

# Measurement Accuracy Assessment in Ship Applied Instrumentation

<sup>1</sup>Romuald Masnicki, <sup>2</sup>Janusz Mindykowski

<sup>1,2</sup> *Gdynia Maritime University, Department of Ship Electrical Power Engineering,  
ul. Morska 81-83, 81-225 Gdynia, Poland,  
phone: +48 58 6901 440, fax: +48 58 6901 261,  
<sup>1</sup> [romas@am.gdynia.pl](mailto:romas@am.gdynia.pl), <sup>2</sup> [janmind@am.gdynia.pl](mailto:janmind@am.gdynia.pl)*

**Abstract**-In this paper the actual practice in measurement result accuracy assessment, following ship classification societies regulations, is presented. Some considerations connected with uncertainty theory applicability to the ship instrumentation conditions are shown. The idea of measurement instrumentation adapted to the marine operation specificity is proposed.

## I. Introduction

A specificity of the marine environment is expressed by various disturbing factors affecting all spheres of activity on board. They have influence on ship operation, safety of crew and vessel, cargo operations and also on performed measurements. The most important are the following [1]:

- electromagnetic disturbances,
- variations of electric network parameters,
- vibrations generated by the main engine, electric generating sets, pumps, compressors, etc.,
- overloads due to sea waving,
- resulting from fast changing climatic conditions.

Lately, it is rising magnitude of the disturbances resulting from the high power devices on ship working on the basis of impulse techniques, e.g. control systems of electrical main drives, shaft generators fitted with converters or the other power electronics units. The disturbing signals are transmitted mainly through a common electric supply network and interfering with a low-signal measurement and control application and automation systems, also based on computer technology. As a result, they can have significant influence on all ship operations, either automated or supported by manual measurement instrumentation users read-outs.

## II. The result accuracy assessment practice in marine operation

The classification societies are responsible for basic rules establishing concerning marine operations. The approval of measurement instrumentation on board and cyclical arrangement of their measurement accuracy checking are one of main their duties. As general principle, the ship classification societies regulations commend the measurement result assessment using classical error theory denominating measurement accuracy using random and systematic errors [1]. Many classification societies assume, that the total measurement error should not exceed  $\pm 2,5\%$ . Such approach is justified in reference to approval of measurement instrumentation. The metrological properties of measurement instrumentation are checked in regular time intervals. This approval is connected with electrical and mechanical inspection of instrument and concentrated on the one of the main metrological properties: instrument accuracy class.

All other spheres of ship crew activity depend on kind of ship, possibly also on cargo owner rules. The ship crew consists of people occupying various ranks and having various skills. Doing their jobs, many of them are obliged to do some read-outs using measurement instrumentation. As well the deck as the engine crew duties are often connected with the control of various ship arrangements. This operations are supported on indications of numerous measurement instruments, usually different taking into account the type and technology. The members of ship crew are usually not familiar with result assessment procedures and they are not able to designate properly even measurement error or uncertainty. Finally, typical measurement operations are often limited to the do ship instrumentation indicators read-out. Either in deck department or in engine department, according to respective operations or ship equipment, there are the typical procedures connected with cyclic report preparation (daily, monthly reports). They concern, among others, to cargo treatment, ballast or navigation

operations, main engine or auxiliary engines as well as electrical power network (e.g. insulation test) exploitation. Usually, such reports contain the value of measured quantities (e.g. temperature, humidity, speed, oil consumption, revolutions, voltage) without any information about measurement results accuracy. Such practice is established because of number of indicators to observe and readout as well as because of specificity of work onboard, where some urgent additional job is always to do.

As a rule in exploitative practice, the actual value of measured quantity is unknown (that's why measurement is done) and it must not be the base to measurement error designation – the error remains unknown. The exploitative operations measurement results, e.g. connected with ship arrangement exploitation, safety of vessel and crew, cargo operations, should be assessed using uncertainty theory. This theory enables to assess of measurement result as the measure of knowledge limitation about measurement result accuracy. Similarly to the land industry, marine technology development should be supported on the same basic principles. As well “marine” procedures of measurement result assessment ought to be carried out on the compatible way to “land” operations.

### III. The uncertainty of measurement result applicability

Marine economy is the part of global economy. They follow the same rules. As well, there in metrological problems the same regulations should be the base of respective procedures. On the other side, it seems to be difficult to change the actual practice. First step belongs to classification societies. They are able to establish the general principles for ship owners, crew and others who are obliged to meet the requirements of adequate conventions and regulations valid for land activity.

For Polish citizens and business activity the most important in considered area is the national regulation “*Prawo o miarach*” (“*About measures law*”) – Act of Polish Parliament, 2004. This act establishes or confirms i.e. the legal measurement units, metrological checking rules under law of measurement instruments, and also competencies and tasks of government administration in above mentioned area.

The ship instrumentation read-outs are usually taken without information about their accuracy, basing on the principle of their supposed correctness. The same as while market shopping. Such procedure is admissible by above mentioned regulation. Additionally, the number of ship crew member is usually established as minimal (*safe manning level*) to fulfill respective ship operations. Finally, the measurement result accuracy assessment is not realized directly. The measurement result remains without accuracy information. All measurement procedures base on assumption, that the resultant accuracy of considered process remains in allowed range and is resulting from used instruments accuracy class. Another words, if the accuracy of instrument used in some measurement process is acceptable, the obtained result is find as correct, independently on the other factors. Such procedure is allowed by mentioned regulation as well as by regulations of classification societies. They oblige the ship owner to do a regular checking and confirming of used instrumentation accuracy class only.

On the other hand, it is well known, that measurement result accuracy gives to the user a lot of additional information about the state of observed process. The result accuracy assessment is applied not to do for the instrument operator any additional problems, but to do measured process more complete. Even if the instrument user does not know how to perform the accuracy estimation procedure, he can notice and assess the value of uncertainty, when it is available.

Taking into account the duties and skills of ship crew members in sphere of measurement result accuracy, i.e. uncertainty assessment, the only way is to apply this procedure into set of functions performed by measuring instruments. To obtain it, the new design of measurement instrumentation should be elaborated. The basic assumptions related to instruments for ship application configuration concern:

- quantitative and qualitative measurement result indication
- measurement result uncertainty indication

The first assumption follows the specificity of work aboard a ship. The qualitative indication of measurement result is helpful when it is necessary to do the rough estimation of ship arrangement or controlled process condition using given number of indicators. The result quantitative indication is useful for accurate process control and also for report preparing needs.

The second assumption seems to be the only way to make real the exploitation measurement result assessment.

In simple form, this function can be implemented to microprocessor instruments in easy way. For given measurement function, the instrument designer can denominate the result uncertainty by calibration and save obtained value, respectively to the used range, in instrument memory. Instrument user reads indicated measurement result and their uncertainty values [2]. This way, instrument user is not forced to know how to assess measurement accuracy taking into account e.g. accuracy class. The problem is,

that the indicated uncertainty value is not depended on various operation conditions and the level of stored uncertainty value has take into consideration these influencies.

More advanced solution of problem relies on adding to basic instrument functions, the auto-calibration procedures enabling accuracy assessment “on-line”. Then, obviously, the instrument configuration has to be modified to fulfill additional function and adequately, measurement channel of instrument has to be equipped with auto-calibration standard sources block. This block output standard signals are used for channel auto-calibration needs. The exemplary configuration of modified channel and the principle of result correction, taking into account the designed ideal and actual channel characteristics, is shown in Fig.1 and Fig.2. The principle of uncertainty designating procedure is described in [2].

For a singular measurement result in the  $p$  point of the characteristics (with assumption, that  $p$  point belongs to actual characteristics (digital data  $w_D''_p$ ), designated as a result of auto-calibration procedure), it is possible to determine the digital value  $\Delta_p$  and use obtained factor to the measurement result correction (1) (Fig.2). Digital data  $w_D'_p$  is the representation of ideal characteristics of considered measurement channel resulting from its mathematical model of measurement channel.

$$\Delta_p = w_D''_p - w_D'_p \quad (1)$$

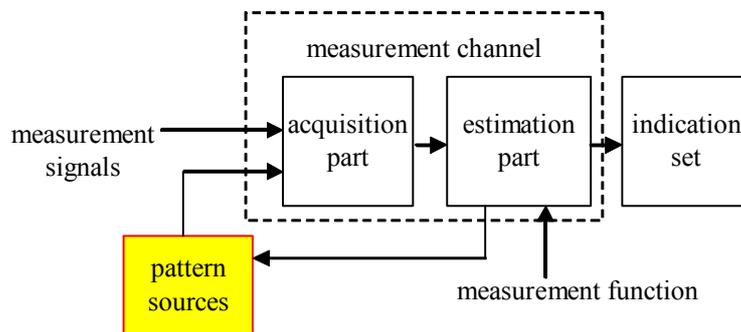


Figure 1. The modified configuration of measurement channel for adaptive error correction and uncertainty assessment

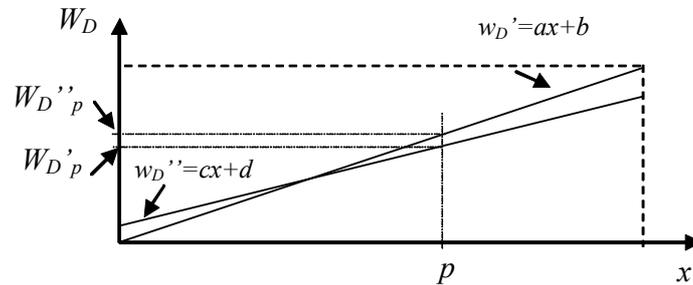


Figure 2. The measurement result correction procedure

The mentioned procedures are examined in new designed test unit. It is equipped with auto-calibration module, two measurement channels and based on TSm module (Target Socket module) with Texas Instruments MSP430F149 microprocessor. The test unit is applied for examination of adaptive measurement algorithms connected with the correction of measurement channel characteristics according to instrument operation conditions and the designation of measurement result uncertainty. The communication interface, included to instrument circuitry, enables the transmission of measurement data to the external central measurement system. All data collected in system can be used as basic information to report preparation, including e.g. acquired uncertainty data which are not used in typical exploitation practice.

The actually carried research concern the configuration of measurement channel enabling designation measurement result uncertainty. The test measurement channel equipped with auto-calibration unit is under research.

The main aim of research is to elaborate the possible simple circuit and adequate algorithms to perform in microprocessor program, which would be applicable in easy way in new designed microprocessor instruments.

The basic unit, essential for performing of such procedures, is the auto-calibration unit [2]. It is linearly growing voltage, changing in full range of input of measurement channel. Some preliminary results obtained using digital oscilloscope during its testing process are shown in Fig.3. This picture contains

the registered course of voltage supplying the input of measuring channel for checking its conversion characteristics. As a result, the actual characteristics of acquisition part of measurement channel, as well as the external disturbances influence on signal converted in this channel, is registered in microprocessor resources. The estimation of collected data enables to determine the correction factors for measurement result and also the uncertainty of this result.

Finally, the access to complete measurement information given in such form in indicating unit of measurement instrument sets free the instrument operator from any additional analyses.

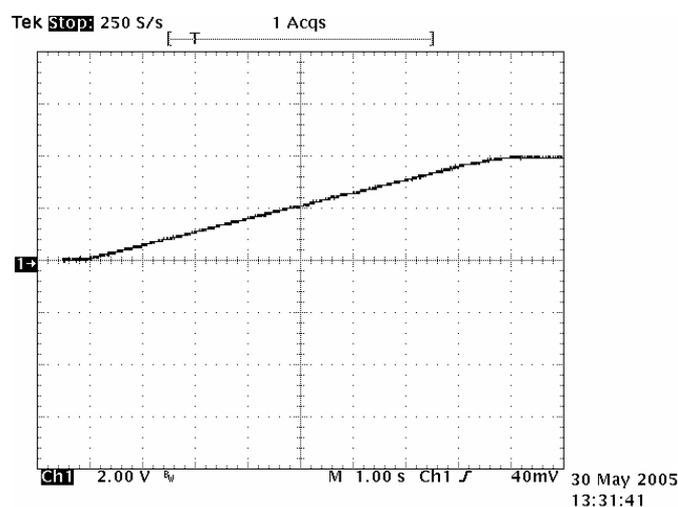


Figure 3. The preliminary test results of auto-calibration unit obtained using digital oscilloscope

Main advantage expected to obtain by implementation of these procedures is the possibility of designation of channel actual characteristics (changing under the ambience conditions influence), its error according to ideal characteristics correction and also the measurement result uncertainty designation. Then, it is the easy way to indicate the uncertainty value in form needed by instrument user.

#### IV. Preliminary conclusions

A specific character of ship crew work is connected with presence of various disturbances accompanying ship arrangement functioning.

The ship measurement instruments accuracy approval is carried out under classification societies supervision. For those operations, to determine an accuracy of instrument, the applying of error designation procedures is needed.

For ship exploitative operations, it is necessary to establish clear rules concerning ship crew members connected with the basic knowledge, how to use the instrument accuracy data to measurement result accuracy assessment in ship operation conditions by applying the uncertainty designation procedures.

At the same time, the new solutions of measurement instruments should be applied for ship arrangement. Those instruments, supported by currently accessible technology, should indicate, beside the measurement result, the information about obtained result uncertainty.

#### References

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- [2] Masnicki R, Mindykowski J., "An uncertainty as a component of the measurement result of the microprocessor instruments", *IMEKO Proceedings*, vol.2, pp.644-649, Athens, Greece 2004.