Virtual Instrumentation Software Applied to Calibration Procedure for Power Quality Meters

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Abstract – **Calibration procedure for power quality parameter measuring instruments, supported by the virtual instrumentation software LabVIEW, is presented in this paper. Reference voltage calibration signals, defined according to European power quality standard EN 50160, are providing by the D/A acquisition card NI 6713, voltage amplifiers and calibrator METRAtop 53. Realized LabVIEW virtual instrument in PC programming environment provides the calibration process algorithm, including comparing of measuring results obtained during calibration procedure with reference voltage quality parameter values. Statistical processing of measuring results obtained using the calibrated electric power quality meter CA 8334, considers evaluation of the average RMS voltage values, the graphical probability distribution parameters and uncertainty components of the measured parameter values.**

Keywords – **Calibration, Electric power quality meters, Virtual instrumentation, LabVIEW application software.**

I. Introduction

Electric power quality level is defined by the interval values of distribution network supply voltage parameters measured at electriic power customer delivery points. The valid measuring data related to real values of the power quality parameters can be provided only by objective continued monitoring of power distribution and consumption processes at the different power distribution network locations. Instruments for measuring and analyzing of the power quality parameter need to be followed by the appropriate metrological traceability chain. Practically, this means that used equipment and instruments for the power quality measuring purposes must be previously metrologically verified and confirmed using the calibration procedures which are carried out within the accredited metrological laboratories.

For the purposes of electric power customer protection, the optimal quality and reliability levels of delivery networks that power supplier need to provide, are defined by the national and international normative and regulation documents, such as the current European electric power quality standard EN 50160. In these documents adopted by respectable international standard organizations (CENELEC, IEEE, ANSI, NIST) are prescribed nominal values and acceptable limit intervals of characteristic quality parameters, under the normal operating conditions [1].

Different types of digital instruments using for analysis and measurement of the standardized power quality parameters are commercially available at the today world markets. Measuring instruments enabling these options, such as the portable power quality analyzers Circutor AR5, LEM Q-Wave Power, LEM Memobox 808 or Chauvin Arnoux CA 8332/8334, are capable for contined monitoring of power quality parameter values, at various delivery network points [2]. These measuring devices are programmed for operation according to the relevant power quality standarda, mostly EN 50160, which enables automatic final quality report generation. Direct two-way measuring data transfer communication between this instruments and standard PC computer is enabled by using standard optical interface IR RS-232. Graphic color display shows the real-time measuring results, including possibilities for measured data chronological recording for the purpose of latter statistical processing using the corresponding software support for the PC based analysis.

Reference measuring devices, such as the voltage or current calibrators, are commercially available in different functional and constructive solutions. Voltage and current calibrators are sources of reference signals of high accuracy, which inside the metrological traceability process correspond to the secondary standards, the laboratory and industrial standards. Also, there are specially designed calibration devices for the known types of power quality analyzers, such as solution of multifunctional calibrator Fluke 5520A enabled with Power quality option [3].

Software controlled procedure for the calibration of electric power quality meters is described in this paper. The reference calibration values of voltage quality parameters are providing using 8-channel 12-bit D/A data acquisition card NI 6713 [4], for three-phase voltage signal generation, three amplifiers and the calibration device METRAtop 53, for measurement of the generated signal parameters. Functional basis of the procedure is ensuring by virtual instrumentation software LabVIEW [5].

II. Hardware Configuration of Power Quality Meter Calibration Procedure

In order to provide measurement traceability of instruments for measurement of power quality parameters, it is necessary to calibrate each used instrument, inside calibration laboratory or directly inside remote measuring stations, for the individual customer network groups. Possible approach to the problem is direct calibration method using reference transferring standard for calibration of power quality meters which are installed into remote measuring stations controlled by data sending from the power distribution center across communication network [6].

The hardware block configuration of calibration process for the portable power quality meter CA 8334, is presented on the Fig.1. The calibration process is consisting of two functionally connected activities, reference calibration three-phase voltage signal generating and calibration process algorithm applied to power quality meter. Reference calibration signal providing is

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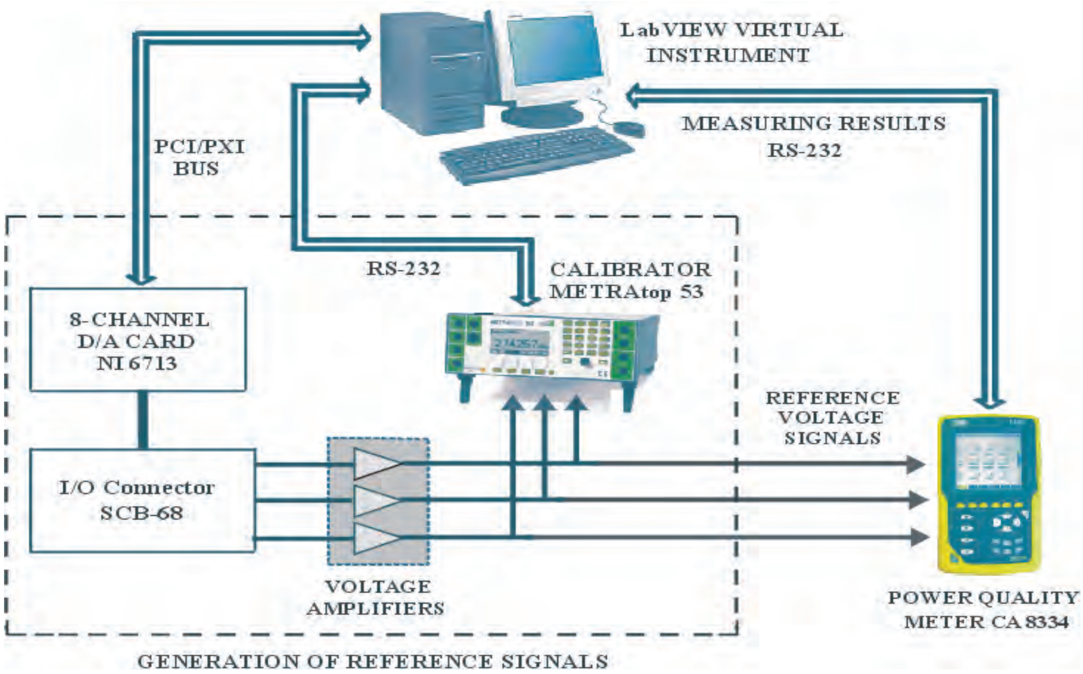

Fig. 1. Hardware block configuration of the electric power quality meter calibration procedure

controlled by the virtual instrumentation application software LabVIEW. 8-channel 12-bit D/A data acquisition card PCI NI 6713 circularly generates three-phase voltage waveforms with frequency of 50Hz, based on the previously determined values of samples per period, memorized into the internal data buffer. The generated three-phase sinusoidal voltage waveforms are digitally synthesized with the 1000 points per one period. Very important feature of chosen D/A card is possibility for double buffering enabling that the replacing of the samples is possible without interruption of the signal generation. Acquisition card provides eight digital to analog output channels with specified resolution of 12 bits, the output voltage generation accuracy of 0.5 LSB and maximum amplitude range of ±10V. Appropriate amplitude and signal effective values necessary for calibration of power quality meter, are providing using voltage amplifiers.

Effective values of amplified signals are measured by using control calibrator METRAtop 53 sending measuring results to the PC computer through the RS-232 standard communication interface. This calibrator is microprocessor based device with 16-bit sigma-delta analog to digital converter, the four voltage output ranges from 30mV to 30V, long time stability, network and local supply and the voltage nominal accuracy 0.02% [7]. Comparing effective voltage values measured using calibrator with calibration reference RMS voltage value of 220V, virtual instrument calculates the new corrected effective values which need to be generated by D/A acquisition card in next iteration.

Nominal values of absolute error components for generated output voltages, specified by card manufacturer, are shown in the Tab.1. [4]. According to the symbols for error components given in the table, total absolute error of output voltage signals generated by D/A card, is calculating using following relation:

$$\Delta V = \left(\frac{p}{100\%}V\right) + V_{OS} + \left(\frac{\Delta T}{100\%}V\right) \quad (1)$$

nominal output voltage range ±10V	absolute error value ΔV		
	reading p (%)	offset Vos (mV)	temper. drift ΔT (% /°C)
	0.0177%	±5,933	0.0005%

Tab.1. Components of generated voltage signal absolute error

For by user selected D/A acquisition card maximum voltage output value 10V, the absolute and relative errors of generated voltage signal are calculated by using the following equations:

$$\Delta V = \left(\frac{0.0177}{100}10V\right) + 5.933mV + \left(\frac{0.0005}{100}10V\right) = 7.753mV, \quad (2)$$

$$\delta V_{\%} = \frac{\Delta V}{V}100\% = \frac{0.007753}{10}100\% = 0.07753\% \quad (3)$$

III. LabVIEW Application Software Support

Power quality meter calibration process is controlled by the virtual instrument in PC programming environment developed using the LabVIEW graphical software language. The realized application provides interactive communication between users and the system, including calibration procedure algorithm and statistical analysis of the measuring results with chronological recording in system database. Front panel of virtual instrument in LabVIEW environment, developed for metrological support of power quality meter calibration process, with possibility of graphical presentation, chronological recording and statistical analyzing of the measuring results obtained during calibration, is presented on the Fig.2. Besides the continued monitoring of

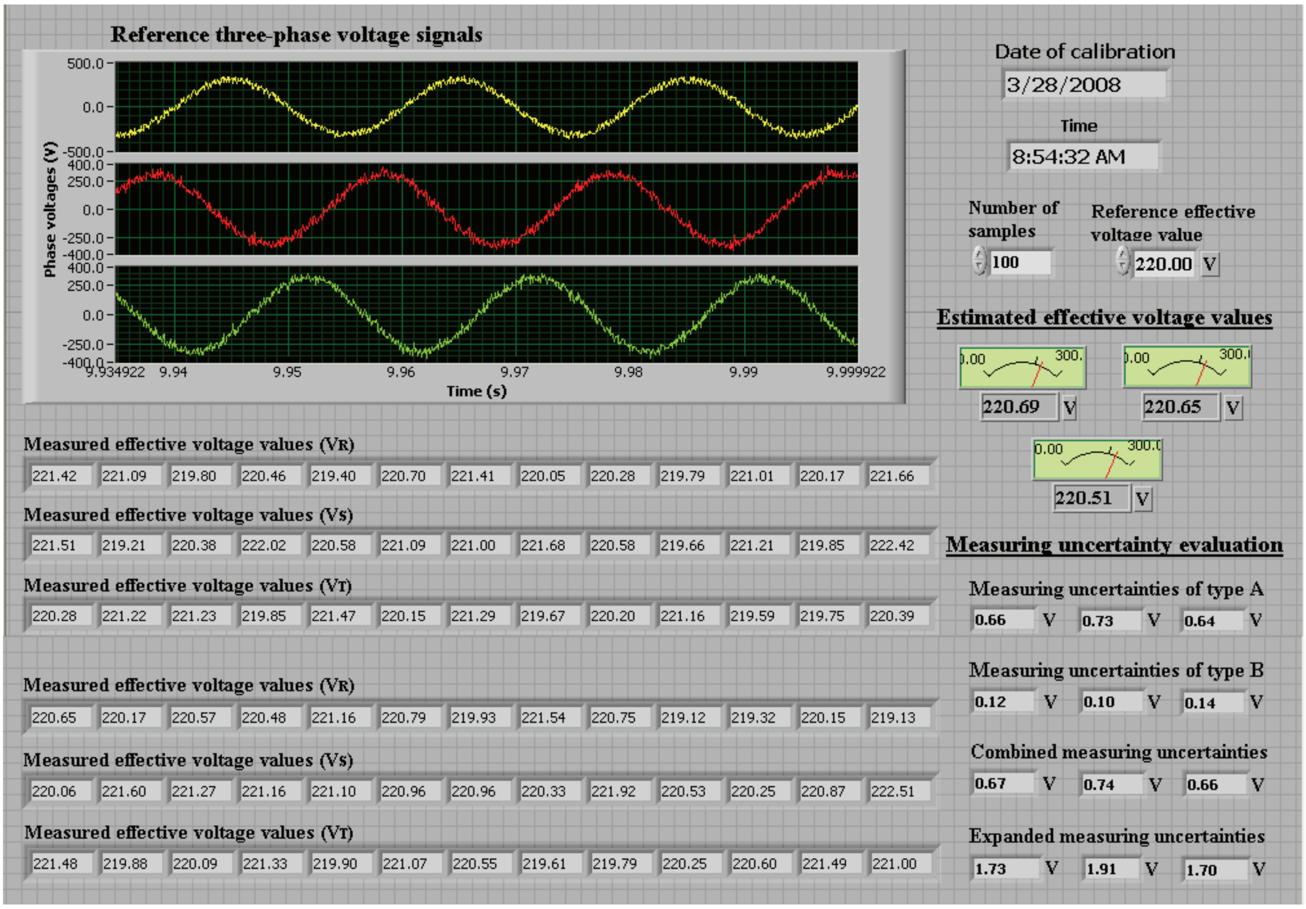

Fig. 2. LabVIEW virtual instrument for metrological support of the power quality meter calibration procedure

the generated reference three-phase voltage signal waveforms, defined according to power quality standards, designed virtual instrument shows the tables containing successively measured RMS phase voltage values obtained by using calibrated power quality analyzer CA 8334. On designed front panel for each of reference three-phase voltage signals are presented twenty six measured voltage values. Statistical processing and analyzing of hundred measuring results obtained for each phase is based on calculation of the mean RMS voltage values and associated standard measurement uncertainties of type A and type B, the combined and expanded measurement uncertainty values [8].

IV. Power Quality Measuring Uncertainty Component Evaluation

In general, measuring results are valid and completed only if they are followed by the corresponding quantitative data about the evaluated values of measurement uncertainty. Uncertainty of measuring results in the CIPM approach generally consists of the several components defined in reference to the methods applied for calculation of their numerical values. According to reference document Guidelines for evaluating and expressing the uncertainty of NIST measurement results [8], components of uncertainty in measurement are arranged in following three primary categories: the standard measurement uncertainty, the combined measurement uncertainty and expanded uncertainty. Type A standard measurement uncertainty evaluation is based on statistical methods applied to measuring results obtained in the power quality analyzer calibration process. In the case of a virtual instrument presented on the Fig.2, standard uncertainty of type A is evaluated using the standard deviation of obtained measuring results, while estimation of effective voltage values is based on arithmetical mean calculation using next relations:

$$u_A(V)=\sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}\left(V_i-\overline{V}\right)^2}\,, \tag{4}$$

$$\overline{V}=\frac{1}{n}\sum_{i=1}^{n}V_i \tag{5}$$

Type B standard measuring uncertainty calculation includes all currently available relevant information related to previous measuring data provided from calibration procedures or other reports and from the specifications for measuring instruments included in process, provided by device manufacturers. On the developed LabVIEW virtual instrument the values of standard type B measurement uncertainty correspond to the accuracy of generation of calibration reference three-phase voltage signals. Combined measurement uncertainties are calculating by using combining of the individual standard uncertainties, according to law of uncertainty propagation which is based on first-order Taylor series approximation given with following relation [8]:

$$u_c^2(y)=\sum_{i=1}^{N}\left(\frac{\partial f}{\partial x_i}\right)^2u^2(x_i)+2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j}u\left(x_i,x_j\right) \tag{6}$$

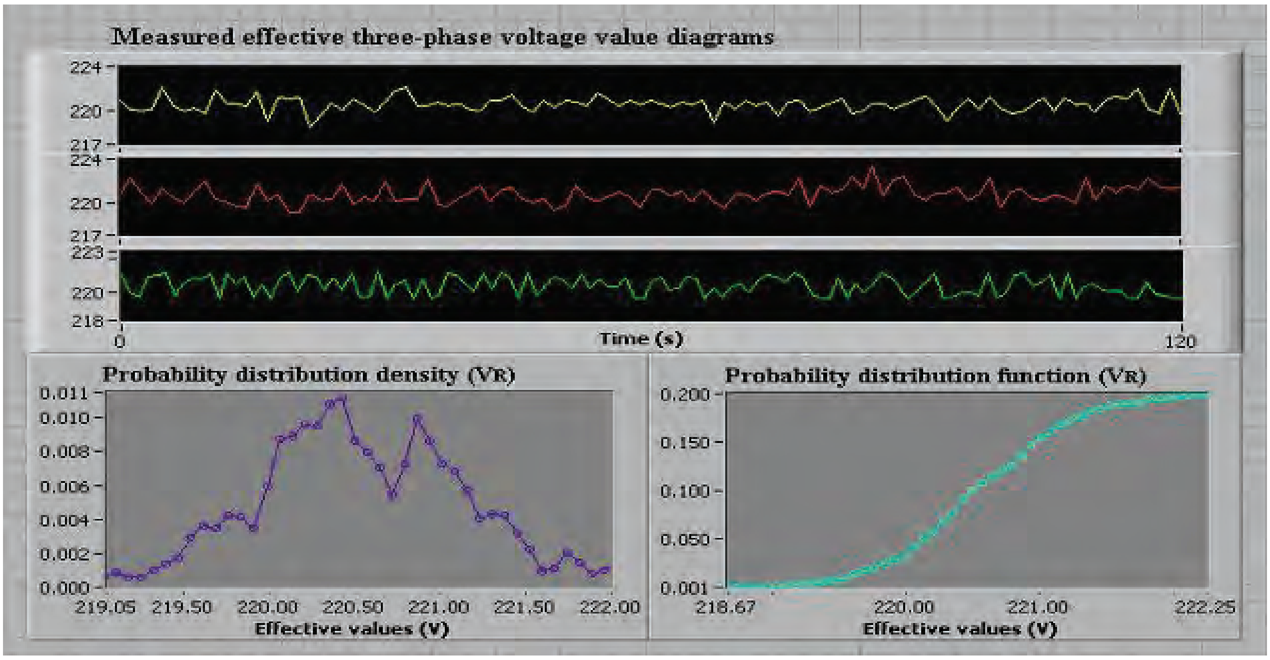

Fig. 3. Diagrams of the measured effective voltage value and graphical probability distribution parameters

For the case of two dependent correlated physical quantities previous expression can be represented in the following form:

$$u_C = \sqrt{\left(\frac{\partial x}{\partial x_1}\right)^2 u^2(x_1) + \left(\frac{\partial x}{\partial x_2}\right)^2 u^2(x_2) + 2\frac{\partial f}{\partial x_1}\frac{\partial f}{\partial x_2}u(x_1,x_2)} \tag{7}$$

Standard measurement uncertainties of the type A and type B related to RMS values previously estimated are independent and uncorrelated quantities, with correlation coefficient value $u(x_1,x_2)=0$. Therefore, the combined measurement uncertainty values for the LabVIEW virtual instrument given on Fig.2. are calculated using the following square root simplified relation:

$$u_C(V) = \sqrt{u_A^2 + u_B^2} \tag{8}$$

For required measuring results confidence level of 99% and the reference effective phase voltage value of 220V, the values of expanded measurement uncertainty are calculated by means of multiplication of combined measurement uncertainties with correspondent uncertainty coverage factor value of k=2,58 [8].

Front panel of the LabVIEW virtual instrument performing the graphical presentation of the measured RMS voltage value diagrams and probability distribution parameters of measuring results, is presented on Fig.3. Some important conclusions can be gained from shown probability distribution diagrams. Most important remark is that probabilty distribution parameters of three-phase voltage value measuring results are approximately corresponding to Gaussian probability distribution parameters.

V. Conclusion

Increasing of the electric power production, distribution and consumption efficiency demands developing of the measuring instruments using for monitoring and analyzing of the defined power quality parameter values. Crucial activity in the process of the measuring instrument traceability verification is regular periodic calibration. In this paper are described possibilities of power quality meter calibration procedures using the reference three-phase voltage signals, generated by data acquisition card NI 6713, the voltage amplifiers and calibrator METRAtop 53. Functional basis of the presented solution is provided by using the virtual instrumentation software LabVIEW performing the control of reference signal generation and power quality meter calibration process algorithm The designed virtual instrument provides the graphic presentation, chronological recording and statistical processing of measured RMS voltage values. At the end of calibration procedure virtual instrument generates final calibration report which includes the estimated mean values of measuring results and the measuring uncertainty components.

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