Transient States in the Intrinsically Safe Measurement Lines of the 4-20mA Standard

Boleslaw Dudojc

Gdynia Maritime University, Marine Electrical Engineering Faculty
Department of Electrical Power Engineering
81-225 Gdynia, ul. Morska 83, Poland
phone: +48 58 6901 440, +48 58 6901 390, fax: +48 58 6901 261
mail: boldu@am.gdynia.pl

Abstract-During the maintenance of the intrinsically safe electric circuits in the hazardous area connecting, disconnecting of the intrinsically safe apparatus and short circuits are acceptable. In this moment the intrinsically safe measurement line is in a transient state. In the article the results of the research on the transient states in the measurement line in the 4-20mA standard are presented.

I. Introduction

One of still very popular methods of measuring different quantities in wide-spread industrial systems is the two wires 4-20mA DC standard. Sometimes it is necessary to execute the measurement in hazardous areas. The hazardous areas are connected with transport, storing, production and using flammable substances in industry processes. The realisation of the measurement in the hazardous areas can be executed by using different explosion protected techniques such as the flameproof enclosure (EEx d, Ex d), the increased safety realisation (EEx e, Ex e), the pressurised enclosure (EEx p, Ex p), the intrinsic safety technique (EEx i, Ex i) and rather rarely other solutions. The type of used explosion protection depends on many factors such as the hazardous zone, the kind of flammable substances, the rate of power etc. For the measurement the most convenient technique is the intrinsically safe realization (EEx i, Ex i) [1].

The measurement of the 4-20mA DC standard can be relatively easily executed as the intrinsically safe realisation. One of the properties of the intrinsically safe realisation is the possibility of maintaining the measurement line under voltage. It is very important for the wide-spread multichannel systems, which cannot be switched of in the operating condition. [4, 5, 6]

The measurement peculiarities of the two-wire measurement line in the 4-20mA DC standard are described by the static and the dynamic characteristics of its elements. The mentioned above measurement line can be also described by an admissible area of operation as a requirement for designing or by diagnostic space for maintenance in exploitation condition. In the intrinsically safe realisation of the measurement line some specific elements have to be attested and they are additionally described by special parameters concerning of the explosion proof safety. While maintaining the measurement line there can occur the necessity of disconnecting and connecting different elements, which can cause a brake or a short circuit of the electric net. This introduces internal disturbances of the measurement current. During this process the measurement line is in a transient state [2].

II. The intrinsically safe measurement lines of the 4-20mA standard

The discussed case concerns the most popular realisation of the intrinsically safe measurement line, assuming that the transmitter is fixed in the hazardous area and it sends the signal to a measurement system placed in the safe area. In this case it is necessary to connect a special interface called an associated apparatus between the transmitter and the standard measurement system. A part of this two wires measurement line of 4-20mA creates an intrinsically safe electrical circuit presented in Figure 1. The intrinsically safe electrical circuit of the measurement line under consideration can be divided into three parts. The first one is located in the hazardous area, whereas the second one in the safe area. Both parts are connected with a cable, which is in the both areas, the safe and the hazardous one and which constitutes the third part of the intrinsically safe circuit. The part in the safe area is the associated apparatus, which plays the role of a power engineering limiter of the energy supplied to the hazardous area. The part installed in the hazardous area, together with the cable and with the input of the associated apparatus, must be made in a way preventing both collecting the energy sufficient to cause an explosion and heating the surfaces of the devices placed there to the temperature causing auto-ignition of the explosive atmosphere.

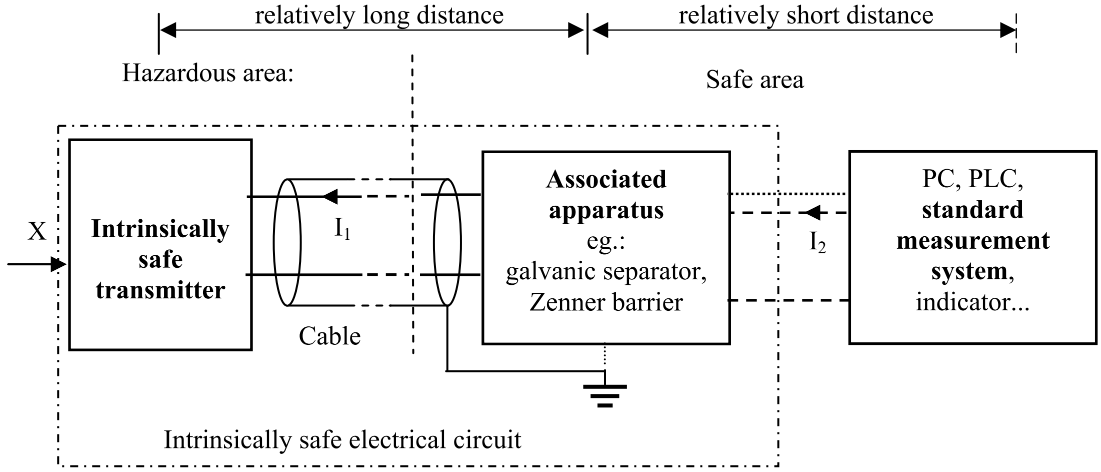

Figure 1. The intrinsically safe measurement lines of the 4-20mA standard, X –measured parameter, I_1, I_2 –current 4-20mA

For the measurement line the first part is the transmitter in the intrinsically safe realisation. Similarly, the associated apparatus also has to be in the intrinsically realisation. Both apparatuses have to be attested.

II.1 The static input properties of the associated apparatus

The static electrical models of the measurement lines are presented in Figure 2.

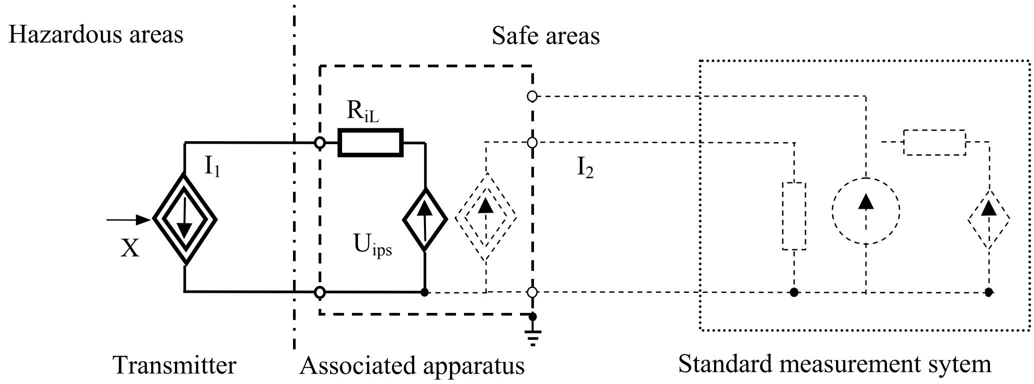

Figure 2. The static model of the intrinsically safe measurement line of the 4-20mA standard, where R_{iL}, U_{ips} –parameters of the equivalent input circuit of the associated apparatus.

Depending on the type of the associated apparatus it is possible to present three models of the intrinsically safe measurement line. One for the Zenner barriers, the next are for the active Zenners barrier and the last one for the galvanic separator. It was symbolically pointed in the Figure 2 by the fine dropped line. For all of them the equivalent input circuit can be similar and in Figure 2 it is presented by R_{iL} and U_{ips}. The static electrical model of the transmitter can be presented as the current source controlled by the value of measurement parameter X. The static input properties of the associated apparatus describe the input parameters as the equivalent input resistance R_{iL} and the voltage of equivalent power supply U_{ips}. The value of these parameters can be different depending on the value of the input current, which in the normal operating condition is controlled by the transmitter between 4 and 20mA (sometimes for the diagnostic purposes the span can be wider, eg: from 3,5 to 21mA). The exemplifying types of the static input characteristics are presented in Figure 3. In each case for the current 4-20mA the equivalent input resistance and the voltage power supply can be easily appointed and have to be known by designers. For the Zenner barriers and for some active Zenner barriers the equivalent voltage supply is changed depending on the voltage from an outer power supply.

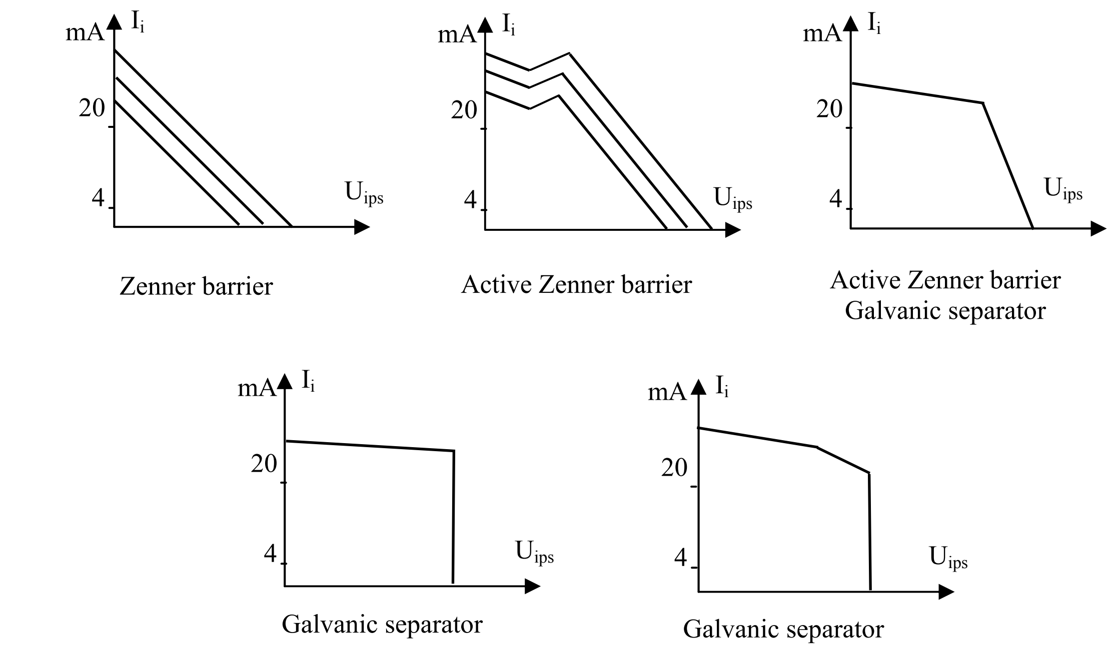

Figure 3. The typical input static characteristics of the different associate apparatus for 4-20mA standard.

II.2 Dynamic properties of the intrinsically safe apparatus of the 4-20mA measurement line

The transmitters are produced as the analogue or the programmable ones, which results in different dynamic properties. The analogue transmitters are relatively very quick, but the programmable ones are much slower.

The associated apparatus can also be of different types. The simplest type is the Zenner barrier. For normal operating condition the static model of the Zenner barrier can be presented by the sum of an “end to end” resistance of each wire. In this case an extra influence of the Zenner barrier is only by the “end to end” resistances. The “end to end” resistance has negligible influence on the dynamic parameters of the measurement line but strongly limits the current disturbances during the transient state. The next type of the associated apparatus is the active Zenner barrier. The active Zenner barrier has a built-in electronic circuit, which extra limits the flow of current by electronic way. The analogue electronic current limiter is supplied separately. Both the Zenner barrier and the active Zenner barrier need grounding. This is a serious disadvantage. The third type of the associated apparatus is the galvanic separator. The separator converts the dc input current into the dc output current with galvanic separation by using magnetic field or by opto-coupling. It is a dc-ac-dc converter. The separators also need outer voltage supplier. The dc-ac-dc converting has influence on the dynamic parameters of separators. The galvanic separators are the slowest from the associated apparatus.

III. Transient states in the intrinsically safe measurement lines of the 4-20mA standard

The transient states can appear during the routine maintenance procedures and concern two cases.

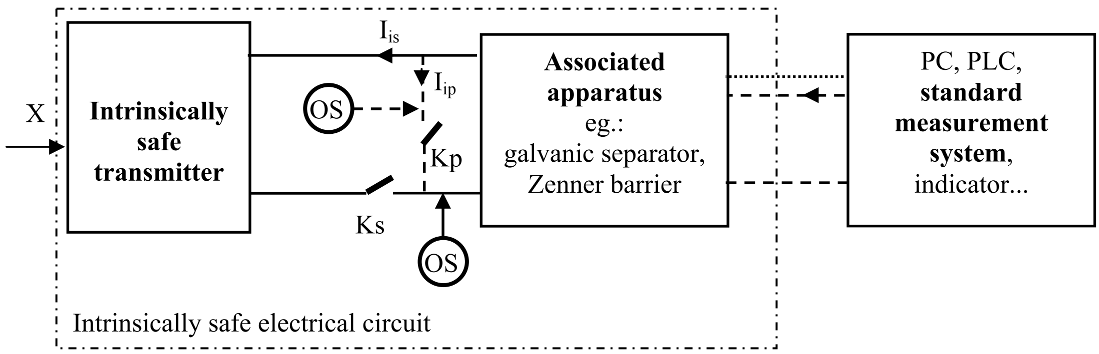

Figure 4. The measurement circuit, I_{is} –disturbances of the current caused by series switch K_s, I_{ip} –disturbances of the current causes by paralleled switch K_p.

The first transient state can be caused by connecting the transmitter to the measurement line and the second one is a result of a short circuit, which can accidentally happen.
The two cases are simulated separately in the measurement circuit presented in Figure 4. The series transient state which is characteristic for connecting the transmitter to the measurement line is simulated by switch K_s but the disturbance of the current I_{is} is recorded by digital scope OS. The paralleled transient state which is characteristic for the short circuit is simulated by paralleled switch K_p. The disturbance of the current I_{ip} is recorded by digital scope OS. In the both cases the transmitter current is settled on the value 20mA by corresponding value of measurement parameter X. In Figure 5 there are presented pattern results of the research on the transient states for the galvanic separator and the analogue transmitter.

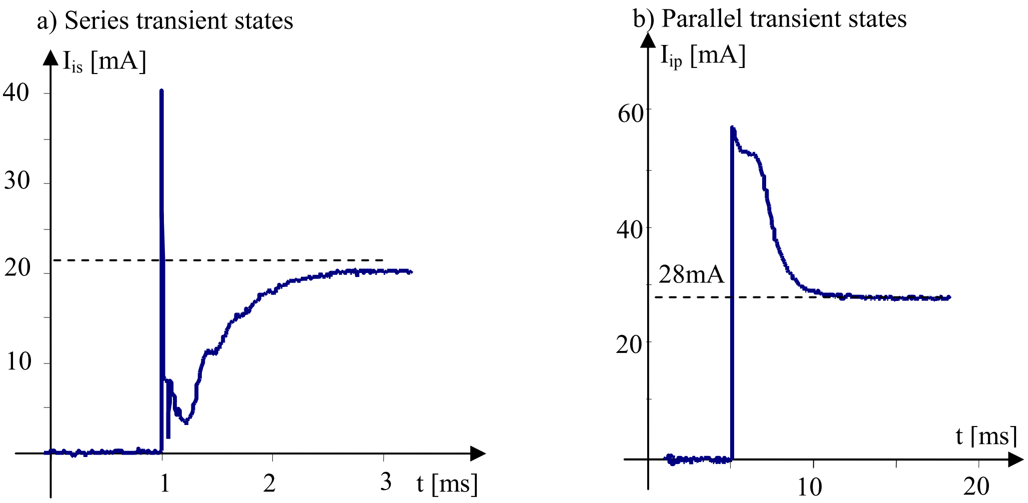

Figure 5. Transient states of the intrinsically safe measurement line for the analogue transmitter and the galvanic separator.

When the transmitter is connected to the galvanic separator the current rapidly rise and during relatively short time is settled to the value 20mA. This disturbance of the current is named as series transient states. It is important that peak value is higher than the limitation of the current resulting from the static characteristic. The series transient state is very short.
In case of the short circuit the transient state of the measurement line is presented in Figure 5.b and is called as the parallel transient states. In this case the time of the transient state is much longer and the peak value is higher than for the series transient states. Similarly as in the previous case the current peak value is much higher than the limitation. Its means that during the short circuit more energy is released then during the series connection.

IV. Conclusions

The measurement peculiarities of the intrinsically safe line in the two wire 4-20mA standard are described by static and dynamic characteristics of all the apparatuses, however, in particular cases it is necessary to take under consideration the transient states. The transient states regard series connection of the intrinsically safe apparatus and the short circuit. During the parallel transient state more energy is released than during the series transient state. For the intrinsically safe measurement line in the 4-20mA standard in the hazardous area the short circuit is more risky situation then the normal connections.

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