Transient states of the transmitters in the 4-20 mA measurement lines

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Abstract-A connection of a new transmitter with measurement line while the system is working is a routine action under exploitation conditions. During this operation the transmitter is in a transient state. Usually, the properties of transmitters in the transient state are not defined by producers. In the paper, the results of the research of transient states of selected transmitters were presented. Basic features of current disturbances and their influence on the measurement line were discussed. Related suggestions for designers were proposed.

I. Introduction

The life time of a measurement system can be divided into several periods. Conception, designing and construction take relatively short time in the relation to an exploitation time, which is very long. The last period is the scrapping time, which is very short. In the distributed systems equipped with two wire 4-20mA measurement lines sometimes it is necessary replaced transmitter during exploitation period.
The measurement peculiarities of the two-wire measurement line in the 4-20mA standard are described by static and dynamic characteristics of its elements [1][2]. In addition, the mentioned measurement line can be described by an admissible area of operation as a requirement for designing or by diagnostic space for maintenance in exploitation condition [3]. Above mentioned characteristics describe the measurement line under consideration of working condition, however in the field conditions it is necessary to mark out the state strictly connected with the replacement of the transmitter. The exchange of the transmitter is often done under voltage while the system is working. A connection the new transmitter with the measurement line causes the disturbances of current. From the moment of connecting to the moment of establishing of the current the transmitter is in a transient state.

1. The measurement line in two wires 4-20mA standard

Two-wire measurement line with current signal transmission in the basic version is illustrated in Figure 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 Zener 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 resistance R_o is a sum of all pieces resistance passed by current signal I. The working point Q of the measurement channel is determined by voltage of power supply U_{ps} and the load resistance R_o is illustrated in Fig. 2 and has to be inside the admissible area of operation of the measurement line. The admissible area of operation (triangle ABC in Figure 2.) is determined by all the elements of the measurement line. The transmitter defines admissible voltage parameters (U_{psmin}, U_{psmax}) and output current I=20mA.

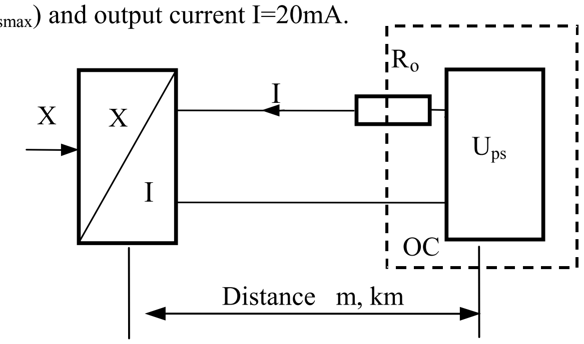

Figure 1. The two-wire measurement line with standard 4-20mA current signal transmission; a) Simplified block diagram; X- measured quantities, X/I- -transmitter, I- current signal, R_o- load resistance, OC- output circuit, U_{ps}- power supply voltage.

The power supply is represented by voltage U_p and the admissible load resistance R_L is expressed by the dependence (1). It is necessary underline that value of the load resistance R_o has to be lover or equal to the admissible load resistance R_L.

$$R_o \le R_L = \frac{U_p - U_{ps\,min}}{0.02} \tag{1}$$

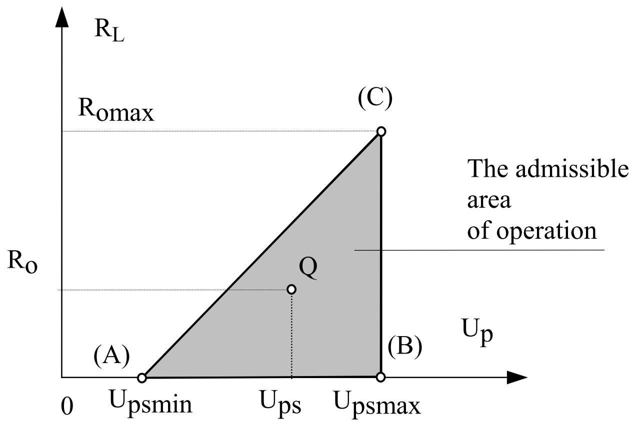

Figure. 2. The admissible area of operation for two-wire measurement line of the 4-20mA standard, R_L- load resistance, U_p- power supply voltage, R_o-the load resistance of measurement channel under consideration.

While 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 the admissible area of operation can also be used by designers to limit a value of disturbance during transient state of the measurement line.

II. The transient state of the transmitter

In normal working conditions the output current signal of loop from transmitter changes its value between 4 and 20 mA. The current higher or lover then above mentioned range can be interpreted as a fault of the measurement line. Actually that situation is often utilized for signalising of some intelligent transmitter's faults. Almost all intelligent transmitters give opportunity to make choose of alarm current value below 4 mA (e.g. 3,75mA) or above 20mA (e.g. 21-23 mA).

Usually designers of measurement systems take under consideration of the loop current in steady-state conditions. Nevertheless on the correct operation of measurement system can be influence a disturbance of current caused during transient state of a transmitter. A nature of disturbances of the current is direct influence on inputs of measurement system and can be treat as an intrinsic disturbance. The shapes of transient disturbances of the transmitter current mainly depend on the transmitter peculiarities but the peak value can be restricted by other elements of the measurement line. Checking the current transmitters during connection process to the measurement line gives opportunity to recognize the kind of the disturbances, which can adversely affect the measurement system.

For the purpose of the research some transmitters of the temperature and pressure both the analogue and the programmable ones were selected. The research was done in a measurement circuit (Figure 3) where the power supply was connected to the transmitter via reed switch and the current was recorded by a digital scope [4].

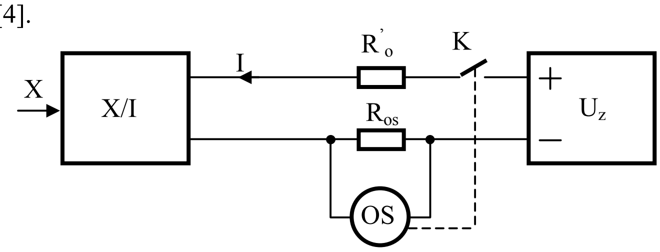

Figure 3. Measurement system of the transient state

The research results were analysed and presented on the illustration of the transient current for one programmable (Figure 4) and analogue (Figure 5) transmitter. For other transmitters selected parameters were collected in the Table 1. The current disturbances were divided into three characteristic periods presented in Figure 4.

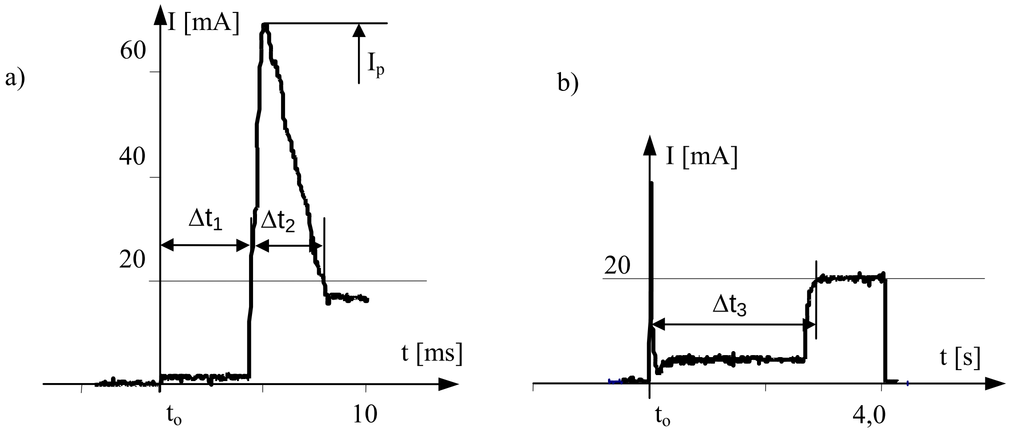

Figure.4. The current of the programmable transmitter (P2 – in table 1) in the transient state, a) the first ms of the current disturbance, b) the first second of the current disturbance.

In order to give a more precise definition of above-mentioned periods the disturbances were presented on the drawing in two parts. The part a) illustrates the first milliseconds of the disturbance, the part b) corresponds to the first s. At the moment t_o, corresponding the connection of the transmitter to the power supply the first characteristic period Δt_1, which is called the time delay, starts. During the next period Δt_2 the current disturbance exceeds the value of 20mA and has different shapes. More exactly the period Δt_2 is a sum of all periods when the current is higher then 20mA during transient state of transmitter Δt_3. The period Δt_3 (turn-on time) defines the time from the connecting moment t_o to the moment of establishing the value of the current, which corresponds to measurement value.

Table 1. Selected parameters of transmitters in the transient state; A1-A5 analogue transmitters, P1-P5 programmable transmitters.

	Δt_1 [ms]	Δt_2 [ms]	Δt_3 [ms]	I_p [mA]
A1	$<10^{-4}$	5	55	800
A2	$<10^{-4}$	0,01	0,02	900
A3	$<10^{-4}$	0,015	20	700
A4	$<10^{-4}$	10^{-4}	1	300
A5	$<10^{-4}$	1,3	4,5	175
P1	$<10^{-4}$	10	220	1050
P2	4	3,5	2800	68
P3	$<10^{-4}$	0,5	1240	600
P4	36	60	3200	123
P5	5	5	2490	64

Taking into consideration obtained research results, the transmitters can be divided into two groups. The first one distinguishes by a very short time of delay Δt_1. The disturbances of current I_p in the period Δt_2 many times exceed the value of 20mA for these transmitters and they are sometimes bigger than 1A. The discussed disturbances last from a fraction to several ms

The transmitters belonging to the second group distinguish by longer time of delay Δt_1, which is different and depends on the transmitter. It can last from a fraction to tens ms. During that period the transmitter gives a low value of the current, much less than 4mA. Just at the end of the period Δt_1 the current violently escalates to the value, which often exceeds 20mA. During the period Δt_2 for transmitters from the second group the value of the current exceeds 20mA but no more than some times. However, the period Δt_2 continued from a few to tens ms, much more then for transmitters belonging to the first group. The total period of the disturbance Δt_3 (turn-on time) when transmitters are in transient state is much longer for programmable transmitters then for the analogue ones.

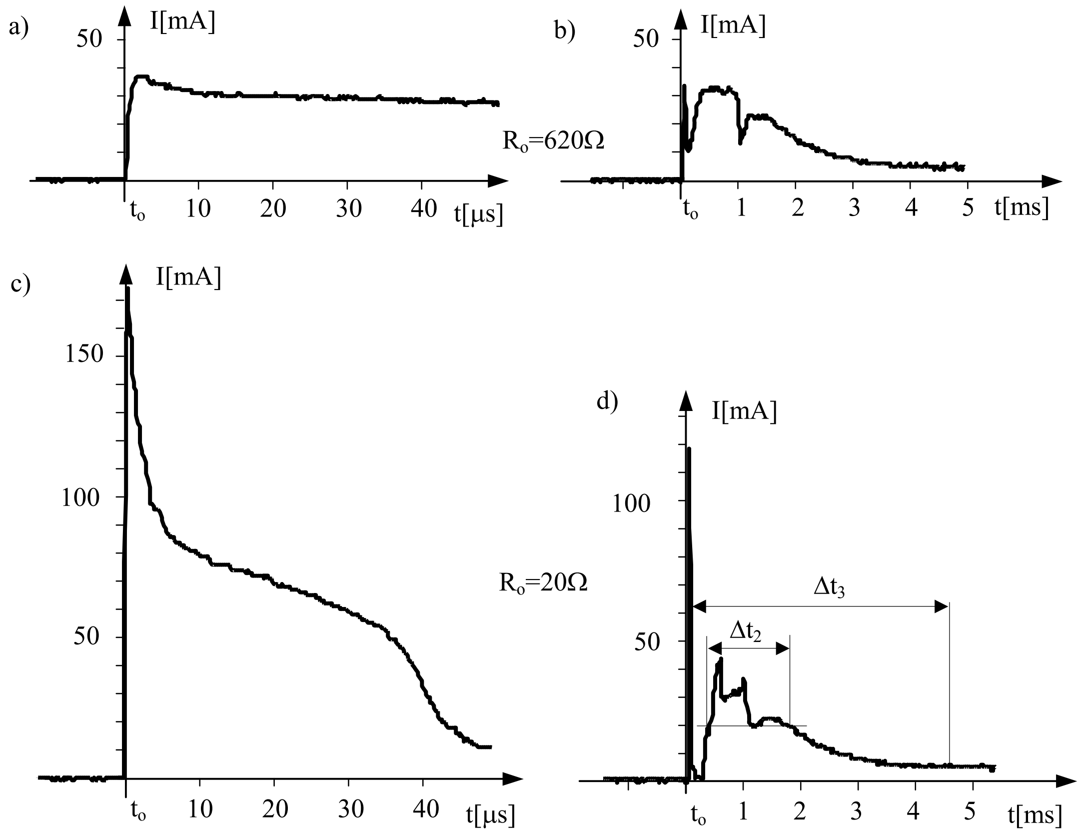

Figure 5. The current of the analogue transmitter (A5 – in table 1) in the transient state: a,c) the first µs of the current disturbance, b,d) the first ms of the current disturbance, a,b) for load resistance R_o=620Ω, c,d) for load resistance R_o=20Ω.

It is worth to underline that the peak value of the current for all transmitters strongly depends on the load resistance value R_o and voltage of power supply of the measurement line. In the Figure 3 the load resistance R_o= R'_o+R_{os}. The first phenomena is illustrated in Figure 5. Parts a) and b) show the current disturbance of the transmitter with load resistance R_o=620Ω and parts c) and d) show the same transient current with R_o=20Ω. It is easy find that the peak value of the current can be easily restricted by an increase in the load resistance R_o what is noted when were compared shapes of transient current during first microseconds presented in part a) and c).

III. Conclusions

The measurement peculiarities of the transmitters in two wire the 4-20mA standard are described by the static and dynamic characteristics, however, in particular cases it is necessary to take under consideration their peculiarities during transient state. The research results of some transmitters showed serious differences between transmitters behaviour in the transient states. The transmitter is only one element of the measurement line. An adequate choice of the other elements such as a load resistance value and voltage of power supply, which set the working point on the operating area of the measurement line under consideration, can actually restrict negative effects of the transient disturbance of a current during transient state of the transmitter. It is worth to underline that the intrinsic safety measurement lines restrict the level of disturbances during transient states.

References

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