N}$ and $U_{1d}$ and phase schift of first harmonics are calculated.

The structure of this virtual device is generrally dictated by the mathematical model described by eguations:

$$g_x = \frac{b_{d1}b_{N1} + a_{d1}a_{N1}}{a_{N1}^2 + b_{N1}^2} \cdot \frac{R_N}{R_d} \cdot 100 + g_N \qquad (6)$$

$$\delta_x = \frac{a_{d1}b_{N1} - b_{d1}a_{N1}}{a_{N1}^2 + b_{N1}^2} \cdot \frac{R_N}{R_d} \cdot 3440 + \delta_N \qquad (7)$$

The equations (6) and (7), expresing the amplitude $g_x$ and phase $\delta_x$ errors as functions of DFT coefficients ($a_{d1}$, $a_{N1,}$ $b_{d1}$, $b_{N1}$). Parameters $R_N$ , $R_d$ , $g_N$ and $\delta_N$ , are comlex, but that mathematical model is both very accurate and easy to implement by PC. Apart from a few electronic moduls, a standard strukture is used, typical for the majority of electronic instruments operating in conjuction with a PC. What really makes this hardware do the necessary task is the dedicated software.

The software package is designed for realisation and programming of virtual instrument that combines all the characteristics of object and graphic programming which simplifies and makes faster the task of writing particular applications. The main advantages of the VI-DFT method are that strong, flexible and standard hardware combined with powerful, flexible and easily changeable software, resulting, compared to the classical concept in improved performances, reduced cost and time of development.

The basic characteristics of the software for virtual instruments are:

- object oriented programming,
- simulation of operation of the measurement instrument in the whole aplication range in order to analiyze measurement errors and test for the correct operation,
- calibration of the instrument and corection of measurement results,
- computer processing of the digital measurement signal and
- visual presentation of results of measurement, archiving and printing.

The experimental test performed on the realised system shows the validity of the followed approach and very good degree of coicidence with the classical instruments. The concept proposed and the hardware and software structures presented are strong enough to support laboratory and on-site, standard and non standard, accuracy testing of instrument transformer.

## 4. CONCLUSION

The devices presented in this paper for testing of measuremet transformer accuracy from part of the class of modern microcomputer based measurement systems. Accuracy, operating speed, reliabilityand integrity remain long-term goals of computer-based instrumentacion. Scientific and technical and technological advances open up new possibilities and approaches in this area of metrology. The role and importance of software aplication in instrument transformers accuracy testing are unavoidable.

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