

CHECKING CURRENT ANALOG MEASUREMENT CHANNELS

B. Dudojc and J. Mindykowski

Faculty of Marine Electrical Engineering
Gdynia Maritime Academy, 81-225 Gdynia, Poland

Abstract: This paper suggests a new approach to checking understood as a validation and diagnostic procedure of the analogue measurement channels in 4-20mA standard. The discussed method is very useful in field conditions especially for widespread long distance systems like those on ships. In each case it supports traditional methods but in the same specific situations of temperature measurement it can indicate a faulty channel.

Keywords: checking procedure; 4-20mA standard; an admissible working area

1 NATURE OF THE PROBLEM

Two-wire measuring channels with analogue standard signal current transmission in 4-20mA standard are a generally accepted solution in industry and in ships' operational conditions [1]. The measurement channels are comfortable for widespread and long-distance measuring systems. A significant advantage of current signal transmission method is its anti-interference ability and furthermore, an easy possibility of switching on the Zener barriers to the measurement channel without involving any additional measuring errors. The second property is especially important for measuring channels installed in hazardous areas [2]. The channels under consideration are used to measure any electrical and especially non-electrical quantities.

Generally, the checking procedure of measurement channels is done in two cases. In the first case, the procedure named a validation procedure is determined by administration rules and should be confirmed by a certificate after a commissioning procedure or periodical one e.g. every half a year or sometime after a serious repair. Checking procedures are often done by specially trained personnel or even by independent laboratories and all calibrators or simulators are accessible in that case. Production process is often paused during the checking procedure.

In the next case the checking procedure is done during working time when a measurement channel shows wrong indication. Such situation is less convenient than the first one and the checking procedure can named a diagnostic procedure. The diagnostics of the measurement channel should be done very quickly. Sometimes the procedure, mainly under exploitation conditions, is limited by the lack of corresponding calibrators or simulators. When they are available, there are sometimes problems with the connection due to difficult access to a transmitter, lack of spare parts, lack of correct documentation or even problems with polluting the product which should be very pure e.t.c. Many of the mentioned conditions are characteristic for ships in merchant fleet.

In all cases the validation or diagnostic procedure is done for one point on an admissible working area of the channel under consideration. A change of working point during checking procedure gives additional possibility for correct estimation of the measurement channel. Suggested method should be treated as a support for the methods used so far, especially in operation.

2 STATE OF THE ART

Two-wire measurement channel with current signal transmission in the basic version is illustrated in Fig.1. A dropped line indicates that a load resistance R_o of the measurement channel is a part of an output circuit OC and partly it is the resistance of wires and other connected circuits like Zeners barriers [3]. The output circuit OC in the simplest figures can be both an analogue miliamper and a voltage power supply U_{ps} . In a more sophisticated system the output circuit can represent an input resistance of A/D converter with a voltage power supply. The checking procedures usually applied are focused on the static characteristic of the measurement channel or sometimes during diagnostics and repairs separately on the characteristic of transmitter and output circuit. Each time the checking procedure was carried out for one working point. The working point of the measurement channel is determined by voltage of power supply U_{ps} and the load resistance R_o . The resistance R_o is a sum of all pieces resistance passed by current signal I . The working point Q is illustrated in Fig. 2 and has to be inside the admissible area of operation of the measurement channel. The admissible area of operation (triangle ABC in Fig.2.) is determined by all the elements of the measurement channel. The transmitter defines admissible voltage parameters (U_{psmin} , U_{psmax}) and output current $I=20mA$.

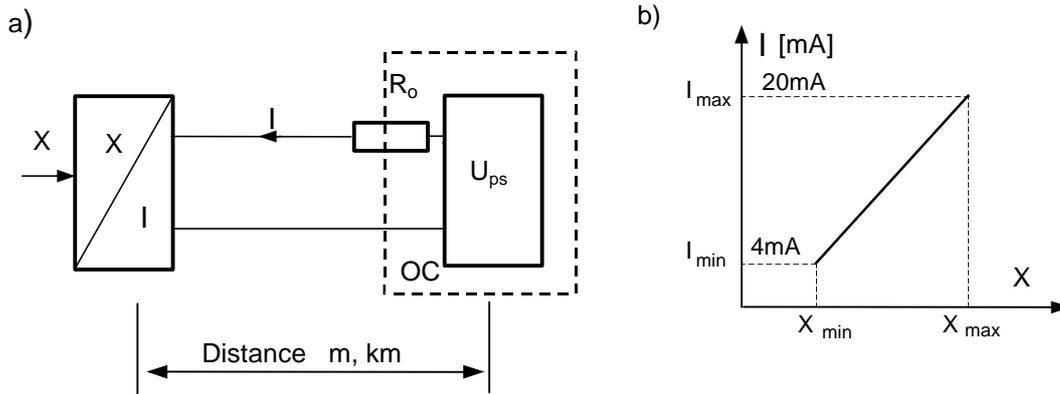


Figure 1. The two-wire measuring channel with standard 4-20mA current signal transmission; a) Simplified block diagram; X- measured quantities, X/I- transmitter, I- current signal, R_o- load resistance, OC- output circuit, U_{ps}- power supply voltage; b) Linear static characteristic of the transmitter.

The power supply is represented by voltage U_p and the admissible load resistance R_l is expressed by the dependence

$$R_l = \frac{U_p - U_{psmin}}{0.02} \tag{1}$$

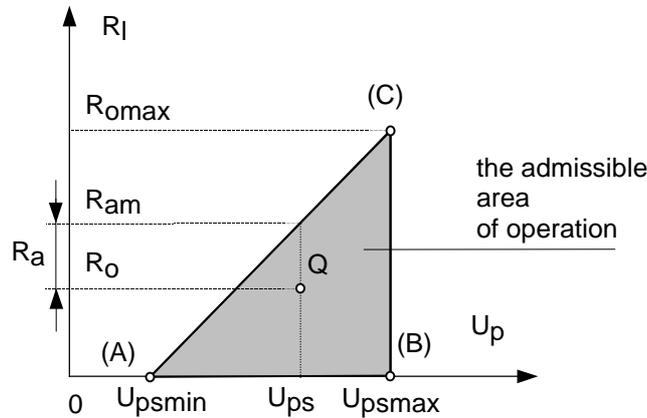


Figure 2. The admissible area of operation for two-wire measurement channel of the 4-20mA standard, R_l- load resistance, U_p- power supply voltage, R_{am}-maximal available resistance for U_{ps}, R_a-available load resistance for checking purpose, R_o-the load resistance of measurement channel under consideration.

When the working point Q is at any place of the admissible area of operation defined above, the current signal depends only on the value of measurement quantities. This attribute of admissible area of operation can be used for checking purposes.

3 STUDY AND INVESTIGATION OF THE NEW APPROACH TO CHECKING PROCEDURE OF THE MEASUREMENT CHANNEL UNDER CONSIDERATION

For the voltage powered the channel U_{ps} working point Q can be changed by connecting additional series resistance with value no more than R_a -available load resistance (Fig.2). While checking, it is necessary to connect independent milliamper to observe the signal current. The current has to be stable independently of the load resistance value with one limit. The sum of all pieces load resistance

series connected should be less than R_{am} . Any change of the signal current value is indicated on a problem with the measurement channel sometimes with the correct static characteristics. Because the admissible area (presented in Fig.2.) is defined for the maximal value signal current equal to 20mA so, in order to carry out the suggested procedure it is necessary to force the input quantity to the maximal value. It generates all problems discussed above with the use of any calibrator or simulator [4]. For the measurement channel correctly designed it is possible to appoint admissible areas for different signal current value. In this way an admissible space of operation for the two-wire measurement channel is set down. The admissible space of operation is illustrated in Fig.3a) and it is limited from the top by a surface expressed by dependence

$$R_o \{U_p, I(X)\} = \frac{U_p - U_{psmin}}{I(X)} \quad (2)$$

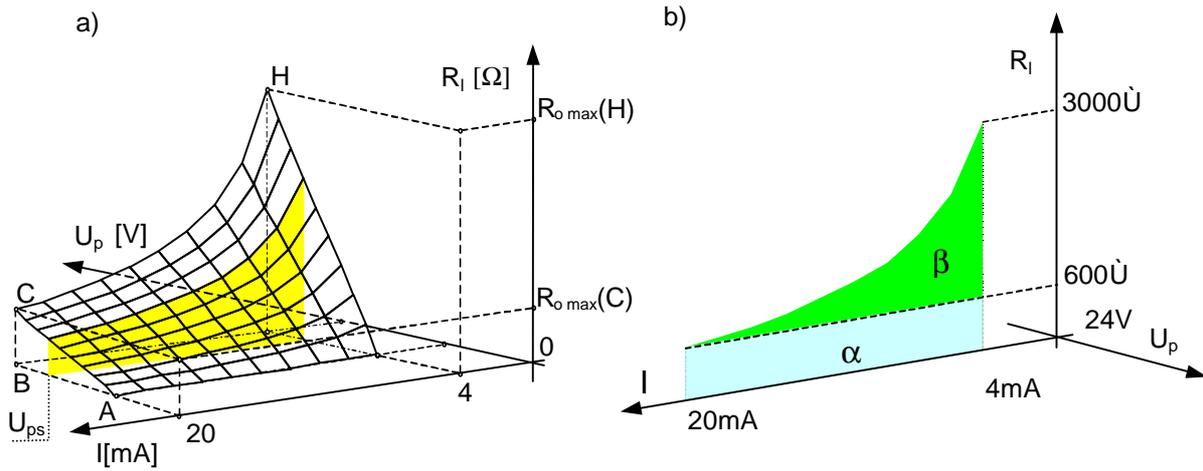


Figure 3. a) The admissible space of operation for the two-wire measurement channel in the standard 4-20mA, b) The diagnostic area of the measurement channel for voltage $U_{ps}=24V$.

The triangle ABC is the same as in Fig.2. For the voltage power supply U_{ps} used in the measurement channel the diagnostic area is marked by the shadow and separately presented in Fig3b). The diagnostic area is calculated for the channel powered by $U_{ps}=24V$ and it was assumed that the transmitter used has admissible minimum voltage supply $U_{psmin}=12V$. The diagnostic area can be divided into two sub-areas a and b. The sub-area a corresponds to maximal available load resistance R_{am} and is available for design purposes. Many times the load resistance is much lower than R_{am} . More interesting is the sub-area b. This sub-area is always available for diagnostic or validation procedures. Inside β area it is possible to check the measurement channel using a process value as an input quantity value which is almost always lower than the maximum. Depending on the current signal value $I(X')$, which is picked up from separately connected meter, the extra available load resistance R'_a is calculated on the basis of the following formula

$$R'_a = \frac{U_{ps} - U_{psmin}}{I(X')} - \frac{U_{ps} - U_{psmin}}{0.002} \quad (3)$$

By connecting temporarily any value of extra resistance but lower than R'_a into the loop of the current signal, the working point of the measurement channel is changed. Any change of the current signal $I(X')$ a problem with measurement channel indicates which can be easily identified by measuring voltage on the transmitter and checking by calculating one point on the static characteristic of the transmitter and the output circuit.

The presented new approach to validation and diagnostics of the measurement channels under consideration was very helpful in exploitational conditions on ships. In each case it supports traditional methods but in some specific situations for measurement of temperature it can be one way to indicate a faulty channel.

4 CHECKING TEMPERATURE MEASUREMENT CHANNELS

A good illustration of the discussed method is the checking temperature of measurement channels. The temperature measurement channel is a complex electrical net, where a sensor eg. Pt-100 is not

only resistance but impedance. Similarly, cables used in field conditions are shielded so for long distances they also function as complex impedance [5]. Taking into account field conditions an electrical model of the temperature measurement channel under consideration can be presented in Fig.3.

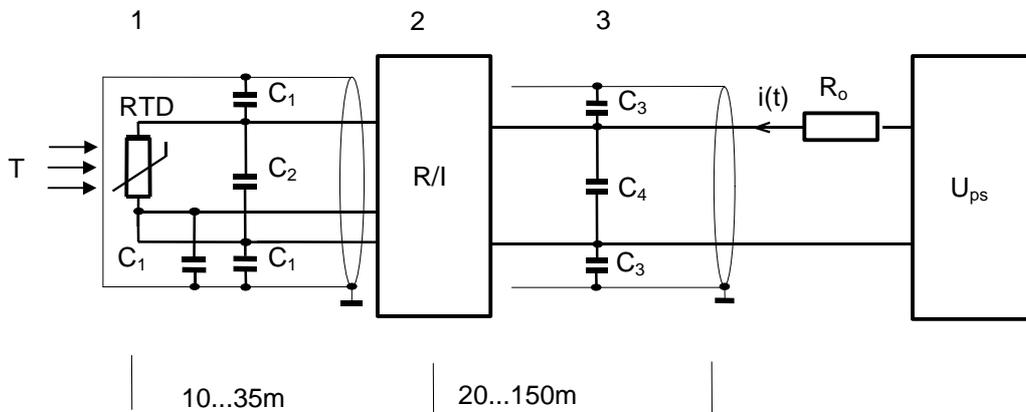


Figure 4. Exemplary two-wire current signal processing and transmission channel including the RTD sensor and considering capacitive coupling influence; RTD- resistance temperature detector, R/I- resistance-to-current transmitter, C_i -capacitive couplings.

The sensor and the shield of the connected cable are grounded [6]. It causes an electrical capacitive coupling between input and output of R/I transmitter. Depending on dynamic properties of the used R/I transmitter the measurement channel can change into generating system of an alternative current.

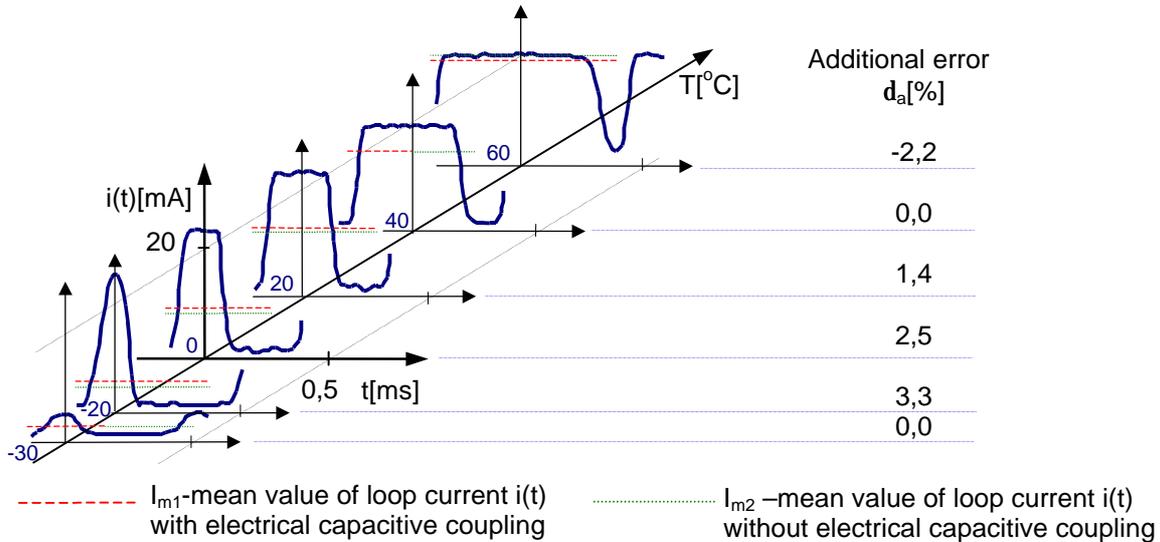


Figure 5. Waveform of current loop $i(t)$ in function of measured temperature T (resistance of RTD) for load resistance $R_o=600\Omega$.

These phenomena can appear for channels in operation in field conditions with oscillatory second order of the dynamic properties of a transmitter.

Discontinuing capacitive coupling eg. by insulating sensor causes, that the alternative current component disappears and the measurement line works correctly as the DC system. Such situation appears during traditional checking procedures. In case of using resistance simulator of RTD sensor the capacitive coupling disappears by disconnecting the original sensor. Using pattern source of heat it is necessary to dismount the sensor and fix in a heater. That operation also destroys the capacitive coupling under consideration.

Using the traditional checking procedure for validation of the temperature measurement channel under consideration it is possible to carry it out but actually the measurement line after connecting of the RTD sensor back can generate alternating current component [7].

An influence of alternating current component is different on an installed type of indicator and can be noted as an additional error δ_a of the readings. It was stated that in case when alternating current component appears, the shape of it was different depending on measured temperature T and value of load resistance R_o . Exemplary waveforms $i(t)$ including alternating current component in function T and R_o are shown in Fig.5 and Fig.6, respectively.

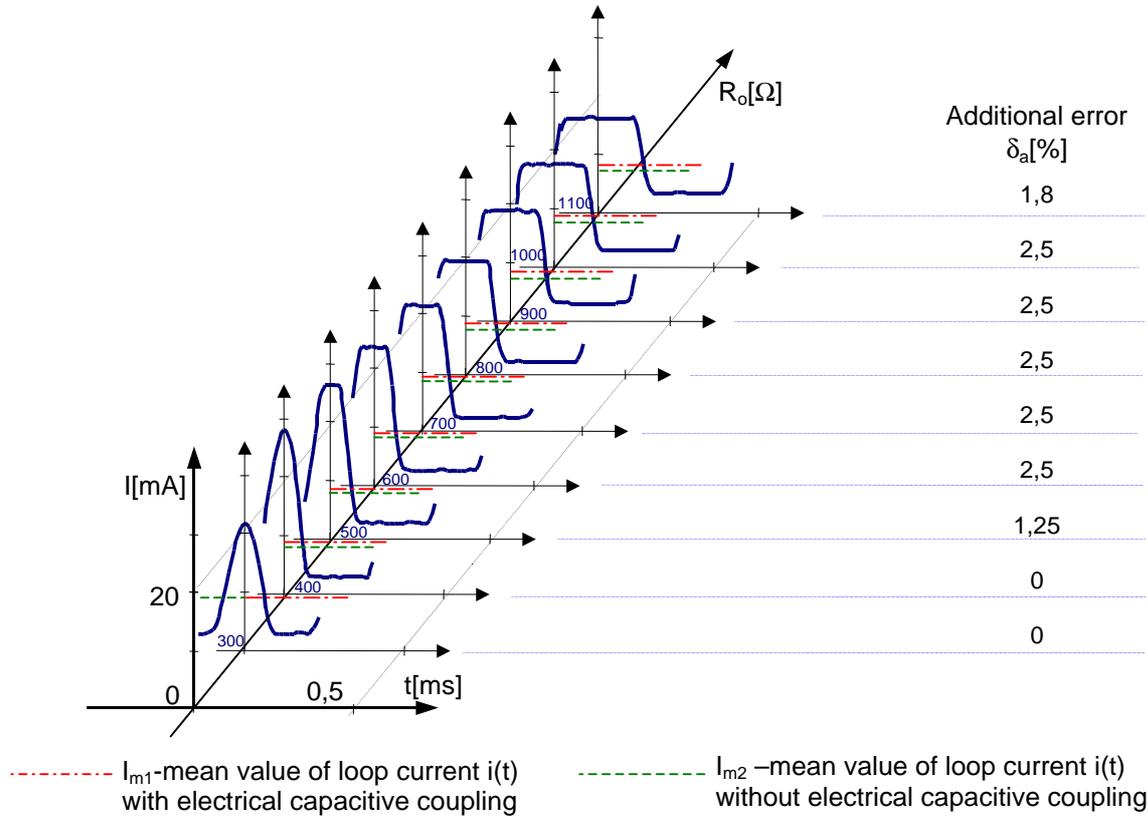


Figure 6. Waveform of current loop $i(t)$ in function of load resistance R_o for measured temperature $T=0^\circ\text{C}$ (resistance of RTD, $R_{RTD}=100\Omega$).

Presented waveforms $i(t)$ were done in laboratory during testing of measurement channel under consideration by simulating field conditions with transmitter TR01-L ($-30^\circ\text{...}60^\circ\text{C}$), RTD sensor 15 meters long and 30 meters shield cable.

The additional error of readings δ_a appears when[7]:

$$\delta_a = \frac{\frac{1}{\tau} \int_0^\tau i(t) dt - I_{m2}}{I_{\max} - I_{\min}} \cdot 100\% \neq 0 \quad (4)$$

where τ - period of loop current $i(t)$.

In both discussed situations measurements were done firstly for the existing electrical capacitive coupling obtaining the alternative wave and secondly after insulating the RTD sensor (the electrical capacitive coupling was destroyed) obtaining correct DC current value (I_{m2}).

First situation ($T=\text{var}$) can appear in operational conditions and when it is difficult to control it from changeable error in function of measurement temperature. The second situation ($R_o=\text{var}$) can be provoked during checking (validation or diagnostic) procedures. Any change of readings during the change of additional load resistance R_o indicates a fault.

5 FINAL CONCLUSIONS

Checking procedure of measurement channels may be considered as validation or diagnostic procedures, depending on the aim of the test. The attribute of admissible area of operation the considered channel, that the current signals depend only on the value of the measured quantities, can be used for checking purposes. The validation and diagnostic procedures can be supported by suggested method applied on the basis of diagnostic sub-areas a and b, respectively (Fig.3), using the

appropriate additional load resistance value for changing the working point of measurement channel. Exemplary results of checking temperature measurement channels illustrated in Fig.5 and Fig. 6 show presence of alternating current component in the analysed signal and related additional errors.

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AUTHORS: Faculty of Marine Electrical Engineering, Gdynia Maritime Academy, ul. Morska 83, 81-225 Gdynia, Poland, Phone (48 58) 21-99-38, Fax (48 58) 20-67-01,
E-mail: boldu@vega.wsm.gdynia.pl, janmind@vega.wsm.gdynia.pl