ExTAG(Cannes/PTB)03

This document prepared by PTB, *Short study on simple capacitive circuits with low decoupling resistance*, is issued for discussion under Agenda item *5.1 Intrinsic Safety – Spark Assessment for the combination of resistive, capacitive and inductive Parameters* - of ExTAG/517C/DA.

Short study on simple capacitive circuits with low decoupling resistance

Introduction

The limiting curves for capacitive circuits according to Figure A.2 and A.3 or Table A.2 of [IEC 60079-11] are based on an experimental setup with a value of the decoupling resistor connected in series to the voltage source in the order of several Kilo-Ohms. In the corresponding graphs this circumstance is barely indicated by the circuit symbol of a switch.
From the requirement in 10.1.4.1 c) of [IEC 60079-11], only a maximum value of this series resistor can be derived. Taking into consideration Note 4 in clause A.3 b), a decrease of the decoupling resistor may lead to cancellation of intrinsic safety (IS).

Since considerable numbers of associated apparatus applied as power sources are approved and existing on the market, it seems that the community did not worry about the above-mentioned circumstance in the previous decades. Unfortunately, the [60079-11] delivers no guidance on how to deal with such a case in detail. The question was raised within the maintenance team IEC/TC31/SC31G/MT60079-11 during the maintenance cycle of Ed. 6 of IEC 60079-11, whether the former and current assessment practice for capacitive circuits – particularly for IS-power-supplies like barriers – is still supportable. At that time and during the time of this study, no experimental data were available in this regard.

Against this background, a short study was done on the impact of low values of the decoupling resistor in capacitive circuits on the minimum ignition voltage has been done. The focus of this investigation was put on capacitive circuits with a voltage source having a linear characteristic in the range of 40 down to 15 volts. The ignition experiments where done with the spark test apparatus (STA) described in [60079-11] using the test gas for gas group IIC adequate for 1.0 safety factor (SF).

Experiments

The procedure described in clause 10.1.4 of [60079-11] is not sufficient for this study. The goal is to get meaningful data for the creation of an ignition voltage curve. Therefore, the procedure had to be adjusted appropriately.

Ignition probability

The “simple” ignition probability (SIP) w of a circuit is defined as the reciprocal value of the arithmetic mean $\bar{x}$ of the number of contacts[1] x_i until ignition of n experiments with the spark test apparatus.

$$w = \frac{1}{\frac{1}{n}\sum_{i=1}^{n} x_i} \qquad (1)$$

[1] One contact is a quarter revolution of the wire holder.

Throughout this study, the calculation of the SIP is based on n = 15 ignition experiments.

Test setup

The experiments have been conducted in consideration of the rules and requirements for testing and measurements which apply to testing laboratories (Ex-TL) within the IECEx-System.

Figure 1 gives an overview about the configuration of components of the simple capacitive circuit under investigation. The above-mentioned decoupling resistor in the setup is directly connected in series with the voltage source.

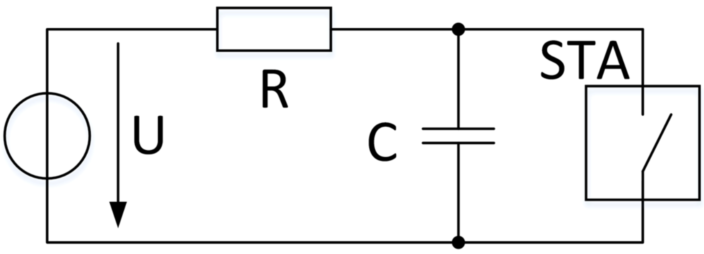

Figure 1: Schematic of capacitive circuit under investigation.

Description of the procedure

Circuits with lumped capacitances of 94 nF, 272 nF, 900 nF and 3 µF have been investigated. For each of these circuits a test series has been done. Within a test series the decoupling resistor R and the voltage U have been varied resulting in three ignition probabilities.
Initially the maximum permissible voltage value was determined according to Table A.2 (IIC, SF 1.0) of [IEC 60079-11]. A first test was performed with a high resistance value getting a charging constant τ of approximately 10 ms. The order of the calculated values of the decoupling resistor R complies with the resistance values used to establish the limit curves and values for capacitive circuits specified in [60079-11]. In a following experiment the decoupling resistor R was decreased to the minimum permissible value according to Table A.1 (IIC, SF 1.0). Afterwards the voltage was decreased until an ignition probability of approximately $w = 10^{-3}$ was reached, which is conform to the ignition probability value on which the limiting curves of [60079-11] are based.

Results

The type of sparks, which ignited the test gas in this study were make-sparks what could have been expected for capacitive circuits. During the short-circuit the spark was fed by the current of the voltage source connected to the resistor and by the discharge current of the capacitance. The discharge current value was in the order of several amps, which made the impact of the voltage source negligible. Therefore, the ignition probability of the investigated capacitive circuits was mainly influenced by the charging time constant τ = RC. A decrease of this time constant led to a raise in the number of potentially ignitable make-sparks, because full charging of the capacitance was now possible not only during the open-circuit-sequence of the contact arrangement but during the movement of a tungsten wire over the cadmium disk. The ignition probability of the circuit increased along with an increase of the number of potentially ignitable sparks per revolution of the wire holder.

In the investigated voltage range, the reduction of the decoupling resistor value of more than two decades leads to a significant increase of the ignition probability w by a factor of up to 60. On the other hand, the results showed a much less significant impact on the ignition voltage. A decrease of the voltage U by a factor between 1.07 and 1.16 was appropriate to achieve an ignition probability of approximately w = 10^{-3}.

The results of the experiments for each test series are summarized in the following tables.

Test series 94 nF			
U / V	40	40	36
C / nF	94	94	94
R / Ω	99.6 k	468	468
τ / ms	9.4	0.044	0.044
$\bar{x}$ / contacts	440	17	1389
w	$2.27 \cdot 10^{-3}$	$59 \cdot 10^{-3}$	$0.72 \cdot 10^{-3}$

Table 1

Test series 272 nF			
U / V	28	28	25
C / nF	272	272	272
R / Ω	32 k	156	156
τ / ms	8.7	0.042	0.042
$\bar{x}$ / contacts	1639	26	1007
w	$0.61 \cdot 10^{-3}$	$39 \cdot 10^{-3}$	$0.99 \cdot 10^{-3}$

Table 2

Test series 900 nF			
U / V	20	20	17.2
C / nF	900	900	900
R / Ω	10 k	43	43
τ / ms	9	0.039	0.039
$\bar{x}$ / contacts	370	16	1274
w	$2.7 \cdot 10^{-3}$	$61 \cdot 10^{-3}$	$0.79 \cdot 10^{-3}$

Table 3

Test series 3 µF			
U / V	15	15	14
C / nF	3000	3000	3000
R / Ω	3.3 k	11	11
τ / ms	10	0.033	0.033
$\bar{x}$ / contacts	2890	189	1493
w	$0.35 \cdot 10^{-3}$	$5.3 \cdot 10^{-3}$	$0.67 \cdot 10^{-3}$

Table 4

For better comprehensibility, Figure 2 in the Annex illustrates the results together with the corresponding limiting curves of Table A.2 of [60079-11]. Of special interest is the location of the curve of the new test data, which is within the area bordered by the limiting curves representing a safety factor SF of 1.0 and 1.5.

Proposed conclusion

Due to the fact, that

- a safety factor SF of 1.5 was never undercut,
- the decrease of the voltage to reach an ignition probability of w ≈ 10^{-3} is not significant,

- the considerable general deviation of the results of the experiments with the STA is respected and
- no fatal accidences are aware,

it is proposed, that no action is necessary for associated and intrinsically safe apparatus currently on the market or installed in the field.

For IEC 60079-11 Edition 7 for example the following perspectives are imaginable.

a) The decrease of the minimum ignition voltage is expected to be negligible for capacitive circuits within the scope of this study for levels of protection ia, ib and ic. Therefore, the previously and currently applied assessment practice of simple capacitive circuits with low decoupling resistance is valid for now and in the future. Chapter A.3 in [60079-11] should be revised accordingly.

b) The decrease of the minimum ignition voltage should be respected. The minimum ignition voltage curves or the according tables for capacitive circuits for gas group IIC should be adjusted, for instance via decreasing the minimum ignition voltage values by 15%.

The impact on the other gas groups and the consideration of distributed capacitances like cables was not part of this study.

References

[60079-11] IEC 60079-11:2011 Ed. 6
Explosive atmospheres - Part 11: Equipment protection by intrinsic safety 'i'

Annex

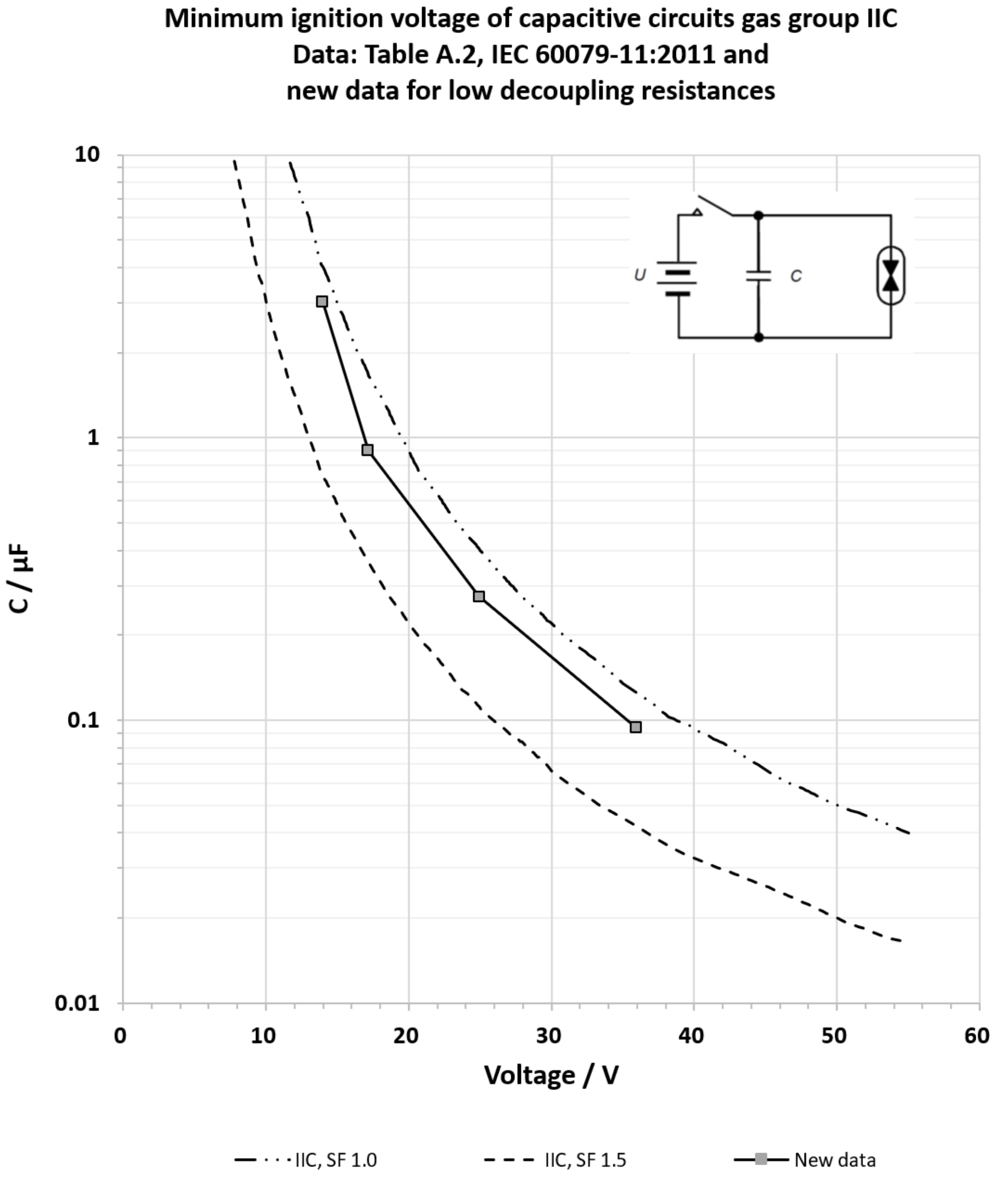

Figure 2: Comparison of minimum ignition voltage curves.