Use of low-voltage fuse-links in switch units like fuse – impact on power dissipation and possible mishaps at overload and short-circuit current breaking

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Abstract

Low-voltage fuse-link's power dissipation and related temperature rise are prescribed with standard IEC 60269. Standard require measurement of power dissipation and temperature rise in free air.

As the use of fuse switch units, i.e. fuse dissconnectors increases, impact on power dissipation of low voltage fuse-links when used in switches is presented in paper.

Impact on power dissipation and temperature rise of fuse-links as well as fuse switch unit when incorrect connection wire like aluminium connector is used are being presented.

Possible mishaps of incorrect breaking of overload and short-circuit currents when using fuse-links in fuse switch units are being presented.

The paper is focused on use of low voltage cylindrical fuse-links in fuse disconnectors.

Keywords: cylindrical fuse-links (Fuse system F- NF cylindrical fuse system), fuse disconnector, overload, short-circuit, connection wire.

1. Introduction

Fuse-link's power dissipation is according to definition in [1]: "Power released in a fuse-link carrying a stated value of electric current under prescribed conditions of use and behaviour".

The power dissipation is also linked to temperature rise of fuse-link and with it to temperature rise of fuse-base used. This means that higher the power dissipation is more the fuse-base will be heated. To avoid over-heating (in case of rated currents) and thus potential damage to fuse-bases and equipment standards [1], [2], [3] limit the maximum power dissipation allowed on fuse-links (depending on type of fuse-links) to maximum rated current of one type of fuse-link and to rated voltage of the fuse-link. With this it limits also maximum temperature rise and maximum acceptable power dissipation of fuse-base.

As well as fuse-link and its power dissipation influence on temperature rise of fuse-base, the type of fuse-base could influence temperature rise and power dissipation of fuse-links, depending on the type of fuse-base. Types of fuse-bases are open bases (open free-air fuse-base) and closed bases (disconnectors, switch units, etc.). On closed bases the temperature rise and power dissipation of fuse-links will be higher than on open bases due to lower heat convection. This is important in case of cylindrical type fuse-links which are mainly used in fuse disconnectors.

Temperature rise is also dependent on connection conductor used. For connections standard [1] prescribes the use of copper conductors although somewhere the aluminium conductors are used. In case of aluminium conductors special attention at conductor cross-section selection is needed. Incorrect cross-section of aluminium conductor causes higher temperature rise and power dissipation, in some cases overheating which could lead to fuse-base and equipment damage.

2. Power dissipation and temperature rise of fuse-link

According to standard [1] the fuse-link shall be so designed and proportioned as to carry continuously, under standard conditions of service, its rated current without exceeding the rated power dissipation of the fuse-link as indicated by the manufacturer or otherwise specified in subsequent parts of [1].

In case of cylindrical fuse-link of size 22x58 (according to [2]), rated voltage 500V and rated current 100A the maximum power dissipation allowed is 9,5W.

In this section of paper the intention is to experimentally present influence of type of fuse-base and type of connection (copper or aluminium conductor) on power dissipation of fuse-link size 22x58, characteristics gG, rated current 100A. For this purpose 1-pole open fuse-base and 1-pole fuse-disconnector type ETI VLC 22 have been used.

2.1 Influence of fuse-base to fuse-link's power dissipation

First the test of temperature rise and power dissipation measurement according to standard requirements have been made. Open fuse-base in parallel with fuse-disconnector have been used. Copper conductors of cross-section 35mm^2 (according to standard) have been used. Test have been made on fuse-links size 22x58, gG, 100A (2 pcs.) with cold internal resistance of 0,582mΩ each (for comparison purpose fuse-links with equal internal resistance have been used).

Measurement of temperature rise have been made in 5 points for open fuse-base and in 7 points for fuse-disconnector (for details see Fig. 1, Fig. 2 and Table 1).

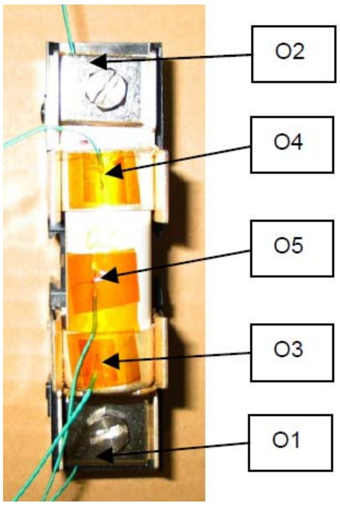

Fig. 1: Temperature rise measuring points on open fuse-base

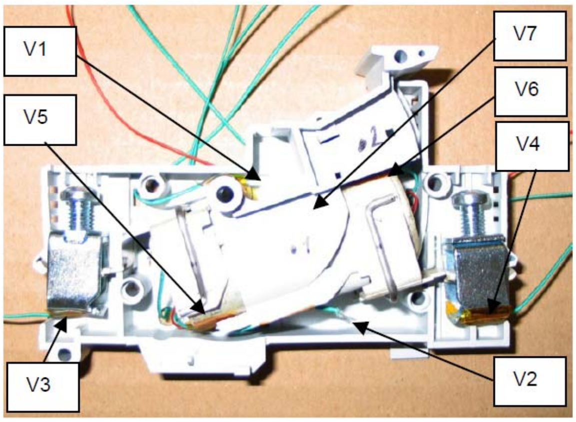

Fig. 2: Temperature rise measuring points on fuse-disconnectors

Table 1: Temperature rise measuring points

Point	**Description**
O1	Terminal – inbound (open base)
O2	Terminal – outbound (open base)
O3	Contact cap – inbound (open base)
O4	Contact cap – outbound (open base)
O5	Fuse body (open base)
V1	Inside space - up (fuse-disconnector)
V2	Inside space - down (fuse-disconnector)
V3	Terminal – inbound (fuse-disconnector)
V4	Terminal – inbound (fuse-disconnector)
V5	Contact cap – inbound (fuse-disconnector)
V6	Contact cap – inbound (fuse-disconnector)
V7	Fuse body (fuse-disconnector)
A1	Ambient
A2	Ambient

Power dissipation measurement have been done at the end of temperature rise test when the stationary conditions have been reached. Measurement points for both fuse-links (on both fuse bases) were at the end of contact cap according to standard [2] requirements (see Fig. 3).

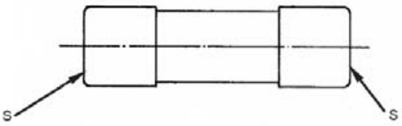

Fig. 3: Measurement points for power dissipation

Test results are presented in Tables 2 and 3 and in figure 4.

Table 2: Temperature rise

Point	T_{max} (°C)	T_{max} (K)
O1	NA*	NA*
O2	NA*	NA*
O3	67,7	44,5
O4	74,6	51,3
O5	76,9	53,2
V3	68,0	44,6
V4	72,5	49,1
V5	90,0	66,7
V6	95,9	72,5
V7	100,1	76,8
A1 (average)	23,1	23,2°C
A2 (average)	23,3	

Table 3: Power dissipation

	ΔU (mV)	P_{diss} (W)
Fuse-link (open base)	79	7,9
Open base	89	8,9
Fuse-link (disconnector)	86	8,6
Disconnector	107	10,7

Remark *: Thermocouple broken/disconnected during test

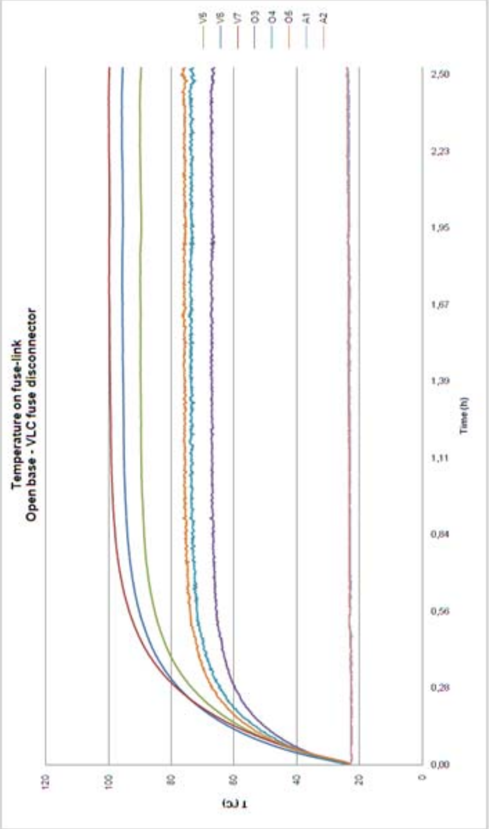

Fig. 4: Temperature rise on fuse-links (copper conductors 35mm^2)

From test results it is clear that fuse-link in fuse disconnector reached significantly higher values at temperature rise than the fuse-link in open fuse-base due to lower heat dissipation in fuse-disconnector. The difference between open fuse-base and fuse-disconnector could be more than 20K. Due to a higher temperature of fuse-link in fuse-disconnector resistance of fuse-link is higher, consequently power dissipation is higher than the power dissipation on fuse-link used in open base.

2.2 Conductor influence on fuse-link's power dissipation

In this case influence of connecting conductor on temperature rise and power dissipation of fuse-links is experimentally presented. Tests have been made the same way as in 2.1. Difference was in connection conductors used. For the first part of test aluminium conductors with cross-section of 35mm^2 have been used. Fuse-links used have had the same internal resistance as in part 2.1. For the second part of test aluminium conductors with cross-section of 70mm^2 have been used. Fuse-links used for test have internal resistance of 0,589mΩ. Results are presented in tables 4, 5, 6, 7 and in figures 5, 6 and 7

Table 4: Temperature rise (conductor Al 35mm^2)

Point	T_{max} (°C)	T_{max} (K)
O1	66,0	42,2
O2	73,6	49,8
O3	71,2	47,4
O4	78,6	54,8
O5	80,0	56,2
V3	NA*	NA*
V4	86,5	62,7
V5	101,3	77,6
V6	109,7	85,8
V7	111,4	87,6
A1 (average)	23,6	23,8°C
A2 (average)	23,9	

Table 5: Power dissipation (conductor Al 35mm^2)

	ΔU (mV)	P_{diss} (W)
Fuse-link (open base)	81	8,1
Open base	92	9,2
Fuse-link (disconnector)	89	8,9
Disconnector	110	11,0

Remark *: Thermocouple broken/disconnected during test

Table 6: Temperature rise (conductor Al 70mm^2)

Point	T_{max} (°C)	T_{max} (K)
O1	NA*	NA*
O2	NA*	NA*
O3	67,5	44,4
O4	70,8	47,3
O5	76,5	53,0
V3	59,2	35,6
V4	64,4	40,9
V5	88,3	64,8
V6	91,0	67,5
V7	103,5	79,9
A1 (average)	22,9	23,0°C
A2 (average)	23,1	

Table 7: dissipation (conductor Al 70mm^2)

	ΔU (mV)	P_{diss} (W)
Fuse-link (open base)	80	8,0
Open base	91	9,1
Fuse-link (disconnector)	86	8,6
Disconnector	106	10,6

Remark *: Thermocouple broken/disconnected during test

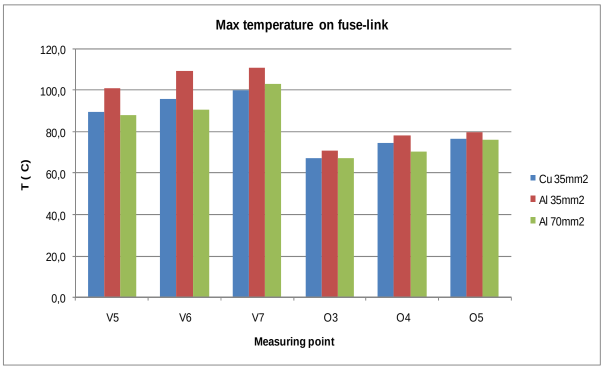

Fig. 5: Temperature rise on fuse-link comparison

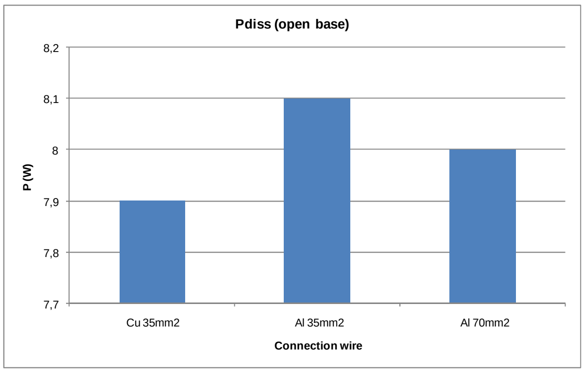

Fig. 6: Power dissipation of fuse-links comparison (open fuse-base)

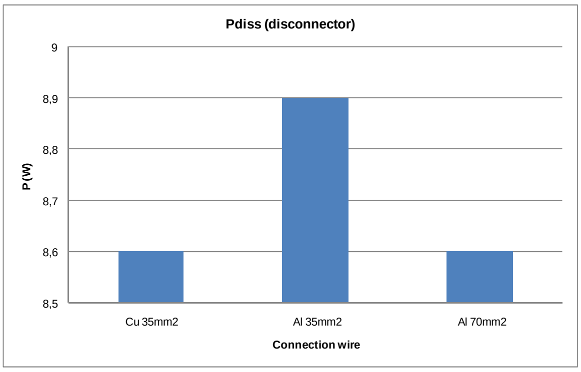

Fig. 7: Power dissipation of fuse-links comparison (fuse-disconnector)

From the results we can determine that type of fuse-base used have a significant impact on power dissipation and temperature rise of fuse-links as well as on fuse-base. Type of conductors also have impact on temperature rise and power dissipation of fuse-links and fuse-bases. If we use aluminium conductor instead of copper conductor with the same cross-section as copper conductor the temperature rise will be higher due higher aluminium conductor resistivity (lower conductivity). This is shown especially in case of use of closed fuse-base where the difference in temperature rise and power dissipation between open fuse-base and closed fuse-base is highest. With use of aluminium conductors with cross-section of two levels higher than copper conductors (according to recommendation/requirements in older standards issues i.e. DIN 57636-21/VDE 0636-21:1984) the impact on temperature rise and power dissipation is minimised.

3. Possible mishaps during fuse-links operation

Like in case of rated currents the choice of fuse base and connecting conductor have in some cases even bigger impact at overload currents. Major defects, fuse-base and equipment damage could occur in connection with incorrect operation of fuse-link or incorrect choice of fuse-link (i.e. fuse-link with higher rated current than fuse-base rated current, fuse-links of unknown origins).

Most defects occur at overloads when overload current occurs and fuse-link starts to operate. In most cases defects occur at 3-phase connections when 3-pole fuse-base is used. In this case the middle pole is heating the most due to both side poles influence (side poles are causing higher temperature rise on middle pole). The most common defect on fuse-bases, especially if closed fuse-bases (i.e. fuse-disconnectors) are used, is when overheated parts become soft, in some cases start to melt, and could bond together. Consequently fuse-base could not be opened (in case of fuse-disconnectors) to replace fuse-links and have to be replaced. In severe cases, when fuse-links for various reasons start to overheat (i.e. incorrect operation during melting time – anomalous M-effect, dispersion of solder into quartz sand, in some cases lack of sand), the consequences are that fuse-base (fuse-disconnector) starts to melt – first the fuse-carrier and then housing. The result is destroyed fuse-base, in most severe cases melting of fuse-base could cause short-circuit between poles. If backup protection does not work or there isn't any, continuous arcing could occur causing fire.

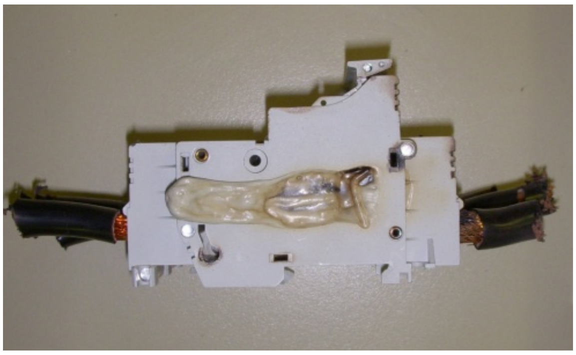

Fig. 8: Damaged fuse-base after incorrect operation of fuse-links at overload currents

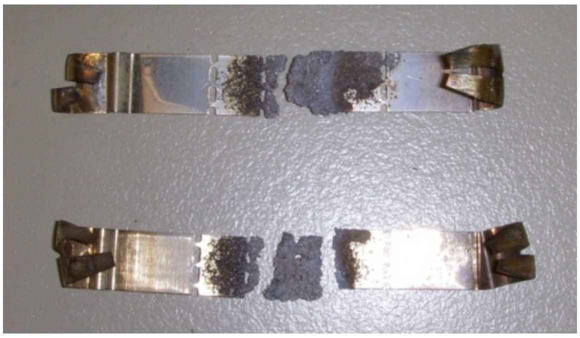

Fig. 9: Melting element after incorrect overload operation

At short-circuit currents most common defect is fuse body breaking. In some cases parts of fuse-link could break apart and stay in fuse-base (especially in closed bases), fuse-base have to be replaced. The worst defect at short-circuit currents is explosion of fuse-link which usually destroys also fuse-base.

The most common cause for fuse body breaking at short-circuits is inability of fuse body to withstand thermal shock that occurs during fuse-link operation. The most common causes for explosions of fuse-links are lack of sand (mostly in fuse-links of unknown origins), insufficient closing of contact caps (in case of cylindrical fuse-links contact cap could slide of the body due to internal pressure during operating causing blow out of arc between the contacts) and weak fuse-body (fuse body could not withstand the internal pressure that occurs during operation).

4. Conclusion

Power dissipation and temperature rise of fuse-links depends on many factors. The choice of fuse-base, open or closed, connecting conductors, use in 1-phase or 3-phase system are some of them.

All these factors influence operation of fuse-links also in case of overload and short-circuit currents causing possible defects and damage on fuse-bases and equipment. The correct choice of fuse-links and its quality also have impact on temperature rise and operation at overload and short-circuit currents. Greater quality of fuse-links means less chance for defects during operation.

References

[1] IEC 60269-1, Edition 4.1, “Low voltage fuses – Part 1: General requirements”, IEC, 2009-07
[2] IEC 60269-2, Edition 4.0, “Low voltage fuses – Part 2: Supplementary requirements for fuses for use by authorised persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to J”, IEC, 2010-04
[3] IEC 60269-3, Edition 4.0, “Low voltage fuses – Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) – Examples of standardized systems of fuses A to F”, IEC, 2010-05
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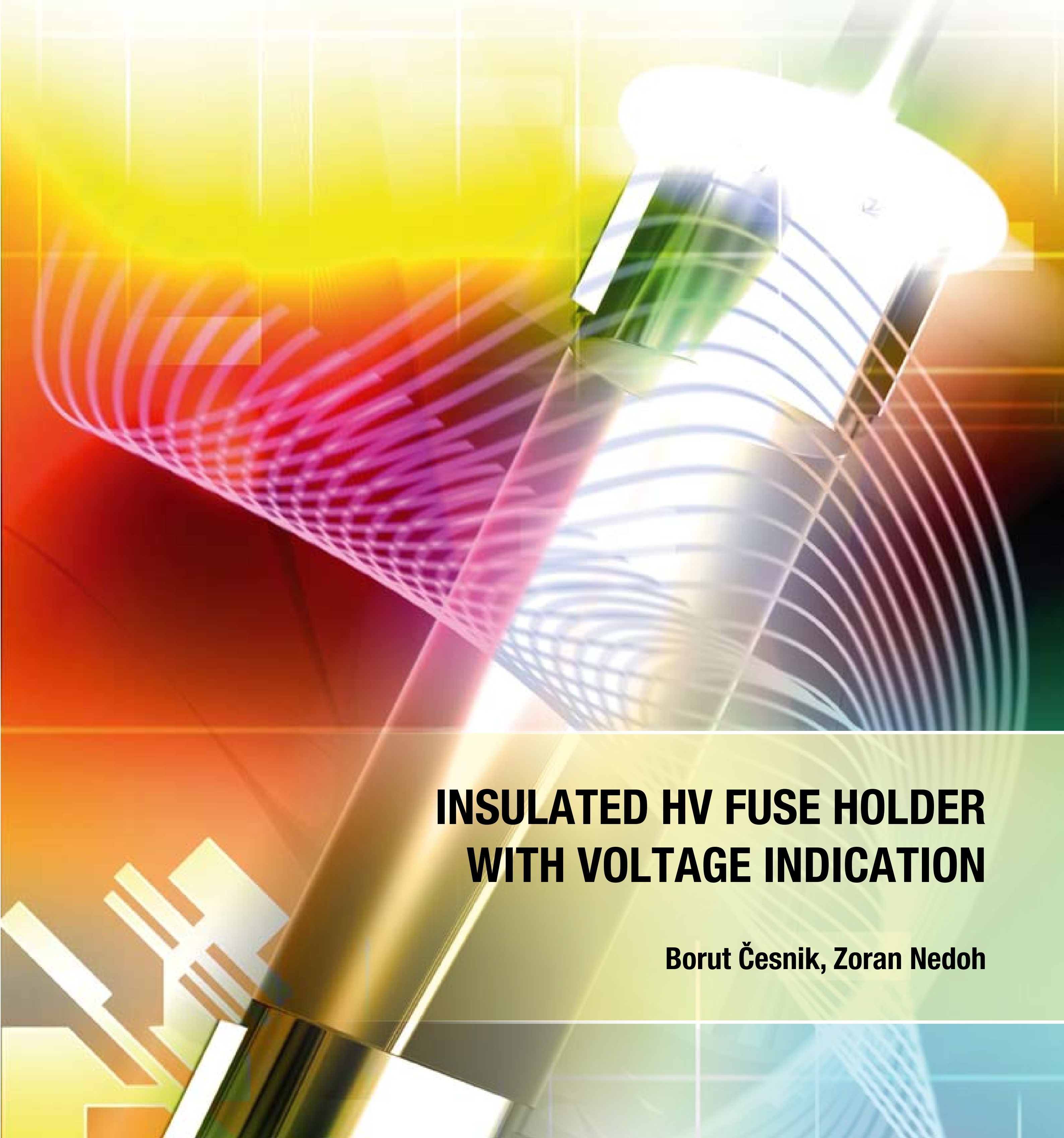

INSULATED HV FUSE HOLDER WITH VOLTAGE INDICATION

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