MEASUREMENT INSTRUMENT FEATURES ESTIMATION

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Abstract: In this paper the concept of virtual system, using graphical environment, designed for approving parameters of microprocessor measurement instruments was presented. The exemplary structure of virtual examining station used for research of metrological features of multifunction instrument for measurement of ship power engineering system parameters was discussed. The selected research results were shown. The automated algorithm of instrument metrological accuracy assessment was presented. The example illustrating the way of formulating of newly-designed measurement instruments research program was proposed.

Keywords: virtual instrumentation, metrological features estimation, multifunctional measuring devices

1   INTRODUCTION

The significant part of the newly-designed meters and measurement converters are microprocessor-supported instruments. The application of microprocessor technology allows to employ effective and quite simple configuration of measurement channels for carrying out complicated measurement tasks. In such applications the microprocessor software takes over some part of measurement functions, traditionally carried out by hardware solution [1]. Besides calculation functions, the software fulfills, respectively for instrument type, e.g. normalization of values of indicated quantities, calibration and autocalibration tasks and also digital communication with considered instrument external systems.

2   DOMAIN OF THE PROBLEM

In the process of new instrument debugging the main problem is the examination obtaining the target algorithms concerning procedures controlling of instrument functioning.

The testing of several procedures can be carried out by means of various software and hardware tools, which are accessible for most of microprocessor types. But usually it is impossible to apply such technique for testing some procedures and specifically specialized microprocessor based units. Additionally, the verification of intermediate values, used for calculation of the final value of measured quantity, computed in procedures that are inaccessible for research developer, is also an essential problem.

The designation of metrological features of designed and performed instrument is the separated research task.

2.1   The traditional approach

The traditional way of instrument measurement features research generally involves providing it with adequate actuation input signals, i.e. test or pattern signals, and registering the response or output signals using some appropriate recorders or by hand written logs, e.g indicator readouts of instant values. The final stage of research is the confrontation and comparison of separately registered data with readouts of pattern reference instrument, analysis and estimation of wrested results. This procedure is carried out mostly „manually" by instrument examining personnel. The designing and preparedness of the automated measurement station for examination of a unique instrument is a task which usually exceeds justified needs.

2.2   The proposed approach

Automation of instrument examining process can be done in several ways. But always few requisitions have to be performed:

- the examining station should contain the central data acquisition unit and also pattern measurement instruments,
- test signals source should be present, respectively to the examined instrument functions,
- the station functioning leans on communication capabilities between system components.

Data collection tasks can be carried out with general-purpose computer (e.g. PC) equipped with appropriate communication interface units. Then, the main problem concerns software controlling system work. Designing the PC executable program in traditional programming language, e.g. TurboPascal or C++, conducting system control, i.e. communication functions, data storage and analysis and also the results' visualization, is indeed a difficult and complicated task.
Graphical programming environment makes new possibilities in this range [6, 7]. Research results of the prototype of multifunction microprocessor instrument FCDIS-10 type for measurement of parameters of ship electrical power system can exemplify the use of LabVIEW environment, applied to control of virtual examination station [2, 3, 5]. Being a powerful data acquisition and analysis program, LabVIEW facilitates instrument examining station controlling program preparedness, including RS-232C or IEEE-488 standards communication links handling.

3   RESULTS AND APPLICABILITY OF THE PROPOSED APPROACH

The research of FCDIS-10 instrument on examining station is based on usage of its communication abilities [3, 6]. The general structure of instrument is shown in Fig.1.
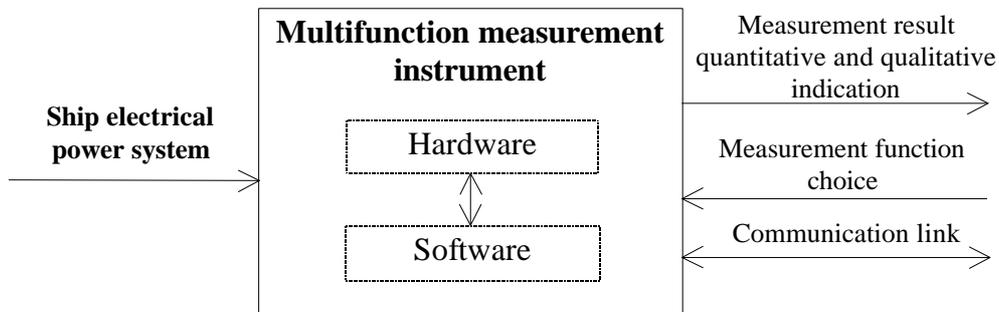

Figure 1. The general configuration of examined multifunctional instrument FCDIS-10.

The digital samples of instantaneous values of phase voltages and currents, acquired while direct analog-to-digital conversion, are stored in RAM memory [4, 6]. The collected samples (u_k, i_k) are used for calculation of values of intermediate quantities. For each L=1..3 phase of electrical network are calculated value of intermediate quantities, e.g.:

$$U_L^2 = \frac{1}{n}\sum_{k=1}^{n} u_k^2 \tag{1}$$

$$I_L^2 = \frac{1}{n}\sum_{k=1}^{n} i_k^2 \tag{2}$$

where: U, I - voltage and current rms values, respectively, n - number of converted samples.
The intermediate quantities are used in respective way for calculating values determined by carried out measuring function, e.g. apparent power S or active power factor λ. The intermediate quantities are unreachable in an indicating unit for instrument's user.
In Fig.2 the base configuration of examining station is shown.
The standard port COM2 of PC is used for communication with examined instrument by means of serial link RS-232C standard. Additional plug-in port IEEE-488 standard enables communication with other instruments applied in examining station. The test signals, generated in alternating voltage and current calibrator C-200 type, are conduced to inputs of the examined instrument, voltmeter V563 type and oscilloscope HP54501A type.
The real mean square (rms) value of calibrator output signals are measured using microprocessor multimeter V563 type. The measurement results are the main reference during instrument prototype examination.
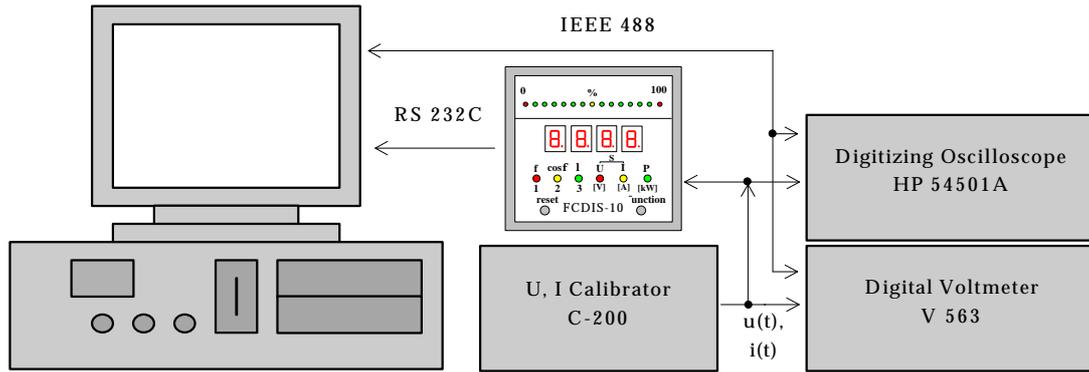The configuration of virtual examining station is shown in Fig. 2.

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Figure 2. The virtual examining station for designation of metrological features of prototype of FCDIS-10 multifunction instrument.

The instrument metrological features research program consists i.e. of:

- supplying the examined instrument FCDIS-10 inputs with voltage and current test signals, alike sinusoidal as distorted, respectively,
- sending to PC, from pattern digital voltmeter V563, information about real mean value of test signals (IEEE-488),
- sending to PC, by means of serial link (RS-232C):
  * primary measurement information from the examined instrument: digital samples of instantaneous value of phase voltages and currents,
  * information about value of intermediate quantities, calculated in the examined instrument,
  * information about currently indicated value, by means of indication unit of examined instrument, respectively to the fulfilled measuring function,
- on the basis of samples u_k, i_k : computing and visualization of effective value of voltages U and currents I, active power P, apparent power S and active power factor 1,
- comparison of PC-computing results with data send from the pattern voltmeter V563,
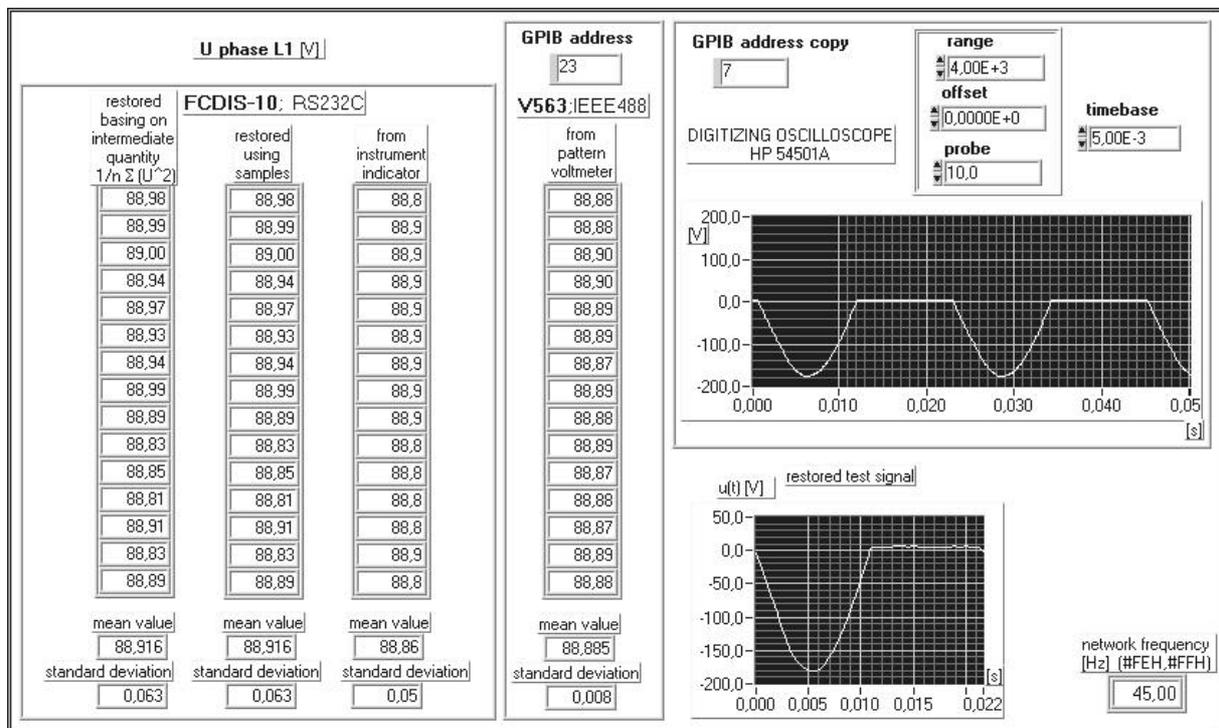- comparison of PC-computed value with measurement results from the examined instrument.

Figure 3. Arrangement of time patterns: restored using data received from FCDIS-10 and from HP54501A for strain test voltage.

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The measurement results were collected in the form of a report using front panel under LabVIEW graphical environment. In Fig. 3, the exemplary front panel is shown.

Besides calculation correctness checkup of the examined instrument, on virtual examining station, the calibration and empirical determination of measuring accuracy for respective measuring function were carried out. The exemplary front panel, containing calibration results, for selected measurement function is shown in Fig. 4.
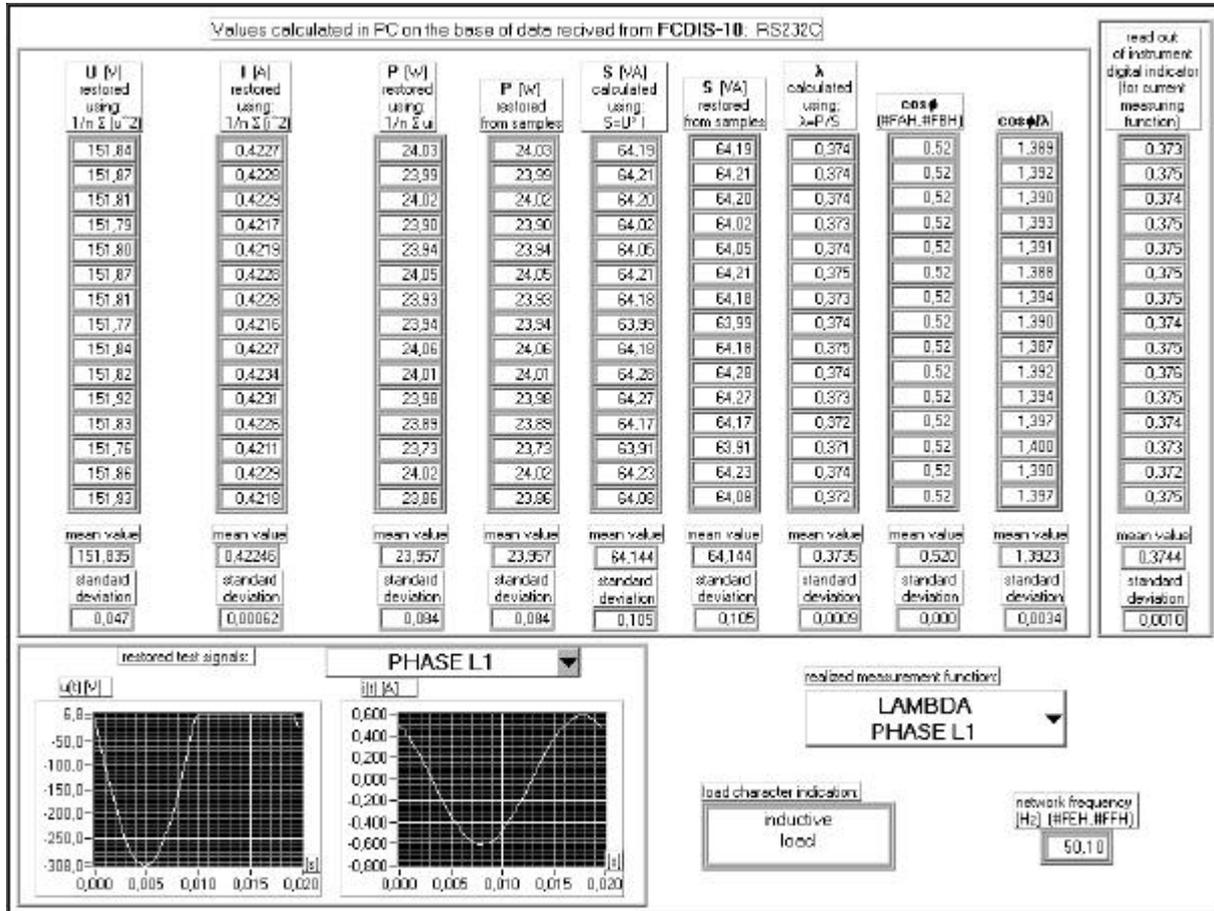

Figure 4. The exemplary research results for measurement function „Active power factor λ phase L1".

The examination of instrument was carried out in a form enabling to determine the systematic as well as the accidental errors, applying respective procedures shown in Fig. 5 [6]. For stationary voltage and current test signals, the measurement data from examined instrument FCDIS-10 and also from pattern voltmeter V563, received in PC by means of serial and parallel links, respectively, were collected in 15-element series. Taking the mean value in series of measurement results as true conventional value, the standard deviation was calculated. The systematic errors were calculated as the difference of mean values in series obtained for examined and pattern instruments. The accidental errors for measurement series were determined using standard deviation of results in series and confidence level equal to 0,9973.

Calculated mean values and also standard deviation for measurement series enabled to determine ingredients of measurement errors and accuracy of instrument for selected measurement function, and also to estimate general correctness of instrument functioning and measurement process.
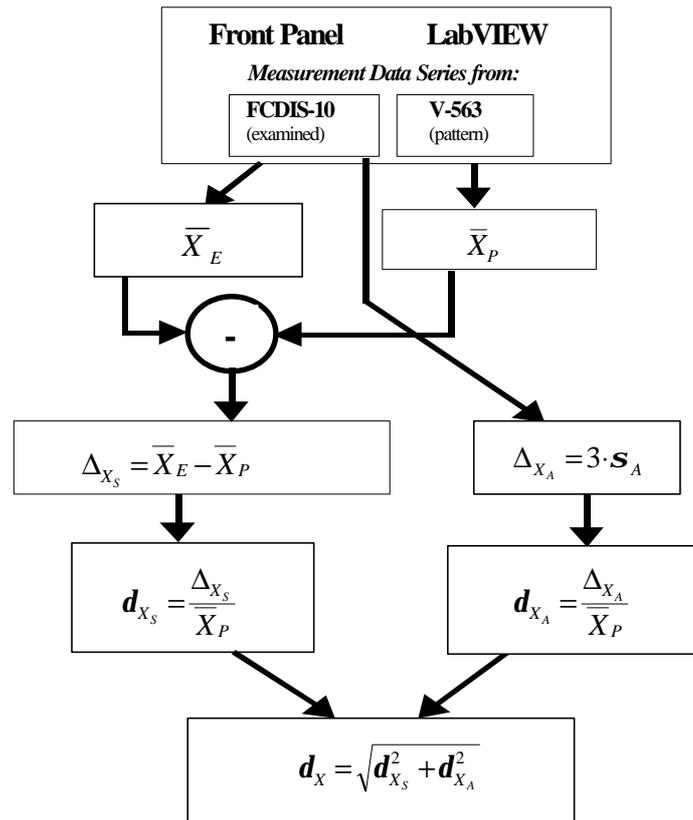
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Figure 5. The algorithm for determination of measurement accuracy of FCDIS-10 instrument: $\overline{X_E}$, $\overline{X_P}$ - mean values of measurement data from examined and pattern instruments, respectively, s_A - standard deviation, Δ_{X_S} , Δ_{X_A} , d_{X_S} , d_{X_A} - systematic and accidental errors, respectively.

4   PRELIMINARY CONCLUSIONS

According to the assumptions, the application of virtual examining station for estimation of metrological features of multi-functional microprocessor instrument prototype enables:

- the verification of main microprocessor procedures and measurement algorithms, i.a. allowing the estimation of communication correctness and propriety of computation of intermediate quantities in the examined instrument,
- the verification of values of calibration factors of measurement channels,
- the checkup of correctness of calculation in examined instrument procedures, in intermediate level of determining the measured quantity value,
- the calibration for respective measurement functions,
- the empirical determination of measurement accuracy for respective functions fulfilled by the instrument.

The comparison of the value of intermediate quantities, calculated in the considered instrument and shift to PC, with the value of intermediate quantities, computed in PC using the same u_k and i_k samples sent to PC, bring the possibility to estimate the quality measurement procedures fulfilled in considered instrument. The satisfied convergence, acquired during the research, meaning understood as the minimal difference between compared values, enabling the positive assessment either of applied measurement method or algorithms and microprocessor program procedures.

The usage of the user's graphical interface in instrument metrological features examination allows to prepare the protocols containing measurement results and at the same time essentially limiting the influence of subjectiveness of the person who carries out the research.

It is worth to add, that designing an examining station, controlled under computer program in some of traditional programming languages, e.g. TurboPascal or C++ is a task much more complicated then applying LabVIEW graphical environment.

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