JANUSZ MINDYKOWSKI,
Assoc.Prof.,D.Sc.,E.E.
DARIUSZ PAJÓREK, M.Sc.,E.E.
Gdynia Maritime Academy
Department of Electric Power Engineering

HENRYK PEPLIŃSKI, M.Sc.,E.E.
Polish Register of Shipping, Gdańsk

On selecting the control - measuring instruments for ship power plants in compliance with the requirements of classification societies

SUMMARY

In the paper an attempt is made to describe performance accuracy of the control - measuring instruments which work in the marine environment, in view of complying with the rule requirements of the classification societies. Empirical principles are given for assessing the limit error of the instruments applicable to ship electric power plants. Regulations for periodic surveying their technical condition are also presented.

INTRODUCTION

Special demands are made to ship electric systems and devices, which arise from their specific operational conditions at sea. The conditions are determined by ship environment stresses, necessary limitations of gabarites and weights of the devices in question as well as by lack of the sufficiently professional maintenance during sea voyage. From among the above mentioned factors the environmental stresses play the most important role [7], which are highly differentiated depending on a navigation region, season, type of ship and equipment etc.

The ship environmental stresses should be known in advance to ensure failure-free operation of the ship electric equipment. This is connected with selection of appropriate testing methods of equipment prototypes on the test stands where the testing conditions equivalent to the real ones with character of their interaction and stress consequences taken into account, are applied. That makes it possible to check in a relatively short time if the tested devices are suitable for marine applications. The procedures make it possible to manufacture the equipment for marine use, the same in principle, but different in details.

For instance marine versions of the instruments usually applied in land-based systems can be prepared by using different insulation materials and engineering processes or specific design solutions such as screening and earthing, or applying special shock absorbers and bearings. Decisions to undertake production of a device for exclusive marine applications are made in specially justified cases only.

Variety and number of classification societies' requirements in respect to particular tests results in discrepancies in assessing intensity of the factors which describe marine environment. Representative statistical data samples should be collected to determine them more precisely. Lack of a common assessment system as well as unified testing methods to be adopted by the classification societies is an additional difficulty in utilizing the results of environmental stress influence assessment.

In consequence the environmental tests used today do not provide the required reliability assurance for the equipment, a.o. because of a discrepancy between the stress parameters applied during tests and their real values.

Therefore collecting the results of empirical investigations of ships in service, apart from analyzing the already collected relevant data, should be continued to prepare a standard set of the marine environmental stress parameters. This results from implementing still novel design and manufacturing concepts in the area of ship machinery and equipment production.

For example an important trend should be noted of introducing the multi-functional, intelligent meters onto ships, based on unified functional blocks and microprocessors, to complete the main electric switchboard equipment but not to eliminate the analogue instruments used today [2,7].

The control-measuring instruments used on ships contain two groups of devices :

- board instruments equipped with indicators which are used for manual controlling and supervising the operation of selected ship systems and
- measurement transducers for automatic control purposes.

Both groups can be applied not only to measure electric magnitudes but also non-electric ones.

Requirements for the control-measuring equipment of the ship electic power plant should be separately considered in each case of the above mentioned groups :

- The instruments equipped with indicators subject to the classification rules indirectly, i.e. subject to relevant procedures for testing the prototypes of ship equipment and electric-electronic instruments in marine environmental stress conditions together with the systems where they are installed.
- The measurement transducers are installed on the basis of their catalogue specifications only in the remote control systems where the entire bloks of the systems (but not their parts) have to satisfy the classification rule requirements on e.g.: permissible error values and/or regulation times and are subject to supervision directly [7].

CHARACTERISTICS OF THE SHIP POWER PLANT ENVIRONMENT

Environmental stress classification according to IEC 75 Publication [3] concerns both land and marine environment conditions and contains the following parameters and factors :

- climatic
- biological
- mechanical
- electric and electromagnetic.

The climatic environment parameters of the measurement intruments applicable to ships depend mainly on the environment conditions which occur in a ship voyage region and time period. The climatic stresses on ships are first of all the following: broad range of temperature and relative humidity changes combined with high air salinity. Both high and low temperatures can occur on ships. In ship power plants the temperature of about 50°C can last for long time periods, and even higher ones can appear instantaneously. The equipment installed under the deck is exposed to seaborne humidity especially high in tropic zones. The relative humidity in ship power plants can often come to 65%, and 97% at most.

The climatic ship environment stresses are usually described by means of the climatograms which are related to a given type of ship compartments or spaces. An exemplary climatogram for the space of Central Control Station (CCS) of a ship operating on the Far East shipping line is shown in Fig.1.

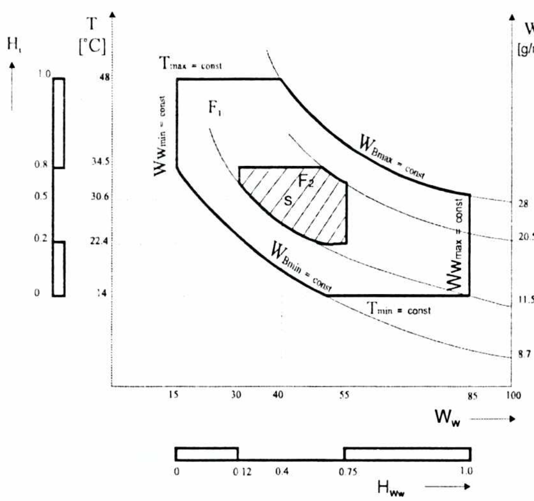

Fig.1. Exemplary climatogram for a ship power plant at the level of electric generators [13]

T_{min}, T_{max} - *min. and max. temperature values recorded during the entire voyage*
W_{Bmin}, W_{Bmax} - *calculated min. and max. values of the absolute humidity*
W_{Wmin}, W_{Wmax} - *min. and max. values of the relative humidity recorded during the entire voyage, in [%]*
H_t - *frequency of occurence of a given temperature value*
H_{Ww} - *frequency of occurence of a given relative humidity value*
s - *point corresponding to the arithmetic mean value of all measurements*
F_1 - *area containing all temperature and humidity values recorded during investigations*
F_2 - *area determined by the mean values of maximum temperatures and relative humidities, calculated from those measured during one month.*

Two limiting lines can be observed on the diagram, the first of which delineates F_1 area and the other - F_2 area. F_1 area contains all the temperature and relative humidity values recorded during the investigations. The limiting line of F_2 area was determined by using the mean values of maximum temperatures and relative humidities, calculated from the values measured during one month. H_t and H_w values were calculated as the ratios of the number of hours of occurence of each of the parameters and the yearly number of hours. As it can be easily checked, F_2 area contains the temperature and relative humidity values which most often occur during the ship power plant exploitation process.

The following active substances belong to the biological and chemical environment factors [12] :

- *biological* :
  - flora (inclusive of moulds and fungi)
  - fauna
- *chemical* :
  - sea salt
  - carbon dioxide
  - hydrogen sulfide
  - nitric oxide
  - ozone
  - organic hydrocarbons
  - ammonia.

Different classification ways of the factors which decide about marine environment aggressiveness can be found when considering different standards; they are usually arranged in a descriptive way. None of the standards defines requirements for a permissible content of the pollutants in compartments, and only a few of them specify approximate data on SO_2 and NaCl content in the athmosphere. For instance TGL 9199/03 German standard, „Umgebungseinflüsse Klassifizierung", states that the content of **NaCl >2000 mg/(m²·day)** can be found at open sea, and IEC document,"Classification of environmental condition" of 1981 only informs that chlorides (NaCl mainly) are present in the athmosphere at open sea and does not specify their content values. The document specifies however SO_2 content values which correspond to 2C3 group of the aggressive environments: **SO_2 content of 10 mg/(m²·day)**. The NaCl content values depend on a navigation zone. The highest ones can be found near the lands of hot zones.

The investigations performed on ships by The Electrotechnical Institute, Gdańsk Division, revealed that the aggressiveness level of the athmosphere depends to a large extent on the location of the decks above sea level. Microclimate in ship compartments is more stable but it depends on a kind of compartment, its tightness, air conditioning etc.

Salinity in the ship power plant space is low but SO_2 content in its athmosphere is high in some cases, sometimes higher than in the industrial districts. SO_2 presence in the space intensifies corrosion processes.

Mechanical factors, out of all stresses acting in the marine environment, are the most decisive for the operation of ship electric devices. The factors, first of all such as vibrations generated by the main and auxiliary engines are the most hazardous. They depend on a type and kind of ship's propulsion system applied. The sea waving which can generate impacts (shocks) is also one of the important sources of such hazards.

The magnetic, electric and electromagnetic fields which occur on ships are usually changeable over broad ranges and their intensities can be very high [13]. Radiation of the electromagnetic field due to operation of the radio transmitters plays an important role among other electric and electromagnetic environment parameters.

The testing disturbance signal of the following parameters :

- the frequency band from 27 MHz to 500 MHz
- the electric field of 10 V/m intensity cannot cause a device either to be disturbed or failed, according to [10].

REQUIREMENTS FOR CONTROL-MEASURING INSTRUMENTS IN VIEW OF THE CLASSIFICATION RULES

The assessment necessary to qualify a device suitable to work in the ship environment conditions is obtained on the basis of results of the environmental tests carried out in an uniform and repeatable way. The test stress factors are usually selected with such stringency as to obtain a possibly short testing time, but without any important change of character and consequences of the considered disturbances in comparison with the extreme operational conditions. A range of the environmental tests, i.e. test types and parameters are left to a decision of each of the classification societies.

Requirements of the Polish Register of Shipping (PRS)

PRS requirements are applicable to the type approval tests of the products intended to be elements of :

- electric equipment
- automation systems
- computer systems.

The requirements specify types of the tests and conditions for their performing (minimum parameters) to which any product prototype should be subjected (complete tests). However PRS may require a serial product to be subjected to all, or to only a few selected, tests. The products should pass with a positive result the following tests in the below stated sequence „i" ,apart from visual inspection (M) and functional testing (M) :

i *test type*
1 - supply power decay, (E)
2 - oscillations of supply power parameters, (E)
3 - dry heat, acc. to IEC 68-2-2 (1974) Publication, (K)
4 - cyclic damp heat, acc. to IEC 68-2-30 (1980) Publication, Db test (K)
5 - cold, acc. to IEC 68-2-4 (1974) and 68-2-1A (1976) Publications, Amendment 1(1983), (K)
6 - sinusoidal vibrations, acc. to IEC 68-2-6 (1982) Publication, Fc test, (M)
7 - heeling, (M)
8 - salt mist, acc. to IEC 68-2-52 (1984) Publication, Kb test, (CH)
9 - moulds, acc. to IEC 68-2-10 (1984) Publication, (B)
10 - electrostatic discharges, acc. to IEC 1000-4-2÷6 Publications, (E)
11 - electromagnetic field radiation, acc.to IEC 801-3 (1984) Publication, (E)
12 - transmitted interference, (E)
13 - insulation resistance measurement, (E)
14 - insulation electric strength, (E)

where the applied symbols stand for the following stresses :
K - climatic, B - biological, CH - chemical, M - mechanical, E - electric.

The PRS requirements for environmental tests were elaborated on the basis of the relevant unified requirements of IACS - the minimum requirements which can be made more stringent by each of the classification societies according to its own opinion. A detail set of PRS requirements for the control-measuring instruments, compared with the similar ones published by other main classification societies can be found in [3,6,10].

Comparison of the environmental test requirements of six classification societies

It can be seen from the comparison of the environmental test conditions of six classification societies, namely: Polish Register of Shipping, Lloyd's Register, Det Norske Veritas, Germanischer Lloyd, Bureau Veritas and Registro Italiano Navale, that most of the tests have to be carried out in compliance with the same requirements or that they contain many common items [6].

The stated similarity of the environmental test requirements makes mutual acceptance of the results of the tests performed under supervision of another classification society associated in IACS possible.

ACCURACY OF CONTROL - MEASURING INSTRUMENTS FOR SHIP ELECTRIC POWER PLANT IN VIEW OF THE REQUIREMENTS OF CLASSIFICATION SOCIETIES

The following parameters are controlled in a ship electric power system :

- current
- voltage
- power
- type of loading
- frequency
- network insulation resistance.

The working process control requirements of a ship power plant are fulfilled if the following measuring instruments are installed in the main electric switchboard for each AC generator, and in the emergency switchboard for the emergency generator [9] :

- an ammeter with a selector switch for current measurements in each phase
- a voltmeter with a selector switch for measuring phase and line voltages
- a wattmeter (for outputs above 50 kVA)
- a frequency indicator (application of a twin frequency indicator with a switch to seperate generators is admissible for generators to be operated in parallel)
- other instruments as required.

Accuracy of the control-measuring instruments

Distinguishing the two groups of conditions: nominal and operational is important for accuracy assessment of every measuring instrument.

The nominal conditions are the reference values of magnitudes which can influence an instrument. The relative error occurring in the nominal conditions is called the basic error δ_p and its allowable value related to full measurement range of the instrument is numerically equal to the accuracy class of the instrument.

The operational conditions are formed by a set of value ranges of the influence magnitudes due to which the metrological features of the instrument can be impaired within established limits. The worsening of the features consists mainly in appearing of additional indication errors. Quantitative assessment of the accuracy worsening is performed on the basis of a value of *the additional limit error* δ_d which is defined as the value by which *the limit error* can increase (in excess of the basic one) in result of a deviation of the nominal conditions still within the operational ranges. *The additional errors* δ_{di} are defined for each i-th influence magnitude separately and called, dependent on its cause, e.g. *temperature error, frequency error etc.* For instance according to the traditional approach [8] each of the causes such as the temperature change by $\Delta T = \pm 10$ K from the nominal temperature, frequency change by $\Delta f = \pm 10\%$ from the nominal frequency value, or instrument standard position change by $\pm 5°$ should not result in arising the additional errors δ_{di} greater than an allowable value of the basic error (class error), e.g. ± 0.1% for 0.1 class, 1% for 1 class etc.

A simplified description of the additional errors in relation to the easuring instruments applicable to ships was presented in [7].

The relative error of the measured magnitude Y at simultaneous occurrence of the several magnitudes q_1, q_2, q_3, ... q_n which are the sources of the additional errors, where e.g. : q_1= T, q_2= f, q_3= U_z etc, can be expressed as follows [1] :

$$\delta Y = \sum_{1}^{n} \left| \frac{\partial Y}{\partial q_i} \frac{q_i}{Y} \right|_{Y_0} \cdot \partial q_i \qquad (1)$$

A very low probability can be attributed to the occurrence of an event when the value of the error δ_d depends on several component errors and the systematic errors of all factors influencing the measurement result simultaneously achieve their limit values and an unfavourable arrangement of signs. Therefore determining the summary limit errors in this way leads to unfavourable, over-estimated results. The resultant error δ_d can be calculated in the same way as the random error if the systematic errors due to particular factors which influence the resultant error are random and independent of each other [1]. The relative, mean square error can be expressed in this case as follows :

$$\delta Y_s = \sqrt{\sum_{1}^{n} \left(\frac{\partial Y}{\partial q_i} \frac{q_i}{Y} \right)^2_{Y_0} \cdot (\partial q_i)^2} \qquad (2)$$

The above described way of determining the measuring instrument accuracy is relevant to land-installed instruments. However divergences appear in the case of measurements in the marine environment conditions and the additional errors can differ considerably from those calculated in accordance with the Polish Standard (PN) [8]. For instance the instrument environmental temperature deviation from the reference temperature in the power plant space can be as high as 35 K, and the heeling angle deviation from the nominal instrument position as high as 20°, whereas the allowable deviations from the nominal conditions in accordance with PN standard [8] are ± 10 K and 5° respectively. The following total measurement error is important for marine applications :

$$\delta_c = |\delta_p| + |\delta_{d_m}| \qquad (3)$$

and simultaneously :

$$\delta_{d_m} \rangle \delta_d \qquad (4)$$

where :

- δ_c - total error
- δ_p - basic error resulting from the reference conditions
- δ_d - additional error resulting from the normal operation range
- δ_{d_m} - additional error for marine applications, resulting from the environmental test conditions defined by the classification societies.

The notion of the total error applicable to marine environment conditions is illustrated in Fig.2.

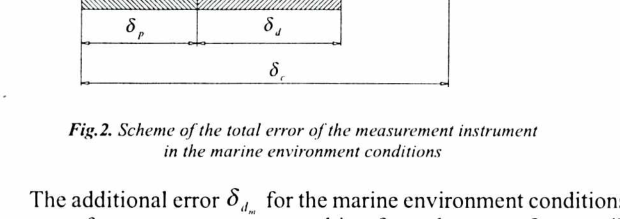

Fig.2. Scheme of the total error of the measurement instrument in the marine environment conditions

The additional error δ_{d_m} for the marine environment conditions is a sum of many components resulting from the stress factors „i" which characterize the marine environment :

$$\delta_{d_m} = f\left\{\delta_{d_{m1}}, \delta_{d_{m2}}, \delta_{d_{m3}}, \ldots, \delta_{d_{m14}}\right\} \qquad (5)$$

where the lower indices 1, 2, ..,14 stand for the earlier specified factors.

The positive result of a particular environmental test means that the error due to stress factor interaction is lower than its allowable value specified by the classifcation society. A redudancy factor provided by the prerequisites for establishing the environmental test parameters takes into account simultaneous, mutual interaction of the δ_{d_m} error components.

It is very hard to separate the particular error components and to recognize their character and the way of infiltrating into the measurement process. The error structure approach applied in [5] may help in describing the problem. Only the serial-parallel structure from among the cases considered in [5] accounts for the additive-multiplicative character of the error. Taking into account that the relative multiplicative error inherent for a serial structure can be expressed as follows :

$$\delta Y_m = \sum \delta q_i \qquad (6)$$

and for a parallel structure as follows :

$$\delta Y_a = \frac{\sum q_i \delta q_i}{\sum q_i} \qquad (7)$$

one can write the equation (8) which expresses the relative error for a structure composed of „n" serial segments connected in series to „k" parallel segments :

$$\delta Y = \delta Y_m + \delta Y_a = \sum_{1}^{n} \delta q_i + \frac{\sum_{n+1}^{k} q_i \cdot \delta q_i}{\sum_{n+1}^{k} q_i} \qquad (8)$$

Selective identification of the character of each error component is necessary in order to apply in practice the cited expressions, which is a very complex task. In such situation a redudancy factor adopted by the classification societies makes it possible to avoid the algebraic or geometric summation of values of the additional errors δ_{dmi} and to substitute it by a global measure of the summary additional error where the structural arrangement of the devices and systems in question is already taken into account.

For instance PRS assumed on the basis of multi-year empirical tests that the average value of the error for the instruments operating in the marine environment should not be greater than $\delta_{d_\Sigma} = \pm 1{,}5\%$.

Therefore :

$$\delta_c = |\delta_p| + |\delta_{d_\Sigma}| \qquad (9)$$

It practically means that the total measurement error value e.g. of 0,5 class instrument operating in the marine environment does not exceed 2% of its measurement range.

Periodical surveys of the accuracy of the control-measuring instruments applicable to ships

A class of the board measuring instruments applied on ships results from their character of operation. The marine environment introduces due to its specific character the measurement errors which are unavoidable and only limiting their values is possible to some degree. Therefore the classification societies usually accept the indicative mode of operation of the board control-measuring instruments. Today the measuring instruments of the class 1, 1.5 or 2.5 are used to controlling the ship engineering systems, e.g. such as the electric power system .

Correctness of functioning and indication accuracy of the instruments is verified during ship surveys. A scope of such surveys can be found e.g. in the PRS Rules, Part I : Classification Regulations. The scope contains : visual inspection, measurements, tests and checking in accordance with the Tab.1.

Tab. I. Scope of periodical ship surveys in respect to the control-measuring instruments installed in ship power plants

Control-measuring instrument position	Scope of periodical surveys of a ship											
	Cycles											
	1	2	3	4	5	6	7	8	9	10	11	12
Main (RG) and Emergency (RA) Switchboards	P	P	P	OEMP	P	P	P	OEMP	P	P	P	OEMP
Group and terminal switchboards		P		OMP		P		OMP		P		OMP

where :

O - visual inspection to ascertain technical condition by ensuring accessibility or dismantling of various items and, as necessary, internal inspection
M - measurements
P - operation tests and external visual inspection of machinery and arrangements
E - checking the availability of documents in force or brands confirming the adjustment of instruments or devices (legalization) if they are to be checked (legalized)
1, 2, ...12 - ship exploitation cycles containing annual surveys and class renewals at 4-year intervals.

During the class renewals the control-measuring instruments installed in the RG and RA are not subjected again to the environmental tests if their indications do not depart substantially from the assumed values. For instance symmetry of the indications corresponding to particular phase and line voltages is the sufficient condition to verify positively the voltmeters which control voltages of particular electric generators.

However verification of indication accuracy of the wattmeters practically consists in comparing the value indicated by each of the meters with the value calculated from the known relationship as follows :

$$P = \sqrt{3} \cdot U \cdot I \cdot \cos\varphi \qquad (10)$$

where voltage, current and phase angle values have to be taken directly from the meters installed on the field of a given electric generator. A wattmeter is deemed suitable to operate further on if the two values (indicated and calculated) are in compliance with each other. The verification of indication accuracy of the instruments installed in the RG and RA is performed, after their dismantling, on the test stands by using the standard meters, or directly on ships by applying special testers [11].

It should be added that the measuring transducers usually manufactured with 0.2 and 0.5 class are not considered individually. The designer selects accuracy of a transducer having in mind the classification requirements to be complied with by the entire automation control block in which the transducer has to be used, since PRS supervises and approves the automation control blocks as complete systems and does not check any of their particular components.

FINAL REMARKS

❒ Carrying out the investigations on ships in order to identify the environmental stress factors during operation of the ship technical systems should be preceded by establishment of uniform measurement methods, number of the stress factors subject to simultaneous recording and uniform classification of ship compartments from the point of view of different microclimates or stress environments.

❒ The environmental stress parameters should be periodically amended to account for permanent modernization of newbuilt ships. This is connected with continuing such investigations aimed at a.o. elaboration of the synthetic quality indices characterizing the control-measuring instruments for marine applications.

NOMENCLATURE

f - frequency
q - source of the additional error
y - measured magnitude
y_0 - approximate value of „y"
I - current
P - power
T - temperature
U - voltage
U_z - supply voltage
δy - relative error
δy_a - relative additive error
δy_m - relative multiciplative error
φ - phase shift angle

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Appraised by Jerzy Majewski, Prof.,D.Sc.,E.E.

Miscellanea

SEA COAST PROTECTION

The more and more vividly discussed problem of thermal climatic changes on the globe, which cause melting the glaciers, is also felt along the Polish shoreline. The growing level of the Baltic Sea and violence of its attacks against the sandy sea shore devastate it rapidly. The process is felt especially acutely in the Rozewie Cape region where Jastrzębia Góra, the farthest north located Polish health resort is located.

For several years the place is an operational site of the water engineering researchers and specialits who investigate wave behaviour and are engaged in strengthening works of the cliff of over 30 m in height at that place. Its sliding endangers several rest & pleasure objects and seacoast natural environment. The results achieved thus far drew much interest from the side of scientists from abroad (inclusive of the American and Japanese ones) who, 160 in number, took part in the special conference on „Coastal Dynamics" held in 1995.

Along the 200m experimental sector the Polish specialists successfully applied the supporting technique of the sliding cliff which consisted in using the „gabions", i.e. steel cubicoid baskets filled with stones. The baskets are imported, but stones are digged nearby.

Effectiveness of the method is paid however by a relatively high cost. A part of it will be refunded by the UNDP agency. The aid makes it possible to carry out further investigations on improving the method, with a benefit not only to protection of the Polish sea coast but also to other countries where similar problems will be solved easier if the method is used.