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HV Fuses,

"Interrupting Currents and Temperatures"

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HV Fuses "Interrupting Currents and Temperatures"

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High voltage fuses in accordance with the German standard DIN 43625 as shown in Figure 1, have been applied in electricity supply networks for many years. Yet, their external dimensions still comply with the limit values specified in 1955. Neither have their construction and their function changed. When compared to the product cycles of electronic appliances, HV fuses seem rather "boring". Still, there are small modifications, noticeable only for the experts, through which the fuses are adapted again and again to meet the users' demands [1–4].

An important step was to advance the fuses' striker pins to fulfil a double function with regard to both overcurrents and temperature rises: No longer were the pins tripped solely by the fault current flowing through the fuses, rather they received their trigger signals via a potential excess warming in the fuses' environment as well. These striker pins have been in use for as long as 15 years under the designations "thermoprotection", "temperature limiter" and "overload tripping device".

Figure 1: HV Fuse Links in accordance with DIN 43625, with a "View of the Inside"

However, what actually are the processes taking place inside the fuse in the case of tripping? What does this tripping device provide protection against? What are its capabilities and what are its limits? You will find the answers to these questions in this article.

1 The Striker Pin's Conventional Task

The primary task of a striker pin is to indicate, after a fault current has occurred, that the fuse has operated. The emerging of the striker pin from the contact cap makes this operation visible from the ground even in pole-mounted substations. In the case of fuses housed in air- or gas-insulated switch-fuse combinations, the pins have an additional task to fulfil. In this type of application the striker pins act on the trip-free mechanism of the switchgear which then initiates a three-phase switch-off of the installation. Needless to say that this requires the tripping device to provide sufficient energy [6].

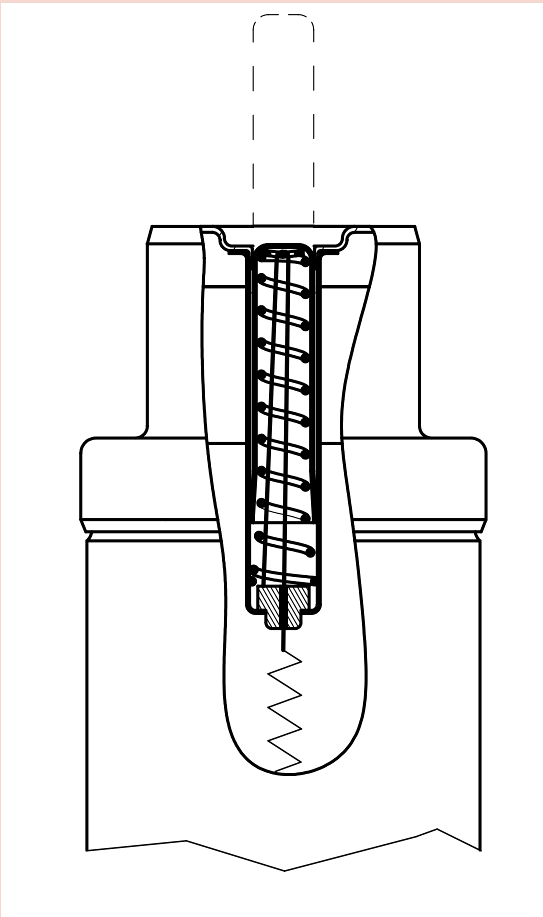
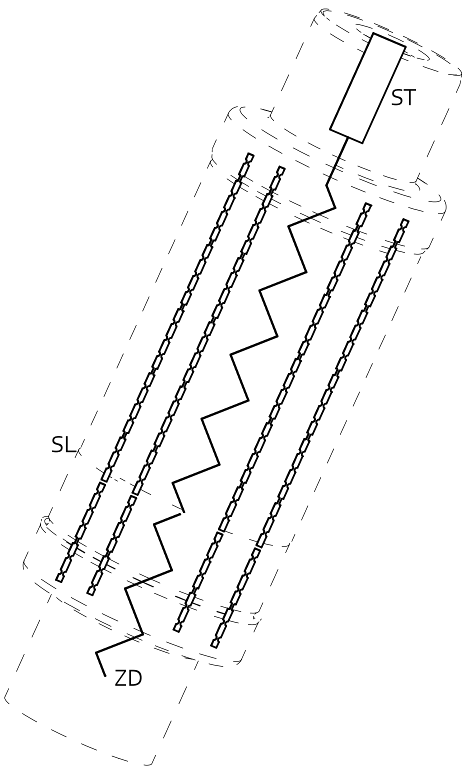


Figure 2: Fuse's Striker Pin



SL Main Fuse-Elements
ZD Feed Wire
ST Striker Pin

Figure 3: Integration of the Striker Pin in the Fuse-Element System

Alongside the fuse housing with its contact caps and the fuse-elements, the striker pin is thus another essential constituent of a high-voltage fuse. The overall system consists of the striker pin which is visible for the user and red in most cases, a coil spring providing the tripping energy, a holding wire retaining the spring and a feed wire for contacting the tripping system. Figure 2 shows a striker pin structured that way.

The striker pin system is connected in parallel with the main fuse-elements (SL, German: Schmelzleiter) (Figure 3). If there is an overcurrent with melting times outside the current limitation, the fuse-element melts and the striker pin emerges immediately afterwards, i.e. as early as during the

Table 1: Striker Pin Characteristics

Type	Energy	Actual Travel	Minimum Withstand Force	Maximum Duration of Travel
Medium	0,5 – 1,5 J	20 – 40 mm	20 N	< 50 ms

arcing phase. In the case of very short melting times, that is, within the rise time of the fault current, the striker pin emerges at virtually the same moment the fuse-elements are interrupted.

While the fuse-element has to fulfil both the controlling function during operation and the switch-off function in the case of a fault, the operating range of the striker pin is limited to cases of faults.

VDE 0670 4 specifies limit values for the striker pin, and Table 1 gives the most important data. In the case of SIBA's HV fuses, the energy is about 1 joule. Typical withstand force values are 50 N, 80 N or 120 N, with the striker pin having a withstand force of 80 N being the one most often used by the German energy suppliers. The striker pins used for SIBA's HV fuses have a diameter of 10 mm and an emerging length of 35 mm. The duration of the emerging movement is defined as the interval between the end of the melting time and the moment the pin has emerged by 20 mm; this duration is as short as a few milliseconds. The characteristics of the other manufacturers' products will probably be similar.

2 The Temperature Limiting Striker Pin

The need for a temperature limiting striker pin results from the high-voltage fuse's function as a back-up fuse. If these fuses are inadmissibly loaded with a current lower than the minimum breaking current (I3), they may get very hot. These high temperatures are a result of the melting temperature of 960 °C of the fuse-element's material which is silver. With increasingly longer melting times the duration of the existing temperature is also becoming more and more important and may even cause a failure of the insulating body; this defines the term "prohibited zone" between the fuse's rated current and the minimum breaking current.

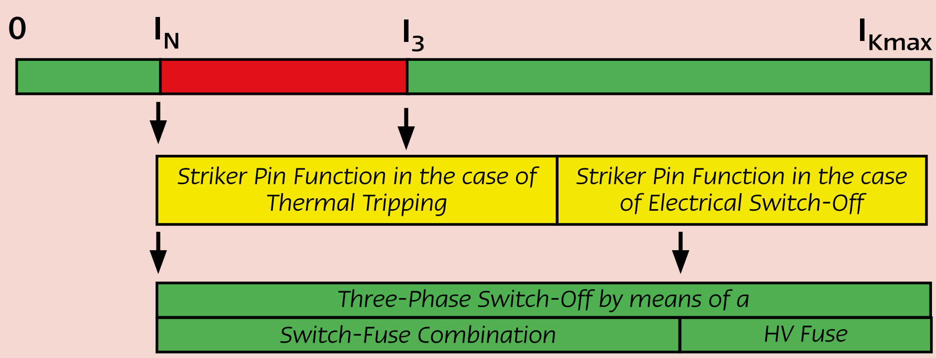
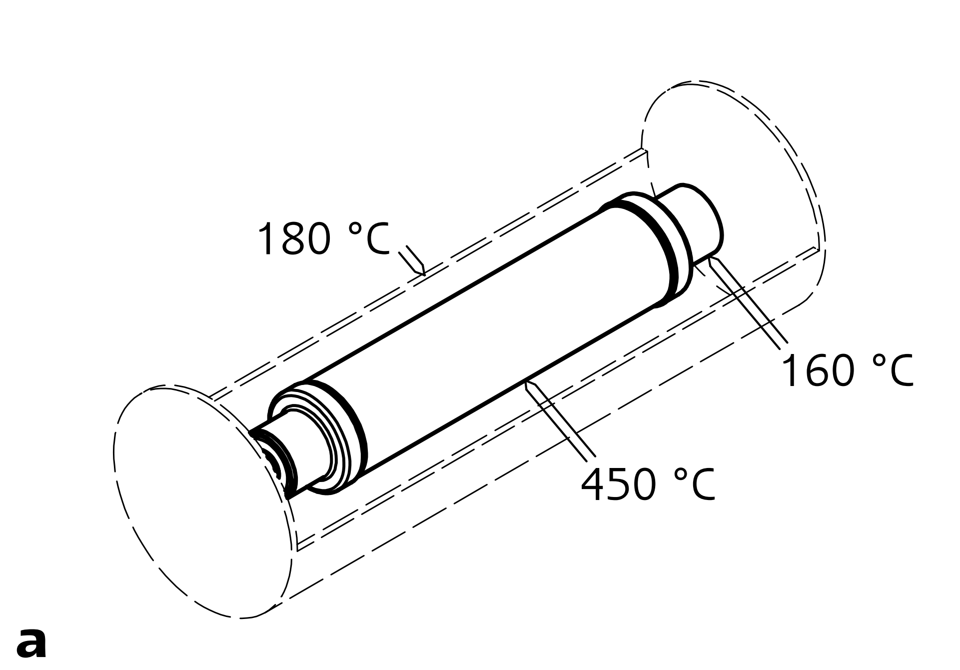


Figure 4: Operating and Breaking Phases of the High-Voltage Fuse



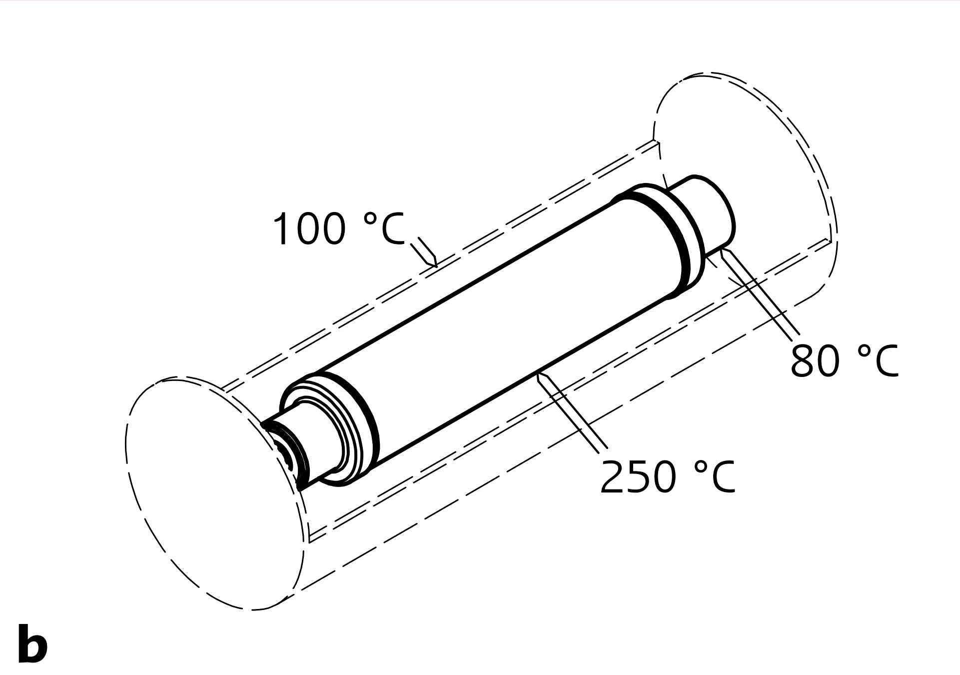


Figure 5: Temperatures at the Fuse Link and the Canister without (a) and with (b) Temperature Limiting Striker Pin

The immediate surroundings of the fuse-link have to be able to cope with these high temperatures as well. This becomes particularly clear when looking at the tight encapsulation of a gas-insulated switchgear in cases of limited heat dissipation. In the "prohibited zone", the encapsulation's plastic materials may easily reach temperatures exceeding 150 °C.

This can be prevented, however, by the temperature limiting striker pin. When the sensor mounted in the striker pin housing reaches a predefined temperature, the pin is released. From this moment on, the switch-fuse combination, which had been triggered by means of the trip-free mechanism of the switchgear, assumes the switch-off task.

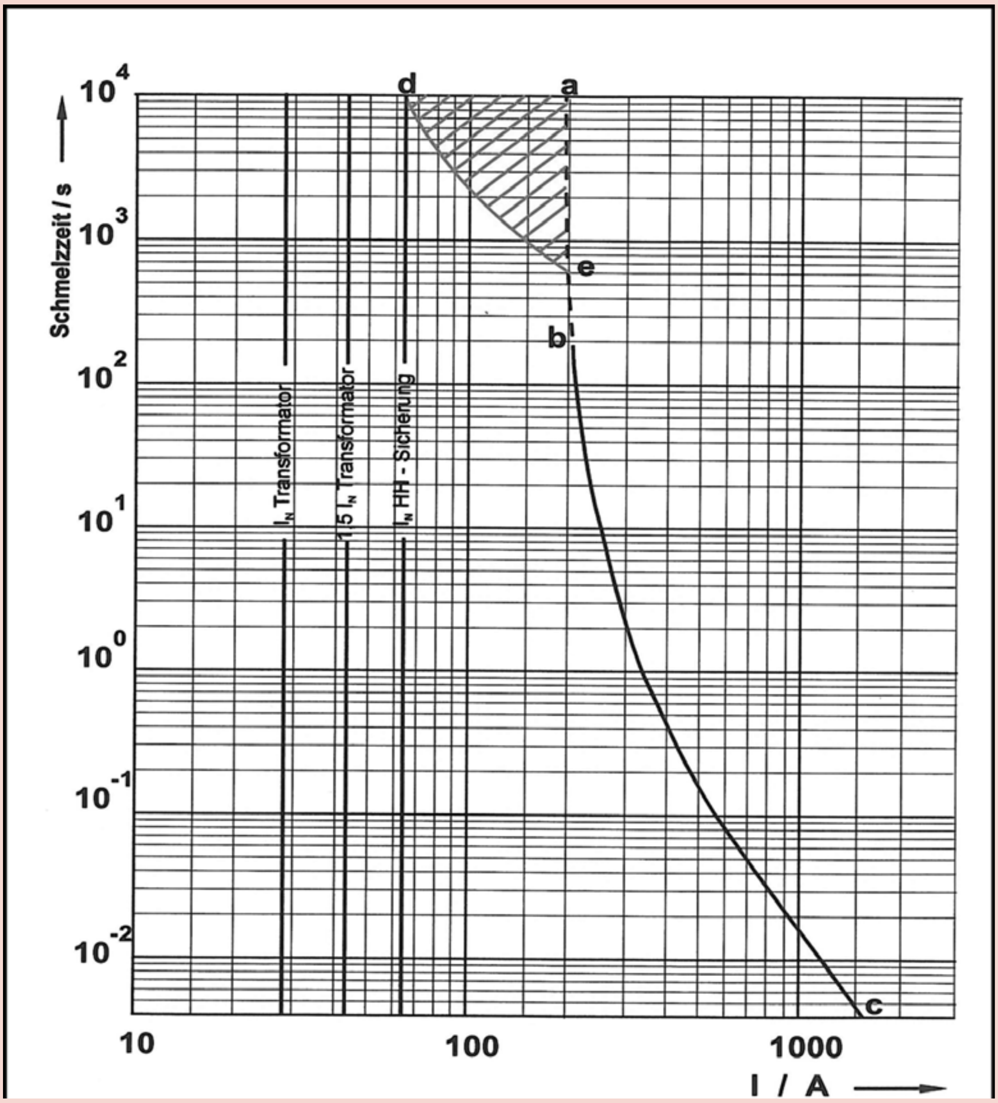


Figure 6: Time-Current Characteristic of a 63 A HV Fuse with a Temperature Limiting Striker Pin in relation to the Operating Currents of a 1 000 kVA Transformer

The striker pin's function in the electrical operation of the fuse is identical to that of a conventional fuse: The holding wire of the tripping spring melts, and the striker pin can emerge unhindered.

In Figure 4, the relevant time intervals are illustrated. The fuse's operating phase is represented by the interval between "0" and the rated current "IN". At values exceeding the rated current, the striker pin fulfils its function of thermal control. Switch-off is achieved via the switch-fuse combination, and this phase may extend beyond the minimum breaking current. In the case of a "full" short circuit, on the other hand, the striker pin is triggered electrically, and the fuses themselves operate.

Depending on the diameter of the fuse canister, temperature limiting striker pins may considerably reduce the temperature values, thus preventing damage to the installation. Parallel tests with the practical objective of giving recommendations regarding a 20 kV 1 000 kVA transformer reveal the differences. The fuse-link recommended for this transformer in accordance with VDE 0670 402 has a rated current of 63 A, the minimum breaking current of this fuse is 210 A. At values below the minimum breaking current it gets very hot, and the maximum temperature is reached at a value of two times the rated current, i.e. at approximately 120 A. In Figure 5 values of the temperatures at the fuse housing and at the fuse canister are plotted with and without temperature limitation [5].

When using the temperature-triggered striker pin, the fuse-link and switchgear components remain relatively cool. A temperature of 100 °C no longer presents a danger of ageing for the fuse canister, even in the case of frequent overloading of this kind.

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3 Time-Current Performance

As it reflects its electrical performance, the fuse's time-current characteristic remains unchanged regardless of whether there is a temperature limiting striker pin or not. The fault current at which, and the time after which, the striker pin operates can only be illustrated qualitatively in terms of a range.

Figure 6 shows such a characteristic. The a-c curve represents the typical time-current characteristic of a high-voltage fuse with a rated current of 63 A. The section between points b and c is the breaking range, while the section between points a and b is the "forbidden range". The minimum breaking current is plotted at point b, at 210 A and 200 s. The area inside the a-d-e triangle is the temperature limiter's operating range. At currents exceeding 63 A and with a melting time of more than 10 min, the striker pin becomes active.

Since the temperature limiting function is solely triggered by a warming of the fuse, the size of the above-mentioned triangle depends also on the fuse's rated current. For this reason, the reaction range of the striker pin is considerably smaller in the case of a 10 A fuse than in the case of a fuse with a rated current of 100 A. What is decisive, however, is that any inadmissible (high or long-term) temperature is detected by the fuse, triggering the striker pin in the process.

4 The System's Limits

Fuse-links with a temperature limiting function are not intended for transformer overload protection. On the one hand, this is something the energy suppliers do not wish for as, in the case of a fault on the low-voltage side, the installer would have to exchange the fuse on the medium-voltage side. On the other hand, a fuse set for overload protection might unintentionally react as early as to the inrush current of the transformer.

A reaction range varying sufficiently from any potential transformer overloads ensures that the

Transformer	*20 kV 1000 kVA*
Transformer's rated current	*29 A*
Assumed overload 1.5 × I_n	*43 A*
Recommended rated current of the fuse	*63 A*

fuses' striker pins do not react in an uncontrolled manner. This can be illustrated using the example of the above-considered transformer:

The fuse's rated current of 63 A is thus "a long way" from the overload of 43 A assumed here.

5 High-Voltage Fuses Limiting Currents but necessarily Temperatures as well

As already mentioned at the beginning, this year (2008), SIBA's high-voltage fuses with temperature limiting striker pins have been in use for 15 years. While, when their production began, these fuses still had a special status, just a few weeks later the then new tripping device was incorporated into the standard programme. This decision was welcomed by both switchgear manufacturers and users on the national and the international levels. Many energy suppliers have since included the provision of such striker pins into their technical terms of delivery.

HV fuses with a temperature limiting function are able to prevent supply disturbances which can be attributed to the following:

- Long-term fault currents, caused by winding faults inside the transformer
- Selection of an inadmissibly low rated current of the fuse
- Fuses operating at values below the minimum breaking current
- Faulty contacting of the fuse-link

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[4] DIN VDE 0670-4 (VDE 0670, Part 4):2006-12 High voltage fuses – Part 1: Current limiting fuses

[5] DIN VDE 0670-402 (VDE 0670, Part 402):1988-05 A.C. switchgear and controlgear for voltages above 1 kV
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Disclaimer:

The fuses described in this document were developed to take over safety-relevant functions as part of a machine or complete installation. A safety-relevant system usually contains signalling devices, sensors, evaluation units and concepts for safe disconnection. The responsibility for ensuring the correct overall function lies with the manufacturer of the installation or machine. SIBA GmbH & Co. KG and its sales offices (in the following referred to as „SIBA") are not in a position to guarantee all features of a complete installation or machine which was not designed by SIBA. Once a product has been selected, it should be tested by the user in all its possible applications. SIBA will not accept any liability for recommendations which are given, or respectively implied, by the above description. No guarantee, warranty or liability claims beyond SIBA's general terms of delivery can be derived from the description.

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