Procedure for Verification of Measuring Transformer Accuracy based on LabVIEW Software

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Abstract – **Solution of the experimental measurement and data acquisition system, designed for verification of voltage measuring transformer accuracy in laboratory conditions, is presented in this paper. Functional basis of developed solution is provided by virtual instrumentation software package LabVIEW. Described acquisition system includes standard PC configuration platform with application software, multifunctional calibration instrument Fluke 5100B for generation of reference voltage signals and data acquisition card PCI NI 6251. Software application developed in LabVIEW programming environment, performs measurement, recording, presentation and statistical processing of transformer output voltage basic parameters. Statistical analysis of obtained measuring results, with possibility for graphical presentation of recorded time diagrams for measured voltage parameter values, provides estimation of the mean measured parameter values and measuring uncertainty components, according to the documents for estimation and expression of the uncertainty in measurement.**

Keywords – **Voltage measuring transformer, LabVIEW virtual instrumentation software, Measuring uncertainty.**

I. Introduction

With rapid growth of the electrical energy consumption and limitations of natural resources for energy production, a basic demand is increasing of the total efficiency level in electrical energy production, distribution and consumption processes. In globally widespread process of liberalization on the electrical energy world market, within the last ten years are created new technological demands for research and development facilities and institutions over the world. Significant characteristics of this process are involving and integration of wide geographic areas in electrical energy trading operations, which include the increased number of energy market participants, much greater amount of the business transactions and significantly higher number of data and information which must be exchanged and processed. Very important segments in the mentioned process of the energy efficiency level increasing, are measurement and analysis of the basic quality parameters regarding to electrical energy delivered to the individual customers. Measurement of basic voltage, current, power and energy parameters includes measuring transformers, applied in various types of regulation and control energy facilities. Measuring accuracy of the used voltage and current transformers, conclusively affects on total accuracy of the complete measurement process. Especially are important measurements performed for precise determination of the individual customers energy consumption level, which demands measuring transformers of high accuracy class [1].

Procedure for checking of voltage measuring transformers accuracy and condition diagnostic need to be performed inside accredited metrological laboratories or directly on locations of the remote measuring transformer facilities, periodically in the specified time intervals. Such accuracy verification procedure requires sophisticated measurement methods and appropriate measurement and control devices, having high accuracy level. This equipment foremost considers calibration instrument for generation of the reference input voltage parameters, defined by relevant documents, with checking instruments applied for measurement of the transformer output voltage parameters.

Realization of experimental laboratory measurement and data acquisition system, described in this paper, developed for checking of the low voltage measuring transformer accuracy, is functionally based on 16-channel data acquisition PCI card NI 6251 [2], supported by PC programming application inside LabVIEW graphical software environment [3]. As a reference instrument for providing transformer input standard voltage signals with 230V RMS value and 50Hz frequency, is applied multifunctional calibration device Fluke 5100B [4]. Designed programming application performs measurement, continuous recording, graphical presentation and statistical processing of voltage parameter values, measured on controlled transformer voltage outputs. Software processing of the measured values is performed according to relevant documents which prescribe calculation and expression of the measuring uncertainty data.

II. Hardware Block Configuration of the Measurement and Acquisition System

Configuration of the experimental laboratory measurement and acquisition system, for low voltage measuring transformer accuracy checking, developed at Department of Measurement on the Faculty of Electronic Engineering in Niš, is presented in the Fig 1. Hardware configuration of the developed solution includes reference calibration instrument Fluke 5100B, data acquisition PCI card NI 6251 and LabVIEW 8.0 application software support, installed on the standard PC programming platform. Calibration device Fluke 5100B is microprocessor based instrument programmable by the users from instrument front panel. Depending on actual requirements, this instrument provides generation of reference AC voltage waveforms with RMS values within the range from 1mV to 1100V and signal frequency from 50Hz to 1KHz. For this specific application, calibration device generates reference standard voltage signals for measuring transformer inputs, having the basic parameters

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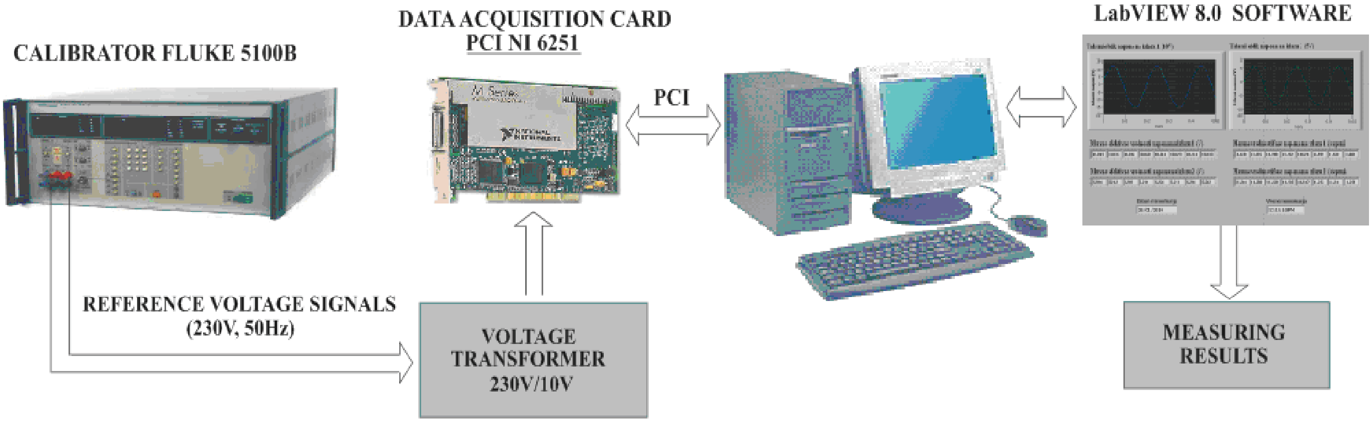

Fig. 1. Simplified block configuration of the developed experimental measurement and data acquisition system

230V RMS values and 50Hz signal frequency, according to European power quality standard EN 50160, which prescribes basic voltage characteristics for electricity supplied using the public distribution systems [5]. Reference voltage waveforms generated on calibration device outputs, are transferring using the standard BNC connectors directly to the inputs of voltage masuring transformer, which accuracy need to be checked. In the next segment of this procedure, voltage signals generated on measuring transformer outputs, within the range of ±10V, must be transferred to the inputs of data acquisition card A/D converter, with 16-bit resolution [2]. Multichannel acquisition card NI 6251, from american manufacturer company National Instruments Corporation, for this specific application purpose uses two analog input channels, which receive voltage signals from measuring transformer outputs having specified 10V and 5V nominal RMS voltage values. Internal communication and two-way data interchange between data acquisition card and PC computer is provided using standard PCI communication interface. Described procedure for verification of the voltage measuring transformer accuracy is software controlled using programming application designed in LabVIEW environment, which will be described in the following segment of the paper.

III. LabVIEW Software Support of the System

Concept of the virtual measuring instrumentation is method for development of measuring instruments, based on standard PC computers or industrial operational stations, cost effective hardware components applied for measuring data acquisition and programming packages specialized for software supported analysis and graphical presentation of the obtained measuring results. Hardware segment of the virtual measuring instrument is consisting of computer and data acquisition card. Software section of such instruments is programmed depending on user requirements using predesigned functioning blocks, individual elements and instrument front panels from software package databases. A most important advantages of virtual measuring instruments are possibilities for performing simple and fast corrections of the software algorithm sequence which controls execution of the computer supported measuring procedure [3].

Automated procedure for measuring transformer accuracy checking, described in this paper, functionally is supported by control software application developed using LabVIEW 8.0 graphical programming package. Developed control software application performs measurements, chronological recordings,

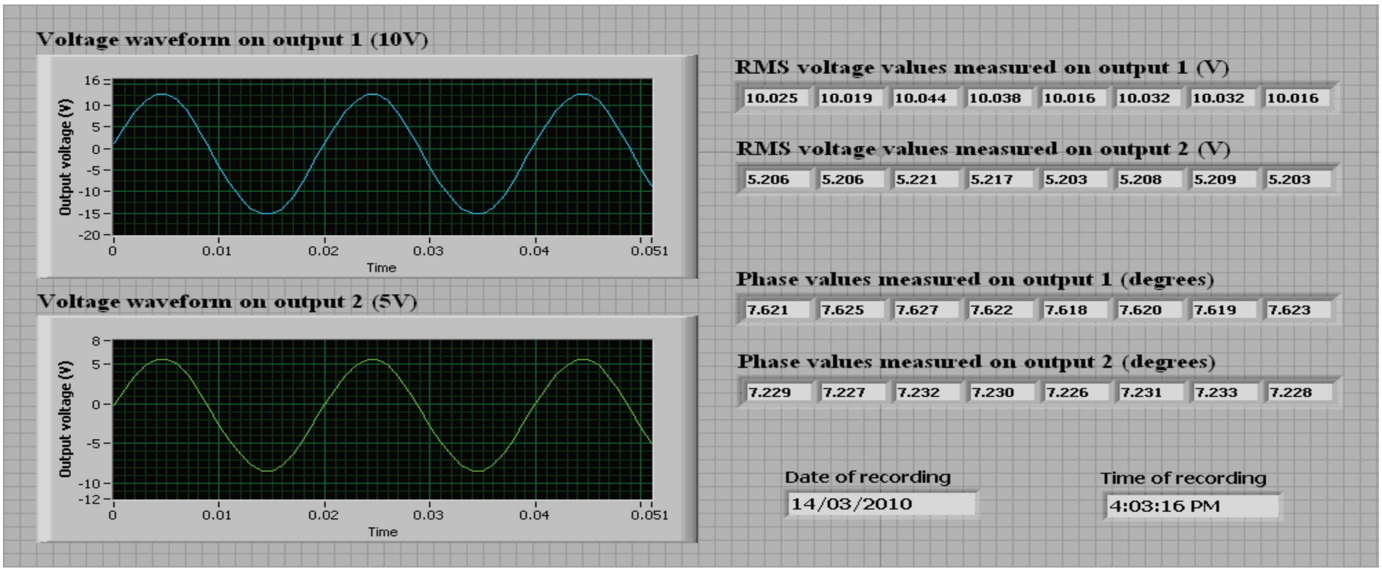

Fig. 2. LabVIEW virtual instrument for graphical presentation of the output voltage waveforms and measured voltage parameters

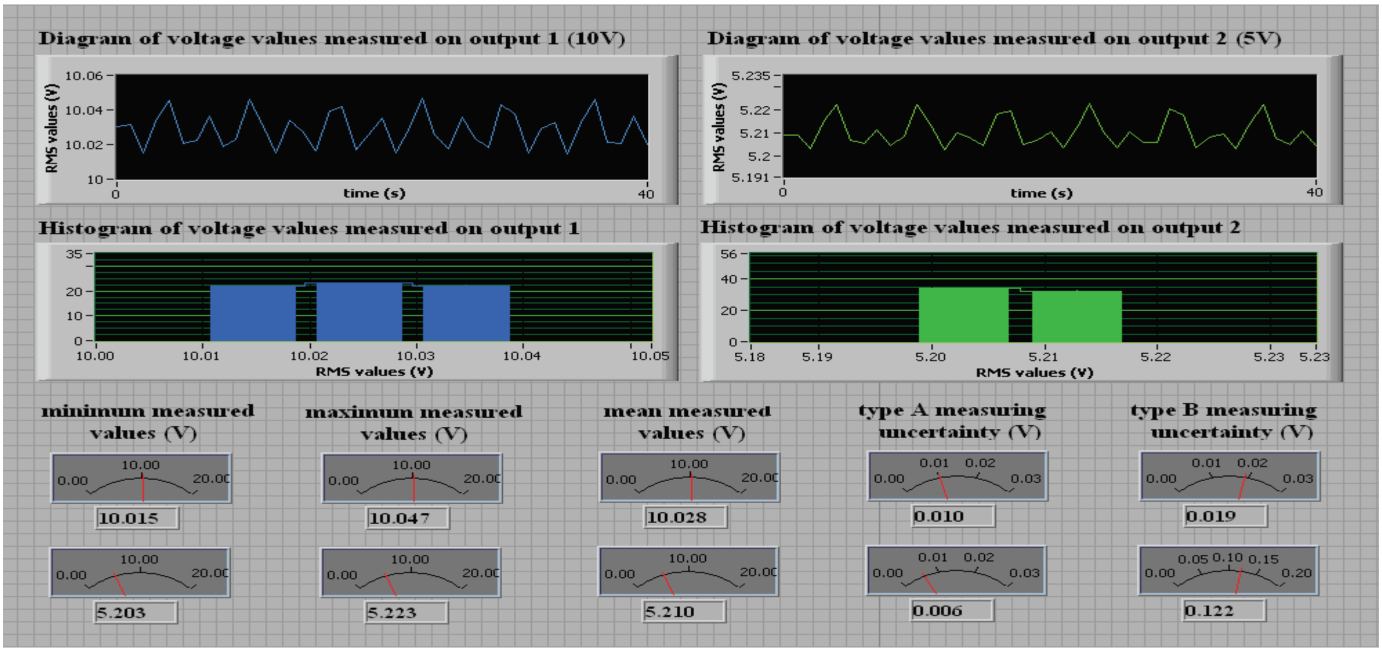

Fig. 3. Statistical processing of the measured RMS output voltage values performed in LabVIEW programming environment

graphical presentations and statistical processing of measuring results concerning RMS voltage values on transformer output, phases, frequency and high-order harmonic components of the output voltage signals. Front panel of the virtual instrument, developed in the LabVIEW programming environment, which provides comparative graphical presentation of voltage signals recorded on measuring transformer outputs, is presented in the Fig 2. Besides graphical presentation of output voltage signal waveforms, on the virtual instrument front panel are indicated measuring results concerning RMS voltage values and phases measured on the transformer 10V and 5V outputs. Additional information regarding to exact date and time of the presented voltage signals recording are also provided on this front panel.

Software supported procedure for statistical analysis of the obtained measuring results regarding to RMS voltage values measured on transformer outputs, performed in the LabVIEW environment, is illustrated in the Fig 3. Developed application software performs comparative graphical presentation of the recorded time diagrams and corresponding statistic histograms for measured RMS values of transformer output waveforms. On presented virtual instrument front panel are also indicated minimum and maximum voltage values obtained during this measuring process on voltage transformer outputs, including calculations and numeric presentation of the mean measured voltage values, with the corresponding measuring uncertainty components for both transformer outputs. The mean measured RMS output voltage values indicated on the virtual instrument front panel, are calculated as an arithmetical mean of obtained measured voltage values, as it shown in the following relation:

$$V_{mean} = \frac{1}{n}\sum_{i=1}^{n} V_i \quad (1)$$

Procedure for calculation of measuring uncertainty values is performed according to recommendations of document: Guide to the Expression of Uncertainty in Measurement [6], defined from the International Organization for Standardization - ISO.

Calculation of type A standard uncertainty component values is performed according to statistical procedures applied on the obtained measuring results, by means of following square root equation for statistical standard deviation of measured values:

$$u_A(V) = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}\left(V_i - V_{mean}\right)^2} \quad (2)$$

Standard measuring uncertainty components of the type B are estimated on the basis of data obtained from specifications of the reference calibration instrument Fluke 5100B, provided by instrument manufacturer. According to these specifications for nominal frequency value of 50Hz, reference AC voltage signals are generated with specified nominal relative accuracy value of 0.05% [4]. Considering this specified accuracy value, for type B standard uncertainty components of the measured transformer output voltages are obtained the following results:

$$u_{B1}(V) = \frac{1}{\sqrt{3}}\frac{0.05}{100}10V + \frac{0.028V}{\sqrt{3}} = 0.019V \quad (3)$$

$$u_{B2}(V) = \frac{1}{\sqrt{3}}\frac{0.05}{100}5V + \frac{0.210V}{\sqrt{3}} = 0.122V \quad (4)$$

From previously calculated individual values of measuring uncertainty components of the type A and type B, combined measuring uncertainty components for measured transformer output voltages are calculated using next square root relations:

$$u_{C1}(V) = \sqrt{u_{A1}^2 + u_{B1}^2} = 0.021V \quad (5)$$

$$u_{C2}(V) = \sqrt{u_{A2}^2 + u_{B2}^2} = 0.122V \quad (6)$$

Software processing of the voltage signal frequency values measured on first and second voltage output of the measuring transformer and performed by means of LabVIEW application software, is presented in the Fig 4. Similar with the previously described procedure for statistical processing of the measured RMS output voltage values, on shown virtual instrument front

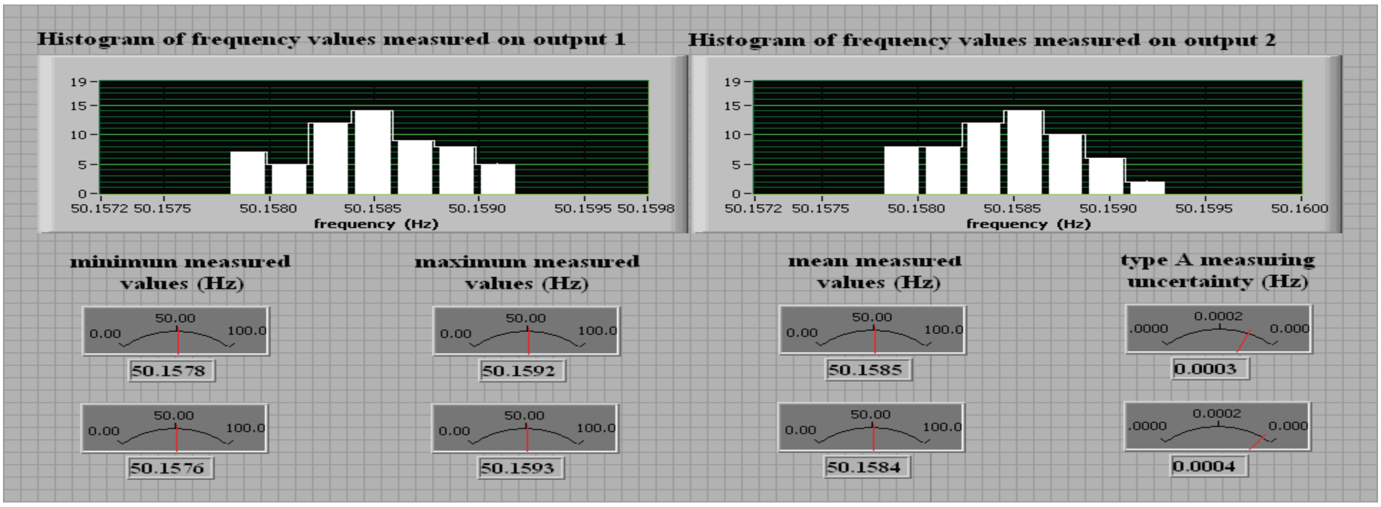

Fig. 4. LabVIEW based statistical processing of the signal frequency values measured on the voltage transformer outputs

panel are illustrated two statistical histograms concerning the signal frequency values measured on 10V and 5V transformer voltage outputs. Presented statistical analysis procedure also includes indication of the minimum and maximum measured frequency values, together with calculation of mean measured frequencies and measuring uncertainty components of type A.

Finally, a form of the final report from previously described procedure applied for voltage measuring transformer accuracy verification, is presented in the Table 1. By this table is given short summary of the measured values concerning transformer output voltage basic parameters, obtained from this procedure.

TABLE I
FINAL SUMMARY OF THE MEASURED OUTPUT VOLTAGE BASIC PARAMETERS

measurement of the RMS voltage values		
measured values	output 1	output 2
minimum values	10.015 V	5.203 V
maximum values	10.047 V	5.223 V
mean values	10.028 V	5.210 V
type A uncertainty	0.010 V	0.006 V
type B uncertainty	0.019 V	0.122 V
combined uncertainty	0.021 V	0.122 V
measurement of the frequency values		
minimum values	50.1578 Hz	50.1576 Hz
maximum values	50.1592 Hz	50.1593 Hz
mean values	50.1585 Hz	50.1584 Hz
type A uncertainty	0.0003 Hz	0.0004 Hz
measurement of the high-order harmonics		
3rd order harmonic	1.583 %	1.589 %
5th order harmonic	0.492 %	0,495 %
7th order harmonic	0.315 %	0,319 %
9th order harmonic	0.194 %	0.197 %

IV. CONCLUSION

Possibilities of using virtual instrumentation software in the procedure for metrological verification of voltage transformer accuracy, based on software processing of measured voltage basic parameter values, are presented in this paper. Reference standard voltage waveforms for measuring transformer inputs are provided using calibration device Fluke 5100B. Hardware section of the developed measurement and acquisition system includes PC computer and data acquisition card PCI NI 6251. Programming application designed in LabVIEW 8.0 software package performs measurement, recording, presentation and statistical processing of measured RMS output voltage values, phase, frequency and high-order harmonic components. This software analysis includes graphical presentation of measured values time diagrams, indication of minimum and maximum measured values, calculation of the mean measured values and standard measuring uncertainties. Presented solution based on the cost-effective acquisition hardware components eliminates demands for manual measurements of output voltage for each point of the input voltage changing, due to providing complete software automation of the metrological verification process.

REFERENCES

[1] T. Chiulan, B. Pantelimon, “Power Transformer Units Condition Assessment Using Virtual Instrumentation”, Jour. of Electronics and Electrical Engineering, Telecommunications Engineering, No. 6(86), 2008.

[2] Data Acquisition Card NI PCI 6251 Specifications, National Instruments Corporation, USA, 2005 (http://www.ni.com).

[3] LabVIEW 8.0 User Manual, National Instruments Corporation, USA, 2007 (http://www.ni.com).

[4] Multifunction Calibrator Fluke 5100 Series B Instruction User Manual, Fluke Corporation, USA.

[5] EN 50160 Power Quality Standard, Power Quality Access Meters and EN50160, Siemens, May, 2003.

[6] Guide to the Expression of Uncertainty in Measurement, ISO organization, Geneva, Switzerland, 1993.