Virtual Measurement Instruments: Traceability Fundamentals And Methods

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Abstract-The problems of metrological ensuring virtual measuring instruments (VMI) are discussed. The VMI classification is proposed. The principles of measuring instrument legalization are formulated as a base for the problem solving. As the basic problems, structural identification of VMI, and unauthorised access, and VMI calibration and standardization are pinpointed. It is shown that complete calibration is foreground for VMI similar as to usual measuring instruments, without necessity to certify, separately, measurement software.

I. Introduction

Expansion of data processing procedures at the sacrifice of relative reduction of physical conversions is the one of the basic tendencies in measurement technology during some last decades.
This tendency was seen always because capabilities of mathematical conversions are extreme in comparison with physical conversions. But its feasibility becomes practical only with advances in technology of physical signal digitalization and digital data processing. Computers and information technology are due to the above-mentioned advance.
Inserting digital conversions into measuring instrument (MI) structure open up new possibilities for measurement improvement.
First of all, connection MI with computer was made possible. In its turn, this has permitted (i) to process large data arrays, (ii) to calculate any characteristics of the error, (iii) to correct readings.
Besides, estimation of any characteristic of variable electrical signal has been made, and so measurand list has been enlarged.
The advent of microprocessors has allowed, inserting them into MI structure, to produce MI as complete (self-contained) both measuring and computing device, which performs any above-mentioned function.
Further development, which was subjected to technical-economical factors, has led to making the new category of MI – so called virtual MI (VMI) [1-6].
As a rule, by VMI is meant technical device, in which measurement function is performed by means of computer programme.
Naturally, the problem of metrological assurance of VMI arises. It means that VMI has to be included into existing metrological system. So legalization (or validation) of VMI comes about, what is important if VMI is to be used in technology and industry.
The basic problem coming on in this connection consists in that whether VMI can be involved into existing metrological system according to usual rules, or the latter must be changed.
The problem is discussed below.

II. Principles of measuring instrument legalization

Traditionally, MI legalization envisages

including it into the classification system,

presetting and representing of metrological characteristics (MC) and MC initial evaluation, or calibration,

scheduled verification of MC.

Classification is meant that not only functional features of MI are to be bringing out but peculiarity of MI as an object of metrological procedures, too. The latter is more important in the context of the paper.
Way of MC presetting is the result of compromise between interests of producer, user (customer), and metrologist. MI producer wants to represent his goods more profitably in the market. MI user is interested in representing functional possibilities of MI more fully and in great detail. Metrologist's chief concern is to get a good chance of verifying, or evaluating reliably, MC representing functional

features of MI. First of all, the case in point is MI calibration, i. e., unit transfer from an appropriate reference standard.
Besides, scheduled verification of MC during the process of MI service (as MI being in operation) enters into the field of metrologists authority.
By choosing the way for solving enumerated tasks, not only technical agents are to be into account. Economical factors are of great importance as well. Obviously, metrological ensuring cost must not be too much in comparison to MI itself. In total, the costs outlined must not be over-significant as compared with "the price" of technology or industrial problem, which MI are used for.

III. Kinds of virtual measuring instrument

The following number of VMI kinds can be pointed in accordance to their structure and functional finality.
The first one is traditional MI with analogous or digital conversions of measurement signals, which equipped, in addition to usual scale or indicator, with output ADC and interface means for connection with PC. It is most close to traditional object of metrological ensuring. PC serves as mean (i) to observe, (ii) to document, and (iii) to measurement data processing. Such a device is, for instance, the instrument APPA-109 produced by the APPA Technology. It can transfer measurement data to computer by RS-232 interface for required processing.
Another sort of VMI is programmable digital measuring apparatus with built-in monitor as indicator. Such a device is, in essence, a mongrel of MI and special-purpose computer. The apparatus TDS-2012 of Tektronix is a good case in point. It is provided with additional interface for connection with PC. So it permits to monitor measurement data not only on the instrument indicator but on the computer display, too. PC can be used to control the mode of instrument operation.
Then, there is VMI, which is formed from constructively completed programmable measuring device and PC. The device contains digital input/output data device, or data acquisition and analysis device, which equipped with microprocessor and special-purpose programme not accessible to users. PC serves as mean for display and documentation making. Such a VMI is, for example, oscillograph, which is formed from the device NI USB-5102 of National Instruments and IBM PC.
The fourth variant of VMI is an aggregate, which consists in input/output device, with controller, and PC, by which the programme delivered by the producer is fulfilled. The user can have access to programme content, or not, but he can use some another programme instead of the delivered one. As an example we refer to the voltmeter (and generator, and oscillograph) realized by the device NI PCI-5911 of National Instruments and IBM PC with fitted up programme NI-SCOPE, which is formed by means of LabView 7.
At last, the final VMI species is a variant of the latter one, which measuring programme is made by the user in. For example, such a VMI is the device based on the device PCL-818 of Advantech.
As may be seen, VMI variations make up some qualitative scale. One of the scale limits represents a device, which is little different from usual (traditional) MI. Another limit corresponds to fundamental new kind of MI. The kinds are distinguished, in essence, by origin of measuring programme and computer, which fulfils it. To put it otherwise, the difference is in what is the computer status: (i) is it an individual device or built-in, (ii) is it universal or special-purpose, (iii) is it used for fulfilling measuring programme or for display and documents making.

IV. Metrological ensuring problems

The peculiarities of above-mentioned kinds of VMI determine the statement of metrological ensuring problems enumerated in Section 2 and the ways of solving them.
The problem of functional classifying VMI is no different from such a problem for usual MI.
The problem of classifying VMI as objects of metrological ensuring is completely governed by other problems. The latter dictate its formulation as the problem of metrological identification of VMI.
It is appropriate at this point to note that the problem of functional identification of usual MI is truistic.
The problem of structural identification is topical only for measuring setup and measuring system. It is treated as the problem of unauthorised user access to the MI structure and elements. It is precisely that makes the problem for usual MI and VMI akin. Moreover, modern measuring setups often, and measuring systems almost without exception, contain system and measuring software. With regard to this, the problem of unauthorised access to VMI is practically identical to that for setups and systems.
Of course, the case in point is the unauthorised access to measuring and system software.
Evidently, the problem of unauthorised access to VMI is valid only for two latter sorts of them.
The problem of structural identification, which is topical for all VMI except of second kind of them, is

formulated as answering the question on including measuring programme and/or computer in its consist.
The problems of MC representation, evaluation and validation (or confirmation), as stated above, can be treated, if they put together, as concrete manifestation of the problem of including VMI into metrological system. The problem is specific for the three latter kinds of VMI.

V. The problem of structural identification of virtual measuring instrument

The problem should be solved reasoning from two considerations: functional fullness and calibration conditions.
Based on this, one can state that computer must not be included in consist of the first kind of MI, which barely could be relegated to VMI. Actually, the MI is complete by itself. Computer serves only for fulfilling functions, which can be relegated to serviceable ones. Calibration of MI can be done by usual way without use of computer. At the same time, computer can be used as convenient serviceable means. But in this case it must be included into the calibration apparatus consist.
As to other VMI species, from the third one to the fifth one, computer must be included into consist of them. In the first line, either of the three VMI fulfil the measurement function completely only if its consist is full. In other words, computer is incorporated into measuring chain. That is why it has to be subjected to metrological procedures among other VMI elements. In the second line, computer is required to perform calibration, and the simplest way would be to use that incorporated in the VMI consist.
Apart from the mentioned above, it is well to bear in mind that computer is potentially interchangeable element of VMI. Its characteristics and software are only to meet the definite requirements.

VI. The problem of unauthorised access

As pointed out above, the case in hand is, first of all, the unauthorised access to measurement software of the two latter VMI kinds.
Admittedly, the problem of the unauthorised access to other VMI elements – an input/output device and computer – is not factitious. Practicably, the objective can be posed to control the absence of access, but not to preclude it where VMI hardware elements are concerned. The objective could be achieved mostly simple by having authentic copy in independent side's keeping. By copy is meant any thing, which identifies univocally the element – from identical sample to photo or set of schemes. As independent side it must be metrological service.
As to software, programme originals (meant as special copies) must certainly be in metrological service keeping and have the status as reference ones.
Besides, reliable, and not very complicated, protection means must be used: electronic sign, intrinsic programme means for the integrity check on each start-up, and so on.

VII. The problem of virtual measuring instrument calibration and standardization

The essence of problem is that one of the general ways of metrological procedures fulfilment must be picked: complete one or of elementwise (component-by-component) one. Advantages and disadvantages of every way are known [7].
Complete calibration (standardization) is traditionally foreground metrological procedure. As applied to VMI the priority is enhanced by the following reasons.
Elementwise calibration is actualized under the assumption that characteristics of singled out element are studied completely and fulsome. It permits to use the element more effectively in various modes.
But, the conditions and possibilities outlined are hardly embodied even for input-output device. Strictly speaking, the plate is not measuring transducer. It contains, besides ADC/DAC and measurement software, additional serviceable hardware and software modules.
The input-output data (or data acquisition and analysis) device is characterised not only by MC but by other important technical characteristics. The complicated software-controlled apparatus is required to study them seriously. All that takes relevant procedures far out of the scope of metrology, requires sizable resources, and hardly contributes to achieving metrological aims. If one limited oneself to evaluation of only MC, then there is no point in isolation of plate from measuring chain.
As to measuring programme, its isolation, strictly speaking, is impossible. Its any characteristic depends on hardware/software environment, which it is fulfilled in. So it has been studied in the same environment, in which it will be used.
The aforesaid about the devices and the programmes is valid in aggregate for computer with its system

software.
So, it seems to be expedient that the three latter VMI kinds are subjected to complete metrological procedures. It is meant that, in the process of relative metrological procedure, VMI indication registered at the monitor screen is compared either with value of measure appearing as measurement object or with indication of traditional reference standard, which measures the same value as VMI. This permits to have no need to certify measurement software, the more especially as, in general case, the certification will require including all VMI components in experiment. Certification (and calibration, and verification, and checking) of multifunction or multi-channel VMI has to be made separately for every measuring chain (channel). By realisation of definite calibration procedure, it is to take into account that including measures of direct voltage and of time or frequency permits to carry out self-calibration of the device just before use.

VIII. Conclusions

So, VMI metrological assurance, despite of their essential constructive and technological distinguished features, would be realised, in principle, on the base of traditional methodology. This upshot could be seen as trivial but it is important regarding methodological and practical aspects.
Practically, metrological ensuring VMI requires no significant additional resources.
Methodologically, it corroborates overstability of the metrology fundamentals, which had been developed by very long metrological practice.
Practical realisation of metrological procedures requires surely using techniques which are specific for information technologies, and relative normative support.
As for measurement software as the basic element, which determines VMI particularity, the upshot concerning that there is no point in separate certification do not conflict with the study of universal programme means. The work on thorough examination such an application programme packages as MatCad, MatLab, LabView is very useful. Its results help to choose suitable mean for solving metrological or measurement problem.

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