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Thermal system protection of switchgear through high voltage fuse links with integrated temperature limiter under consideration of IEC 420

Technical essay

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Type tested high voltage fuse links (HV-fuse links) according to
IEC 282-1 are intended for distribution transformer protection to limit respectively interrupt inadmissible short circuit currents. Moreover the fuse links can interrupt overload currents three phase if their striker pin works in combination with the switchgear trip-free release. (1)

Here temperatures of several 100°C can be developed being absorbed without damage by the high temperature resistant materials of the fuse link. In case the fuse links are used in gas insulated or narrow enclosed air insulated switchgear this high temperature level has to be managed by the surrounding synthetic material of the fuse link enclosure.

At the type test of fuse/switch combination according to IEC 420 using fuse links with relative high rated current and also at cases known from practice the arising temperatures can exceed the admissible values of the switchgear. Ageing of the synthetic material, microcracks or deterioration of contacts within the fuse enclosure may be the result. (2)

On the basis of numerous temperature rise tests with fuse links in switchgear of different manufacturers SIBA has developed a tripping device system which - independent of the reason - starts fault interruption at inadmissible temperatures.

HV-fuse links with this integrated temperature limiter reduce the developing temperature rise by reaction on the switchgear trip-free release.

1. How do high temperatures arise

According to their definition fuse links represent a cross-section reduction of the conductor branch to the consumer to be protected. Compared with a medium voltage cable 35 mm² the cross-section of the melting element inside the fuse link is just 1 mm². Therefore the current flowing through the fuse link causes a temperature rise being much higher than the temperature values of the other components and conductors in the net concerned.

These comparatively high temperatures are emitted to the contacts of the fuse base by axial heat flow and radial to the direct environment of the fuse link.
The maximum temperature limits determined in the standard will only be reached at full load of the fuse link current and also at fuse link rated current values intended for transformers above 1000 kVA. If the fuse links are selected according to VDE 0670 part 402 the operating current reaches less than half the fuse rated current *(Fig. 1)*. Under normal operation (50-150 % capacity of the transformer 1000 kVA / 24 kV) temperature values of up to 50°C at the caps and 70°C at the insulating body are to be measured at a fuse link 24 kV, 63 A in an air-insulated switchgear. (3)

In narrow enclosed gas- or synthetic material insulated switchgear the temperature level is essentially higher due to the missing air convection and a quasi-heat insulation by the switchgear. Consequently up to 80°C at the contact caps and 120°c at the insulating body are reached. *(Fig. 2)*

During these temperature rise tests the conditions at the fuse container are very important. Here the maximum load temperatures of the synthetic material selected by the manufacturer must not be exceeded. Regarding the example of the fuse for a transformer 1000 kVA at 150 % load up to 70°C are to be measured right in the middle at the synthetic material depending on the volume of the fuse enclosure.

2. Fuse links in fuse/switch combination

Much higher temperatures are reached if the fuse links mounted in a fuse/switch combination have to interrupt a current in the range between their minimum melting current and the minimum breaking current. In this so-called prohibited range of back-up fuse links the measured values easily approach the limit temperature of the fuse enclosure of the switchgear.

Because of the introduction of the new IEC 420 and the already known British regulation ASTA 22 SIBA has intensely worked on the temperature conditions in fuse/switch combinations in the overload range of the fuse links. Switchgear of famous German and European manufacturers have been tested to determine limiting temperature rises. (4)

A first test serie showed the maximum of temperatures arising under load. *Fig. 3* shows the temperature course of a HV-fuse links when loaded in the range of 0,5 times the rated current up to the minimum breaking current. It is clearly to be seen that the maximum temperature rise starts when loaded with approximately 1,5 times the fuse rated current (approximately 4 times the transformer rated current) and lasts on the same level up to melting times of 15 min.

During these tests temperatures have been measured which under repeated load would certainly have led to damages in the switchgear by ageing of the synthetic materials. The measured values vary depending on the type of the switchgear, however, a longer lasting temperature of 110°C may result in frailty, weakening or ageing of the used synthetic material.

Fig. 4a shows typical peak values of temperatures. In vertical position the fuse link reaches 160°C at the fuse caps, the insulating body of the fuse link warmed up up to

450°C, the temperature drop to the fuse link enclosure varies according to its volume. The measured peak values were at 180°C.

According to IEC 420 test duty 3 represents the highest thermal load for the fuse link by loading the fuse link with approximately 2-3 times the rated current. This test shall point out that the fuse/switch combination is able to withstand thermically long lasting overcurrents on one side and by means of striker pin release is able to interrupt below the minimum breaking current on the other side. Here as well the measured temperatures have been confirmed out of the maximum value determination.

3. Fuse links limiting current and temperature

During the tests it has become clear very soon that it is necessary to reduce the temperature during and after the interruption to protect the switchgear.

Therefore SIBA has further developed its high voltage fuse. The fuse should not only work as current limiting fuse, but also as
temperature limiting fuse. By using a melting activator the melting temperature of the silver melting element responsible for the temperature rise of the fuse has been drastically reduced from 960°C to 230°C. Now opening of the faulty switchgear is no longer caused by interruption of the melting element, but a striker pin release is started by the activator which in turn acts on the 3-pole trip-free release of the switchgear.

Components of the fuse link and the switchgear stay comparatively cool. Approximately 80°C are still measured at the caps, with 250°C the fuse barrel stays considerably below the values without the temperature limiting. *(Fig. 4b)*

Now it is especially advantageous that the temperature of the fuse enclosure, measured at the switchgear with the smallest volume, is just 100°C. This is a temperature value which even at frequent repetition will cut down the danger of ageing of the synthetic materials.

The activator is placed in the housing of the fuse tripping device. As shown in *Fig. 5* this newly developed tripping device does not require more volume than the common one. Use is made of the free space available within the pressure spring. This grants a sufficient distance to the source of heat - the fuse elements. The activator gives the system the necessary delay in order not to let the tripping device immediately respond at a temporary current increase. The power part of the fuse link remain unchanged when using the temperature limiter. The fuse element design and its arrangement correspond to the type tested and certified design level. The auxiliary melting element, the electrical contact of the tripping device, has not been changed as well. The function as back-up fuse is therefore granted. Up to the rated current and from the minimum breaking current up to the rated breaking current this new developed fuse link completely corresponds to the conventional one. It is 100 % compatible and can directly be replaced with the conventional fuse link of the same rated current and same rated voltage if required. Internal classification tables remain valid to the same extent as regulations of VDE 0670 Part 402.

4. Operating points of the temperature limiter

Fig. 6 shows the time-current characteristic for the new high voltage fuse. Here line a-c shows the typical time-current characteristic curve of a high voltage back-up fuse. The range b-c is described as breaking range and the range a-b as forbidden range where the fuse link must not be operated. At point b, the crossing of the broken line with the straight line, there is the minimum breaking current and at point a the minimum melting current.
The operating range of the temperature limiter is within the area between the points a-d-e. The exact operating point may vary depending on different installation conditions, ambient temperatures and switchgear types. It is even conceivable and admissible that a fuse link interrupts at its rated current if the prescribed temperatures are exceeded.

This means best possible protection for the switchgear. Random trippings are excluded, after all there is sufficient distance to the transformer operating current - even at 150% load (hatched range).

The operating points of the temperature limiter are in a range where temperature rises last longer than 10 minutes. Such temperature rises occur in case it comes to failures in the switchgear as follows:

- Faults between windings in the transformer cause a long lasting fault current.

- The transformer is considerably operated above its capacity limit.

- The fuse rated current chosen for transformer protection is too small.

- An inadmissible high temperature for example by discharge or poor contacting is brought externally to the fuse link.

- Fuse links switch a fault current below the minimum breaking current.

- The fuse link current carrying capacity will be reduced because of transient influences damaging individual melting elements of the melting element system.

During the last-named fault a situation would arise when only one or two fuse elements open, the fuse link for example, however, is equipped with a total of six melting elements. As the fuse links, according to the classification tables, are only loaded up to half of their rated current anyway, the developing temperature is eventually not sufficient to activate the temperature limitation. Only in case additional melting elements open, and consequently inadmissible high temperatures arise, the temperature limitation becomes active.

5. Summary

SIBA has further developed the type tested and certified high voltage fuse links. They have been equipped with a temperature limiter in order to avoid inadmissible high temperatures - regardless of the reason - in gas-insulated or narrow enclosed air-insulated switchgears. On the basis of a melting activator the temperatures at the housing of the fuse link container have been reduced from more the 160°C to below 80°C.

Here we have attached special importance to the power supply safety in customers switchgears. Not every short time overcurrent immediately leads to response of the fuse. Only when the admissible limits are exceeded the release system of the new fuse link activates and acts on the trip-free release of the switchgear.

The new fuse links are fully compatible to conventional back-up fuse links; all classification tables remain valid.

Now the operating range of the fuse in connection with a fuse/switch combination has expanded into a comprehensive switchgear system protection.

Literature

(1) IEC 282-1 : 1985 High voltage fuses
Part 1: Current-limiting fuses

(2) IEC 420 : 1990 High-voltage alternating current switch-fuse combinations

(3) VDE 0670 Part 402 : 1988
Alternating current switchgear for voltages above 1 kV

(4) ASTA 22 : 1979
Rules for the Short-Circuit Testing of High Voltage Combination Units

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Transformer Protection with High Voltage Fuselinks according to DIN VDE 0670 part 402

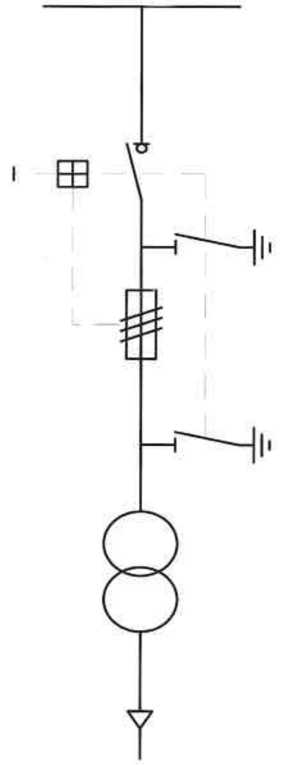
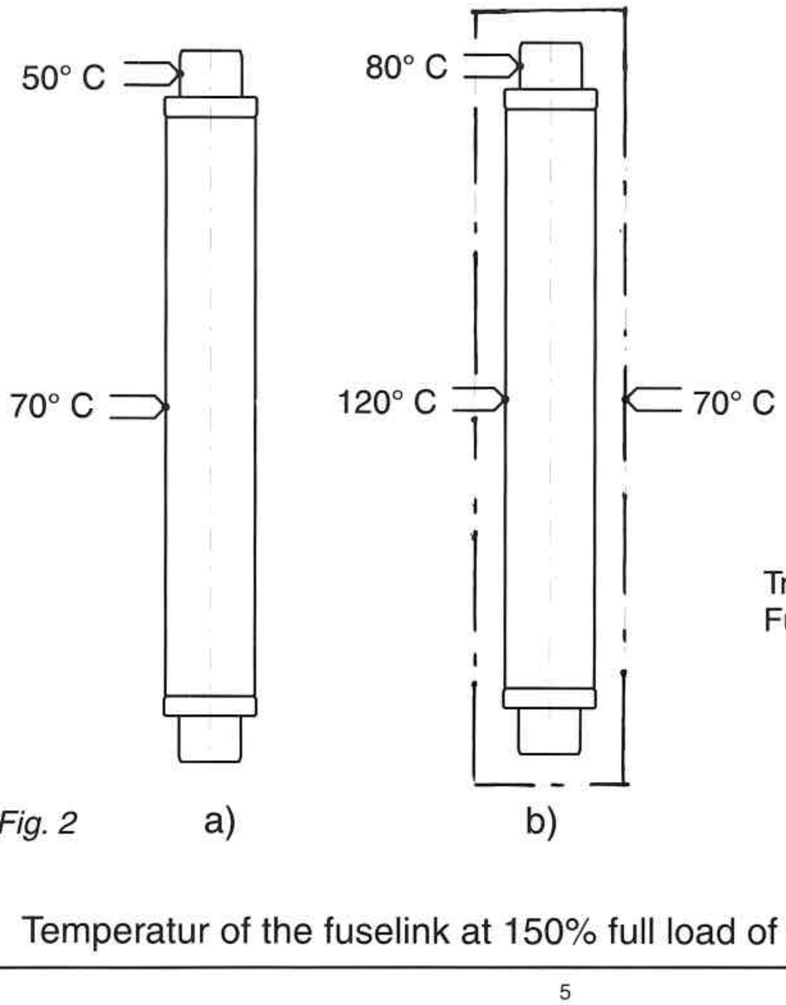


Fig. 1



Transformer 1000 kVA 24 kV
Fuse link 63 A 24 kV

a) air insulated switchgear
b) gas insulated switchgear

Fig. 2 a) b)

Temperatur of the fuselink at 150% full load of a Transformer 1000 kVA

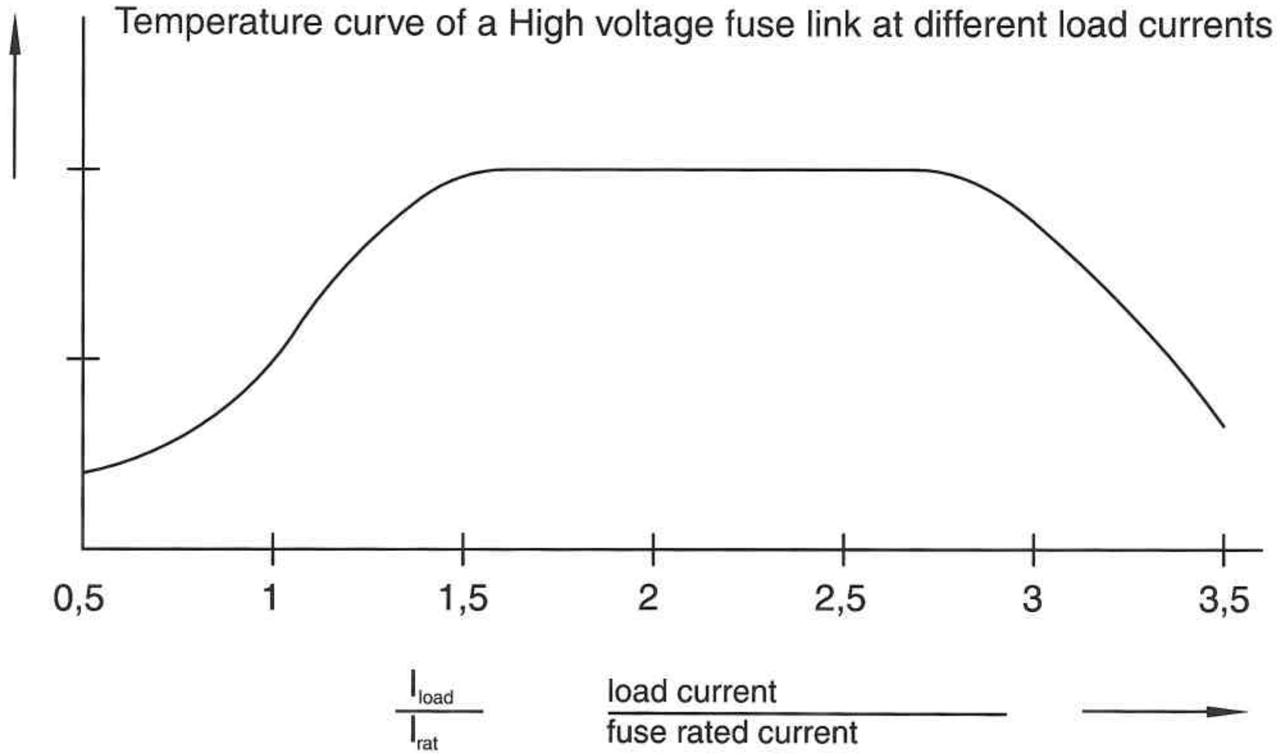


Fig. 3

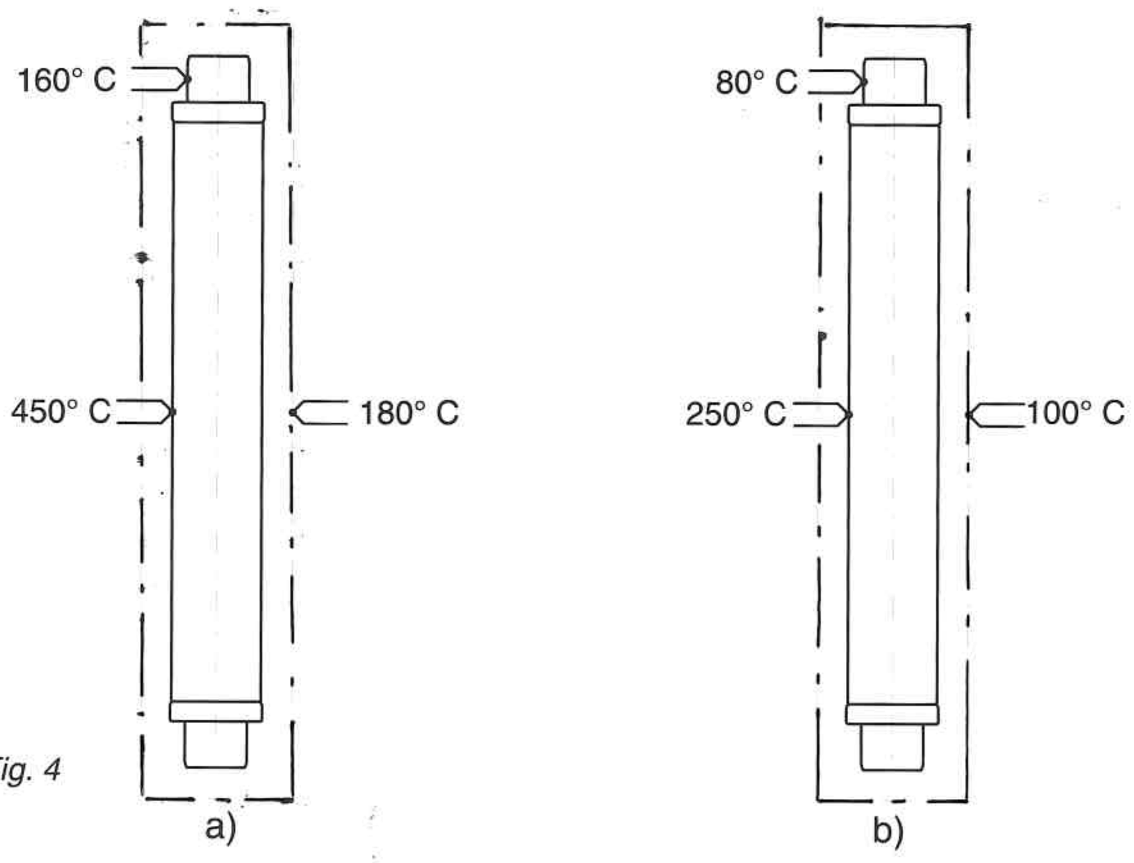
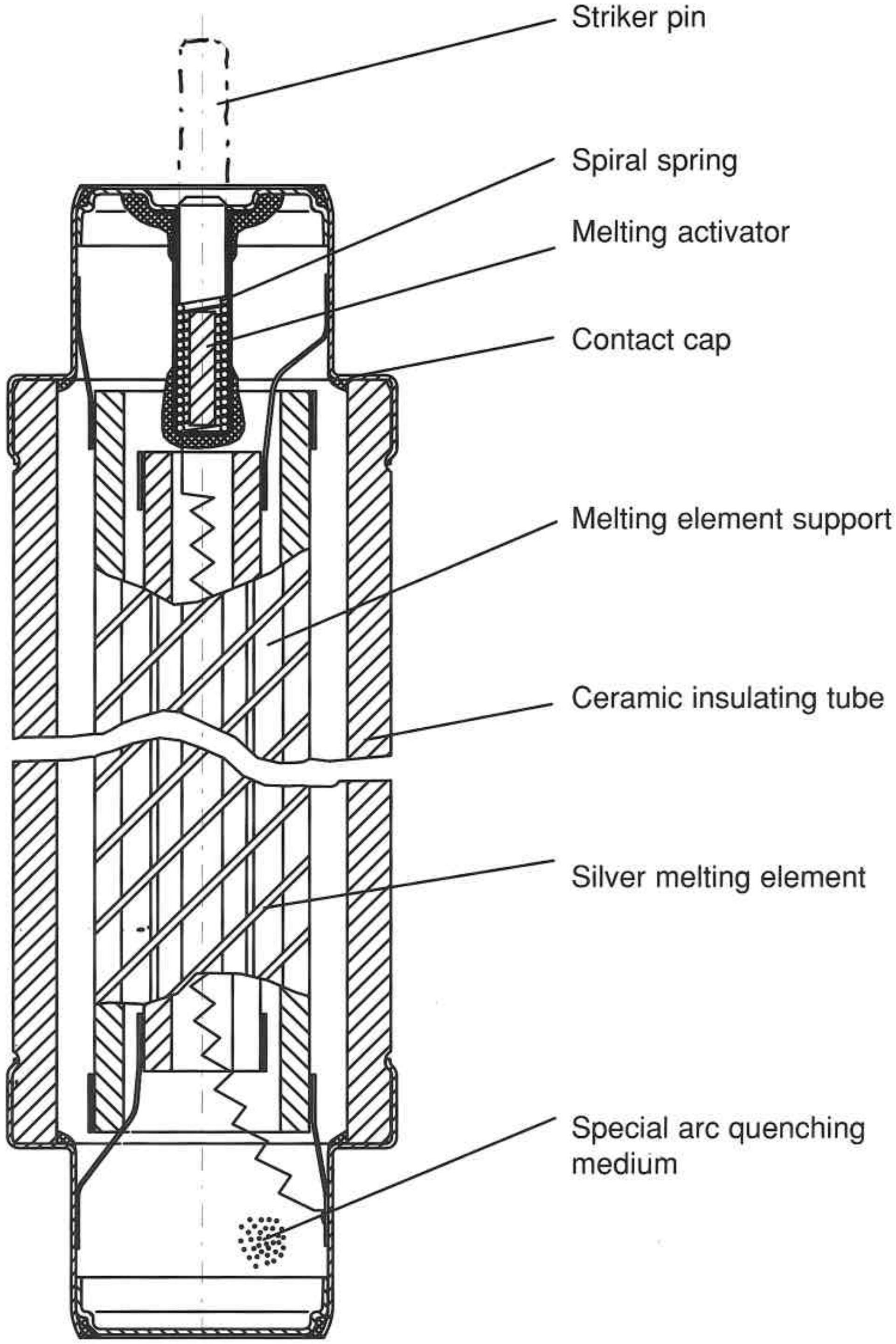


Fig. 4

a) Temperature of a conventional High voltage fuse link 24 kV 63 A

b) Highest Temperature values with melting activator



Temperature- and current limiting High voltage fuse link

Fig. 5

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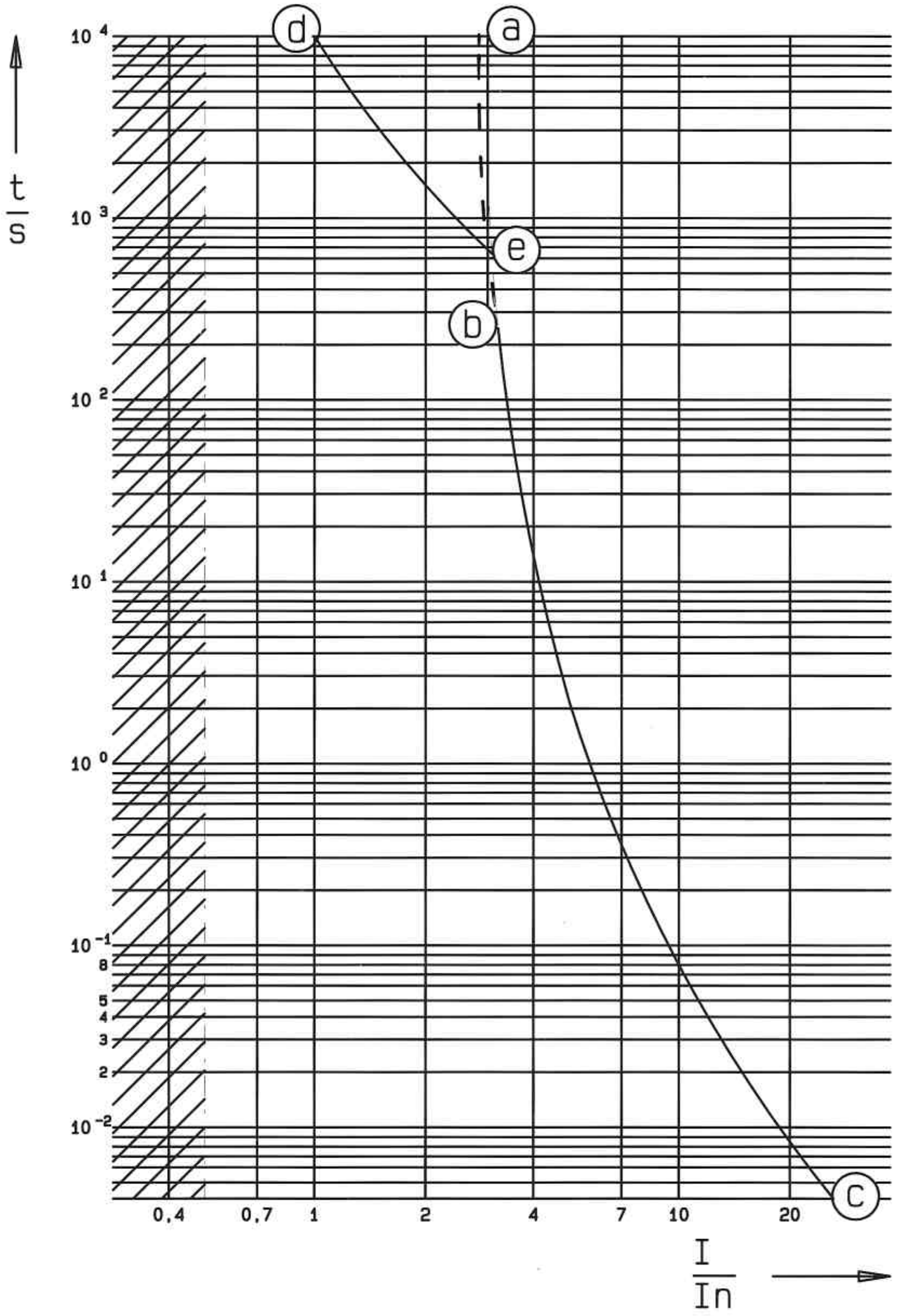

Time - current characteristicof a temperature limiting HV -Fuse link

Fig. 6