The application of the LabVIEW environment to evaluate the accuracy of alternating voltage measurements

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Abstract. Possible application of the integrated LabVIEW environment to final evaluation of the accuracy of alternating voltage measurement is presented in the paper. The paper shows the measurement results of selected alternating voltage meters, which were obtained on a designed measuring position. The designed measuring position has both research and teaching qualities and advantages. Thanks to such instrument, we can recognise those properties of alternating voltage meters about which there is no information in available manual, or verify the parameters declared by the manufacturer. The analysis of measurement results obtained should take into account a limitation in the accuracy of the method for processing the measured value, caused by, among others, the shape of the waveform measured or the meter’s frequency band. These problems are frequently omitted or hardly emphasized. The authors consider how the measurement results could be presented and visualised in a convenient and user-friendly form. The topics discussed in the paper were analysed with the use of selected LabVIEW applications.

1. Introduction
Finding the true value of a measured quantity is the aim of every measurement. We can never find this quantity accurately because both the measuring devices and methods are imperfect. The result obtained from the measurement is a certain evaluation of the true value. The evaluation is the better the higher the measurement accuracy. The measure of a discrepancy between the value obtained from the measurement and the true value is the measurement error. According to document [1], the measurement error is the difference of the measurement result and the true value of the measured quantity. Because we never know the true value accurately, in practice we often make use of a conventional true value. This is the value attributed to the determined quantity and regarded, sometimes by convention, as the value determined with an uncertainty that is acceptable in a given application [1].

2. Quantities describing the alternating voltage
Basic quantities describing the alternating voltage are: instantaneous value $u(t)$, rms value $U$, rectified value $U_r$, peak value $U_{pm}$, form factor $F$, and peak factor $PF$. The choice of a concrete voltage measure depends on the aim of its application and application potential of the measuring system. The most frequently used voltage value is the rms value, determined in formula (1):

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Currently utilised voltmeters of alternating voltages are graduated in the rms values of sinusoid waveform. Depending on their working principle, they can react to the rms value, the rectified value, or, quite rarely, to the peak value. Meters reacting to the rectified value are graduated according to formula (2):

\[ U_w = U_r \cdot F_a \]  

where: \( U_w \) is the value indicated by the meter, and \( F_a \) is the value of the form factor for sinusoid signal. Meters reacting to the peak value are graduated according to formula (3):

\[ U_w = U_m \cdot \frac{1}{PF_a} \]  

where: \( PF_a \) is the value of peak factor for sinusoidal signal.

For distortion signals, the indications of meters utilising formulas (2) or (3) contain errors, and the error is the greater the more distorted from sinusoid waveform is the waveform under investigation. The reliability of measuring the distortion signals is also considerably dependent upon the frequency characteristic of the meter. Meters with electromechanical transducers are usually designed to measure signals with frequencies not greater than several Hz. Meters with electronic converters available on the market have the upper frequency of measuring band of the order of several or tens kHz. Therefore, the application of a meter with a converter reacting to the rms value is not a sufficient condition to indicate the proper value of alternating voltage. E.g. an electromagnetic meter with 400 Hz band does not ensure proper measuring of distorted voltage containing upper harmonics.

3. LabVIEW programming environment

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is graphical programming software used in developing programs for simulation, data acquisition, control, and communication application. In the LabVIEW environment icons are interconnected to create a program generally referred to as a VI (Virtual Instrument) [2], [3], [4]. All VI’s must have two components: the Front Panel and the Block Diagram. The Front Panel contains various controls and indicators while the Block Diagram includes a variety of functions. The functions (icons) are wired inside the Block Diagram, where the wires represent the flow of data. The execution of a VI is data dependent, which means that a node inside the Block Diagram will execute only if data is available at each input terminal of that node. By contrast, the execution of a traditional program, such as C program, follows the order in which the instructions are written [5]. VI’s make up a new generation of measurement equipment. In these new devices the hardware realization of some functions is replaced with an appropriate program executed by a PC computer [6]. It concerns mainly the device handling and the execution of signal processing algorithms. Thanks to those facilities, it is easy to modify such device and execute the signal processing algorithms. In particular, the LabVIEW environment seems to be commonly used at the university level teaching process for realization of specific programs for presentation of various problems.

4. Measuring position

The measurements were carried out on a designed measuring position, presented in Fig. 1, consisting of the source of a testing signal of voltage \( u(t) \), a meter indicating the conventional true value, the
voltmeters of alternating voltage under investigation, and a computer with control software. In the discussed measuring system the function generator 33120A was used as the testing signal source. The voltmeter measuring the reference voltage, depending on the type of voltmeter under investigation, is multimeter 34401A – in case of voltmeter designed for average measuring applications, or 3458A – when we carry out research on meters with high accuracies.

![Diagram of measuring position to examine the accuracy AC voltmeter](image)

**Figure 1.** Diagram of measuring position to examine the accuracy AC voltmeter

The reference voltmeter and function generator, utilised in the system, are equipped with communication interface IEEE-488.2, which makes it possible to control them remotely from the level of computer and developed application, written in the LabVIEW environment, based on the commands of SCPI standard.

5. **Virtual instrument designed to determine the error of measurement results**

A program was developed in the form of a virtual device, designed to determine the values of the errors of measurement results. The prepared application makes it possible to realise a number of functions such as:

- implementation of an arbitrary form of the investigated signal,
- storage of measurement results,
- determination of the values of relative and absolute errors of measurement results as well as their visualisation,
- recording of measurement results and calculations in a text file.

The evaluation of the measuring accuracy of alternating voltage of selected multimeters is carried out in a measuring loop, which is realised in four stages:

- examination with sinusoid waveform at 50 Hz frequency,
- examination with standard waveforms with the form of sinusoid, triangle and rectangular,
- examination with strongly distorted waveforms with arbitrary form,
- examination of the influence of testing signal frequency on the indications of voltmeters.

Fig. 2 presents the block diagram of elaborated application which shows the method of accuracy evaluation of alternating voltages measurement.

For every realised stage of research a separate application panel was prepared, designed for a given type of measurement.
After the application is run, the GPIB bus is tested in order to detect the source of testing signal and reference voltmeter, and in appropriate fields of the panel their identification and communication parameters are displayed. After the data are approved, the labels of investigated measuring devices should be introduced. These operations end the stage of configuring the program, required before the measurements.

![Block diagram of elaborated application](image)

**Figure 2.** Block diagram of elaborated application

In Fig. 3 an example of panel was presented, referring to the examination of the accuracy of measuring the alternating voltage for distortion function.

![Panel of virtual device for examination of distortion function](image)

**Figure 3.** Panel of virtual device for examination of distortion function
As an example of distorted voltage we used the simulation of a waveform that is obtained in a control system with triac. The panel is divided in two parts. In the upper part we have the settings of the generated waveform, such as rms value, frequency and the triac ignition angle – expressed in percents. The button “Generate signal” runs a process in which the settings are converted into the SCPI language and sent to the generator. After the proper execution of these operations, the waveform generated in the program is displayed and a signal is sent to the reference voltmeter, which triggers the measuring of alternating voltage. Then, as a result of this operation, in the lower part of the panel, in the field “Reference meter” the measurement result obtained from the device is displayed. The values indicated by the examined meters should be inscribed in the fields placed by their names. Based on the introduced measurement results the values of errors are determined, together with graphic interpretation, as well as the values of form and peak factors. The remaining panels, although they concern different tasks, were prepared in a similar graphic layout and are operated in a similar way. After the measurements are finished, a measurement report is automatically generated and printed on a attached printer. Fig. 4 shows a fragment of the diagram of the application designed to the examination of the accuracy of measuring the alternating voltage for distortion function.

![Diagram](image)

**Figure 4.** Fragment of the application designed to determined to the examination of the accuracy of measuring the alternating voltage

6. Conclusion

The measuring position shown in the paper, together with the developed application, makes it possible to apply advanced methods of computer aid, using the LabVIEW environment, into the process of verifying the metrological properties of commonly utilised devices for measuring the alternating voltage. The designed measuring position has both research and teaching qualities and advantages. Thanks to such instrument, we can recognise those properties of alternating voltage meters about which there is no information in available manual, or verify the parameters declared by the manufacturer. These problems are frequently omitted or hardly emphasized.
The possibilities of presenting and visualising the error of measurement results in a convenient and user-friendly form are discussed. By using the LabVIEW environment – as it is illustrated with an example of the developed application – we can support or add variety to the teaching of students in the field of metrology and measurement theory. The authors’ present experience demonstrates that the developed software is a very useful instrument assisting the teaching process. The application of computer simulation in teaching is a requirement of modern education.

7. References

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