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VOLTAGE TRANSFORMER CHECKING PROCEDURE BASED ON THE VIRTUAL INSTRUMENTATION SOFTWARE

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Abstract: *Possibilities of using virtual instrumentation software in the voltage transformer checking procedure based on software supported processing of transformer output voltage measurement results, are presented in this paper. Reference voltage parameters on the transformer inputs are providing by multifunctional calibrator Fluke 5100B. System hardware segment includes computer and data acquisition card NI USB 6008. Transformer output voltages are transferring directly to the acquisition card A/D converter. LabVIEW software application performs measurement, recording, presentation and processing of measurement results concerning RMS values, frequency and voltage harmonic components. Statistical processing of measurement results, with possibility for presentation of recorded measured values diagrams and histograms, provides calculation of mean measured parameter values and measurement results uncertainty components.*

Key Words: ***Voltage Transformer/LabVIEW Virtual Instrumentation Software/Measurement Uncertainty***

1. INTRODUCTION

Deregulation and liberalization of the world electrical energy market, as globally widespread processes in the last ten years, are created new technological demands for research and development facilities and institutions over the world. Basic characteristics of mentined activities are involving and integration of wide geographic areas in the electrical energy trading operations, including increased number of energy market participants, greater amount of business transactions and significantly higher number of useful data and information which need to be exchanged and processed. With rapid growth of the electrical energy consumption and limitations of the natural resources for energy production, imperative demand is increasing of total efficiency level in energy production, distribution and consumption processes. In the procedures for voltage transformer checking and condition diagnostics, as very important aspects of the mentioned demands, individual measurement processes need to be rapidly replaced with the integrated software supported measurement and data acquisition systems. On the other hand, periodically time planned transformer maintenance inspection is replaced by diagnostics required by current transformer condition, which considers prediction of probable unwanted events and includes applying of modern sophisticated computer communication technologies and global databases [1,2].

Performing of valid and reliable voltage transformer accuracy checking process inside accredited metrological laboratories, requires adequate measurement and control equipment. This foremost considers reference instrument for generation of by standards defined reference voltage signals and checking instrument for measurement of the transformer output voltage parameters. In this paper is given solution for experimental laboratory measurement and data acquisition system designed for checking of the low voltage transformer characteristics. Solution is based on 12-channel acquisition USB card NI 6008 [3], which is supported with PC programming application realized in LabVIEW 8.0 graphical software environment [4]. As reference instrument for providing the transformer input standard voltage signals with 230V RMS value and 50Hz frequency, is used the multifunctional calibration device Fluke 5100B [5]. Designed software application provides measurement, graphic presentation, continuous recording and statistical analysis of basic voltage parameter values measured on controlled transformer outputs, according to relevant documents which prescribe the calculation and expression of measurement data uncertainty components.

2. HARDWARE CONFIGURATION OF THE MEASUREMENT SYSTEM

Hardware block configuration of the experimental laboratory measurement and data acquisition system for low voltage transformer accuracy checking, developed at Department of Measurement on the Faculty of Electronic Engineering in Niš, is presented on the figure 1. Realized solution includes reference calibration instrument Fluke 5100B, data acquisition card NI 6008 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 across instrument front panel. According to current user requirements, this instrument provides generation of reference AC voltage signals having RMS values within the range from 1mV to 1100V and signal frequency from 50Hz to 1KHz. In this specific case calibrator generates reference standard voltage signals for transformer inputs, having the basic parameters 230V RMS values and 50Hz

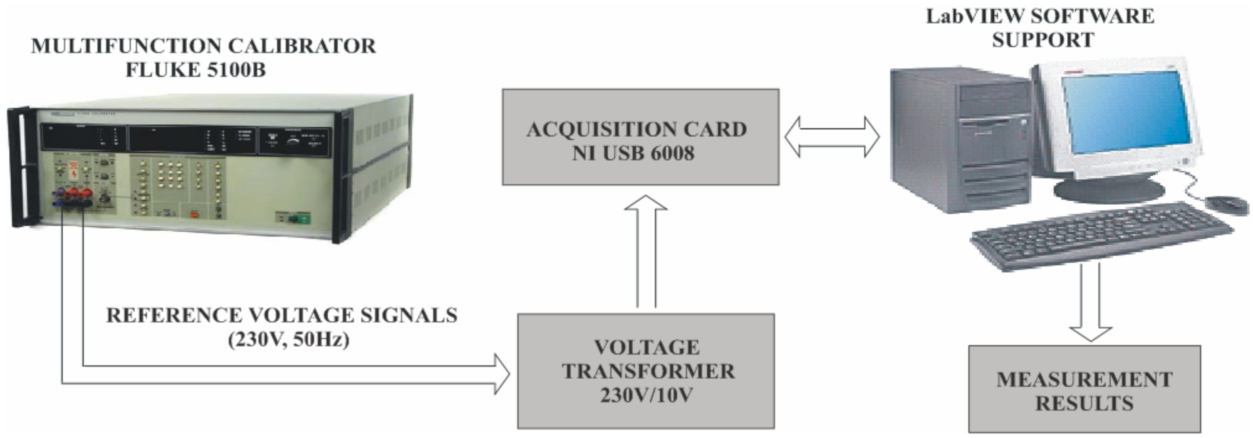

Fig. 1. *Hardware block configuration of the experimental measurement and data acquisition system*

frequency, according to European power quality standard EN 50160, which prescribes basic voltage characteristics of electricity supplied by public distribution network [6]. By using the standard BNC connector wires generated reference voltage signals are transferred directly to inputs of the voltage transformer, which need to be checked. In a next stage real voltage signals generated on transformer outputs, within a range of ±10V, need to be transferred to inputs of the data acquisition card A/D converter having 12-bit resolution. Multichannel acquisition card NI 6008, produced by the american company National Instruments Corporation, for this specific application uses two analog input channels, which receive measurement signals from transformer outputs, having 10V and 5V RMS nominal voltage values. Internal two-way communication and data exchange between acquisition card and computer is provided by the standard USB communication interface. Described procedure for checking of voltage transformer characteristics is software controlled using programming application developed in LabVIEW environment, which will be described in the following segment of this paper.

3. LABVIEW BASED SOFTWARE SUPPORT

Virtual instrumentation concept means methodology for development of measurement instruments, based on standard PC computers and industrial working stations, cost effective hardware components for data acquisition and specialized software tools for analysis and graphical presentation of obtained measurement results. Hardware segment of virtual instrument includes computer and data acquisition card. Virtual instrument software segment is programmed depending on user requests on the basis of predesigned functional blocks, elements and instrument front panels from software databases. A most important advantage of virtual instruments is possibility for simple and fast correction of software algorithm sequence which controls execution of certain measurement procedure [7].

Voltage transformer checking procedure, described in this paper, functionally is supported by control software application in LabVIEW 8.0 programming package. This software application performs continuous measurement, chronological data recording, graphical presentation and statistical based processing of measured output voltage RMS values, frequency and high-order voltage harmonic components. Front panel of virtual instrument developed in LabVIEW environment, which performs comparative graphical presentation of voltage waveforms recorded on transformer inputs and outputs, is presented on figure 2. Besides presentation of the voltage signal waveforms, on virtual instrument front panel are presented measurement results concerning RMS voltage values measured on the transformar 10V and 5V outputs. Additional information regarding to exact date and time of the presented voltage signal recording are also provided on instrument panel.

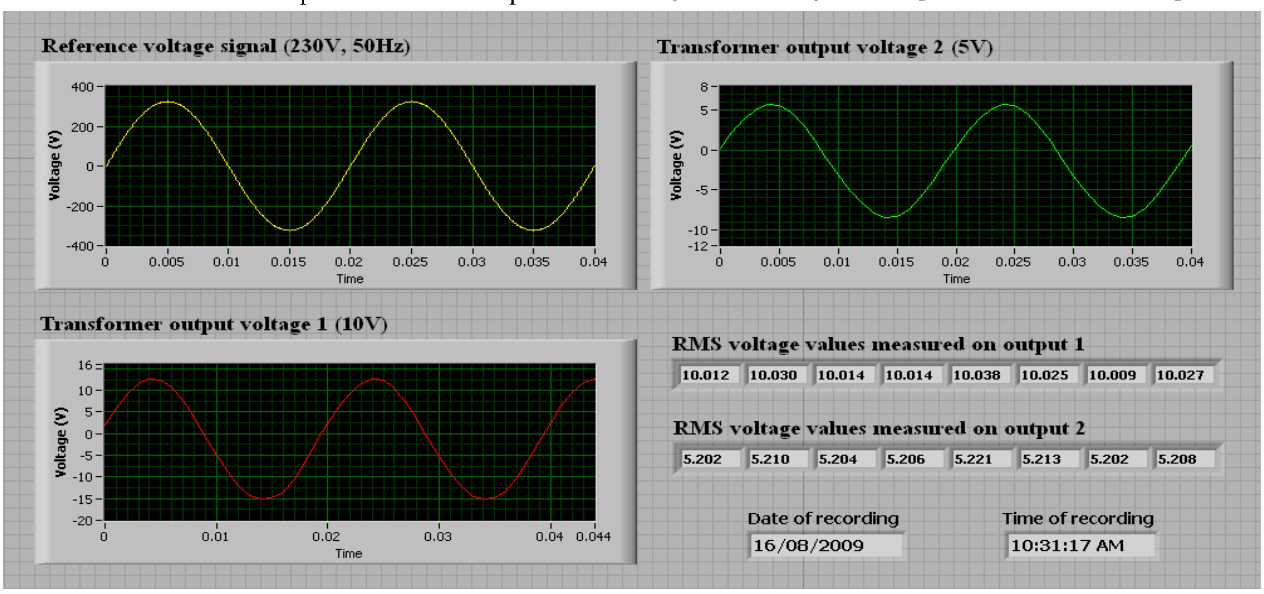

Fig. 2. *LabVIEW presentation of the transformer input and output signals and measured RMS voltage values*

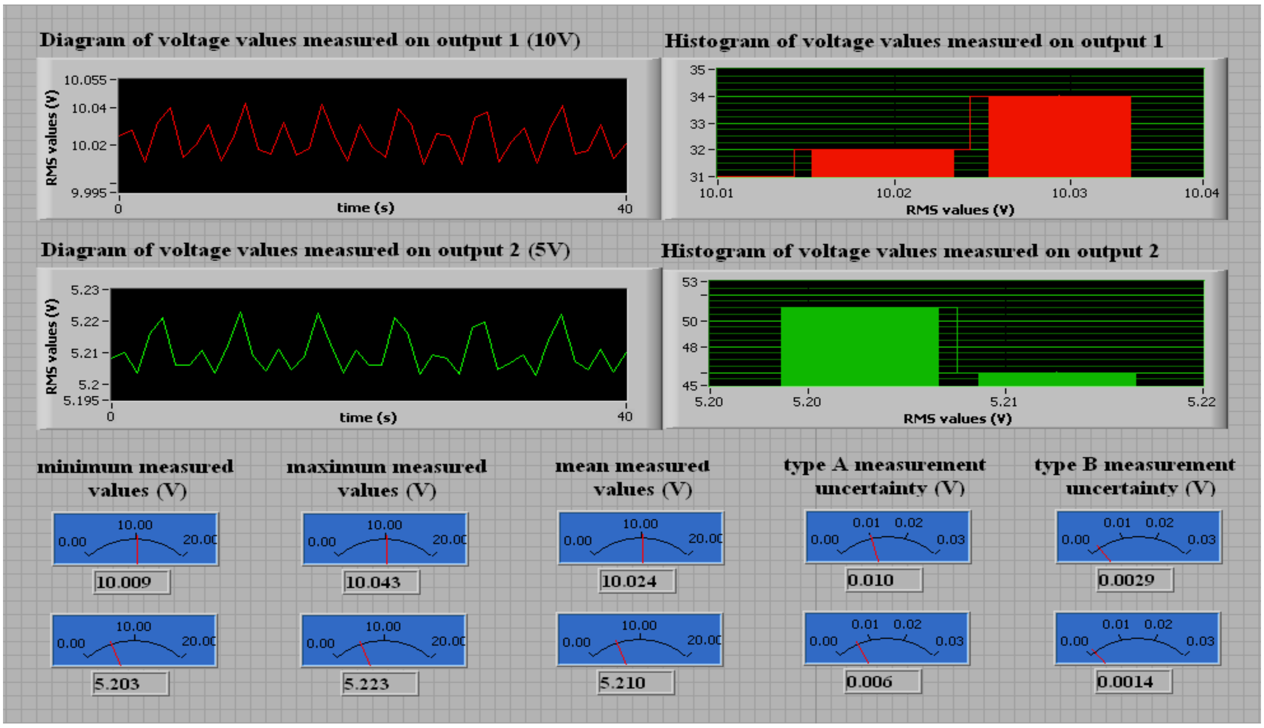

Fig. 3. *Statistical analysis of the measured RMS output voltage values in LabVIEW software environment*

Statistical processing of obtained measurement results concerning RMS voltage values on transformer outputs, performed in the LabVIEW programming environment is illustrated on the figure 3. Designed software application provides graphic presentation of recorded time diagrams and corresponding statistical histograms for successively measured RMS transformer output voltage values. Also, on presented virtual instrument front panel are indicated minimum and maximum voltage values measured on two transformer outputs, including calculation and numeric presentation of mean measured output voltage values and corresponding measurement uncertainty components for both transformer outputs. Mean measured RMS output voltage values indicated on this virtual instrument front panel, are calculated as arithmetical mean of obtained measurement data, as it given by following relation:

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

Procedure for calculation of measurement uncertainty components is performed according to recommendations of document Guide to the Expression of Uncertainty in Measurement [8], defined by International Organization for Standardization - ISO. Calculation of type A standard uncertainty component values is performed according to statistical methods applied on the obtained measurement results, using following equation for standard deviation:

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

Standard measurement uncertainty components of the type B are calculated on the basis of data obtained from reference calibration device Fluke 5100B specifications, provided by instrument manufacturer. According to these specifications for 50Hz nominal frequency, reference AC voltage waveforms are generated with specified nominal relative accuracy value 0.05% [5]. Considering specified data, for type B standard uncertainty values of measured transformer output voltages are obtained following data:

$$u_{B1}(V) = \frac{1}{\sqrt{3}}\frac{0.05}{100}10V = 0.0029V \qquad (3)$$

$$u_{B2}(V) = \frac{1}{\sqrt{3}}\frac{0.05}{100}5V = 0.0014V \qquad (4)$$

Using previously calculated individual measurement uncertainty components of type A and type B, combined measurement uncertainty values for transformer voltage outputs are calculated from the next square root relation:

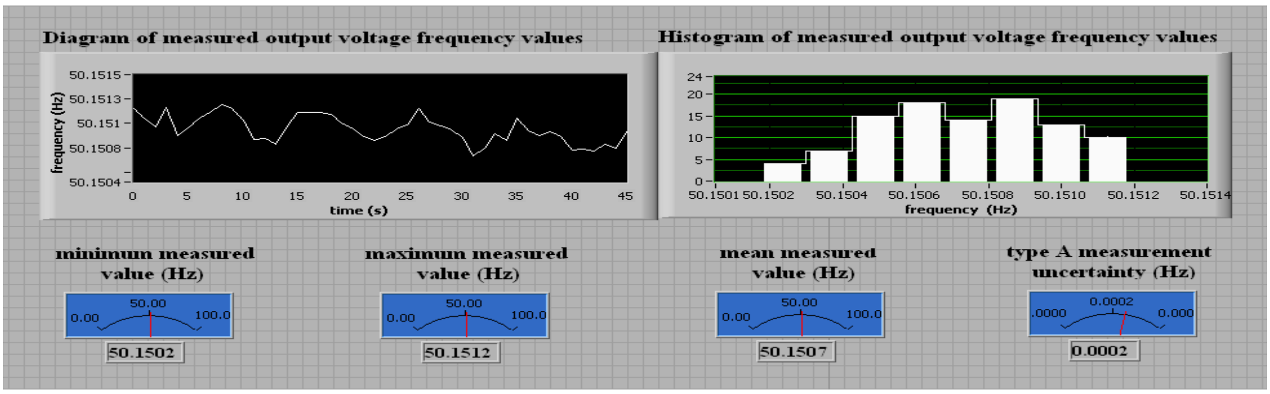

Fig. 4. *LabVIEW software analysis of the signal frequency values measured on transformer output*

$$u_{C1}(V) = \sqrt{u_{A1}^2 + u_{B1}^2} = 0.0104V \quad (5)$$

$$u_{C2}(V) = \sqrt{u_{A2}^2 + u_{B2}^2} = 0.0062V \quad (6)$$

Software analysis of the voltage signal frequency values measured on transformer output performed by LabVIEW software application, is presented on the figure 4. Similar with previously described RMS voltage value analysis, here are also presented time diagram and histogram for measured frequency values, including indication of the minimum and maximum measured values, together with calculation of the mean values and type A measurement uncertainty. These results of software processing include frequency measured on 10V nominal transformer output.

Comparative graphical presentation of time diagrams regarding to characteristic high-order voltage harmonic component values, measured on 10V transformer output, is given on the figure 5. Besides presented time diagrams of third, fifth, seventh and ninth order harmonic recorded in LabVIEW environment, on programming application front panel are indicated maximum percentage individual harmonic values obtained during measurement process. Maximum measured high-order harmonic levels 1,595%, 0,491%, 0,305% and 0,196% are expressed in percentage relation to nominal transformer maximum voltage value.

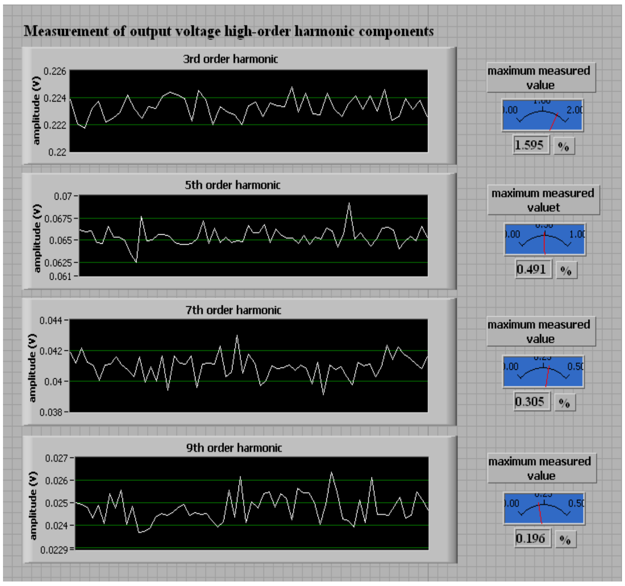

Fig. 5. *Measurement of high-order voltage harmonics*

Finally, form of the final report from voltage transformer accuracy checking procedure, is presented in the table 1.

Table 1. *Report from transformer accuracy checking*

measurement of the RMS voltage values		
measured values	output 1	output 2
minimum values	10.009 V	5.203 V
maximum values	10.043 V	5.223 V
mean values	10.024 V	5.210 V
type A uncertainty	0.010 V	0.006 V
type B uncertainty	0.0029 V	0.0014 V
combined uncertainty	0.0104 V	0.0062 V
measurement of the output voltage frequency		
minimum values	50.1502 Hz	50.1520 Hz
maximum values	50.1512 Hz	50.1541 Hz
mean values	50.1507 Hz	50.1531 Hz
type A uncertainty	0.0002 Hz	0.0005 Hz

4. CONCLUSION

Solution of laboratory measurement and acquisition system applied to voltage transformer accuracy checking procedure, is presented in this paper. Functional basis of described solution is provided by virtual instrumentation software package LabVIEW 8.0. This system includes calibration instrument Fluke 5100B for reference voltage signal generation, 12-bit data acquisition card NI 6008 and standard PC configuration having installed software support. Acquisition card uses two analog input channels which receive voltage signals from transformer outputs. Presented virtual instruments in LabVIEW environment are developed for measurement and software analysis of basic voltage parameter values measured on transformer outputs. Software analysis of measurement data includes graphical presentation of time diagrams and histograms of measured voltage parameters, indication of minimum and maximum measured values, calculations of the mean values, standard and combined measurement uncertainty. Presented solution based on standard computer and data acquisition hardware components eliminates demand for measurement of output voltages for each point of input voltage changing during transformer checking processes or measurement instrument calibration, due to providing complete software based automation of these procedures.

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