Thermal system protection of switchgear through high voltage fuse links with integrated temperature limiter under consideration of IEC 420:1990

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1 General

High voltage fuse links (HV fuse links) type tested according to IEC 282-1 are intended for distribution protection to limit and interrupt prohibited short circuit currents. Moreover the fuse links can interrupt overload currents in three phases if their striker pin works in combination with the switchgear trip release. [1]

Here temperatures of several hundred degrees C can be develop without damaging the high temperature resistant materials of the fuse link. If the fuse links are used in gas insulated or narrow enclosed air insulated switchgear, this high temperature level has to be handled by the surrounding synthetic material of the fuse link enclosure.

In the type testing of fuse/switch combination according to IEC 420 using fuse links with a high rated current, and from practical field experience, the subsequent temperature rise can exceed the permitted values of the switchgear. Ageing of the synthetic material, microcracks or deterioration of contacts within the fuse enclosure can result. [2]

On the basis of numerous temperature rise tests with fuse links in switchgear from different manufacturers, SIBA has developed a tripping system which, independent of the cause, starts fault interruption at prohibited temperatures.

HV fuse links with this integrated temperature limiter reduce the developing temperature rise by operating the switchgear trip release.

2 Fuse links in fuse/switch combination

The current flowing through the fuse link causes a temperature rise much higher than the temperature values of the other components and conductors in the net concerned. These temperatures are transmitted to the contacts of the fuse base by axial heat flow and radiate heat to the immediat 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 1000kVA. If the fuse links are selected according to DIN 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 1000kVA/24kV transformer) temperature values of up to 50°C at the caps and 70°C at the insulating body are to be measured on a 24kV, 63A fuse link in an air insulated switch. [3]

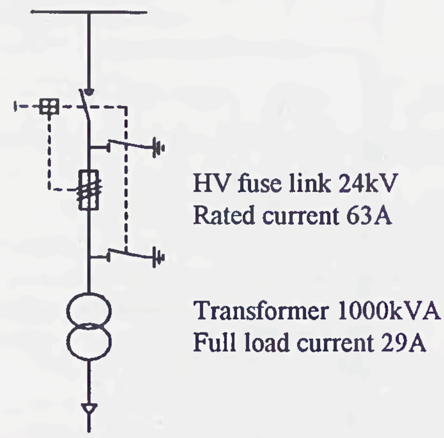


Fig. 1
Selection of HV fuse links for transformers acc. to DIN VDE 0670 Part 402

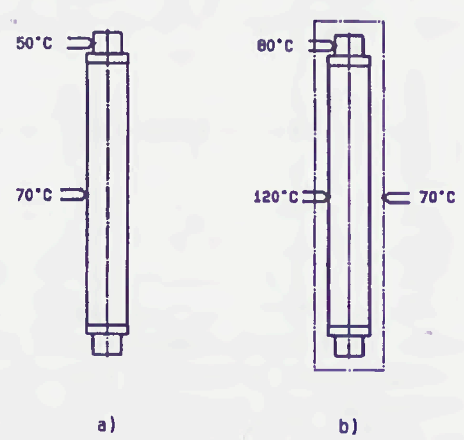


Fig. 2
Fuse link teperatures with transformer overload 150%
a) air insulated switchgear
b) gas insulated switchgear

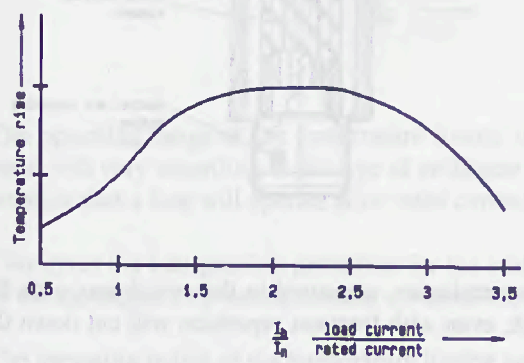
In narrow enclosed gas- or synthetic material insulated switchgear the temperature level is essentially higher due to the lack of air convection and quasi-heat insulation by the switchgear. Consequently up to 80°C at the contact caps and 120°C at the insulating body can be measured. (Fig. 2)

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. With regard to the example of the fuse for a 1000kVA transformer at 150% load, up to 70°C can be measured right in the middle of the synthetic material depending on the volume of the fuse enclosure.

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 range of back-up fuse links the measured values easily approach the temperature limit of the fuse enclosure of the switchgear.

Because of the introduction of the new IEC 420 and the established British regulation ASTA 22, SIBA has worked intensively on the temperature conditions in fuse/switch combinations in the overload range of the fuse links. Switchgear from well known German and other European manufacturers have been tested to determine limiting temperature rises. [4]

A first series of tests showed the maximum of temperature arising under load. **Figure 3** shows the temperature course of a HV fuse link when loaded in the range 0,5 times the rated current up to the minimum breaking current. It can clearly be seen that the maximum temperature rise is reached when loaded with approximately 200% fuse rated current (approximately 4 times the transformer rated current).



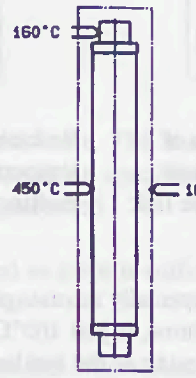


Fig. 3
Temperature rise at different load of HV fuse link

Fig. 4
Max. values of temperature at 200% fuse rated current

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

Figure 4 shows typical peak values of temperatures of a 24kV, 63A HV fuse link. In vertical position the fuse link reaches 160°C at the fuse caps and the body of the fuse link heated 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 it with approximately 2-3 times the rated current. This test will indicate that the fuse/switch combination is able to withstand, thermally, long lasting overcurrents, and by means of striker pin is able to interrupt faults below the minimum breaking current.

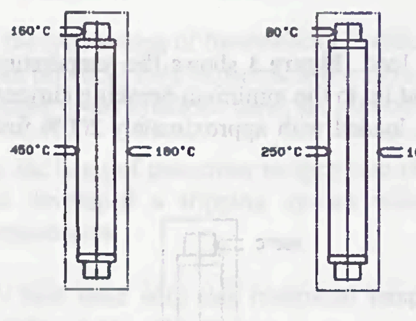
Here too the measured temperatures have been confirmed out of the maximum value determination. While the fuse link materials overcame these high temperatures easily, ageing of the switchgear materials cannot be disregarded.

3 Fuse links limiting current and temperature

Therefore SIBA has developed high voltage fuses further. The fuse link should not only work as current limiting fuse, but also as temperature limiting fuse. By using a melting activator the resulting temperature inside the fuse has been drastically reduced to 230°C. Now the opening of a fault on the switchgear no longer relies on the melting of the elements (melting temperature 960°C), but a striker pin release is started by the activator causing the striker to operate the 3-pole trip mechanism of the switchgear.

The Components of the fuse link and the switchgear stay comparatively cool. Approximately 80°C can still be measured at the caps, and at 250°C the fuse barrel stays considerably below the value without the temperature limiting. (Fig. 5)

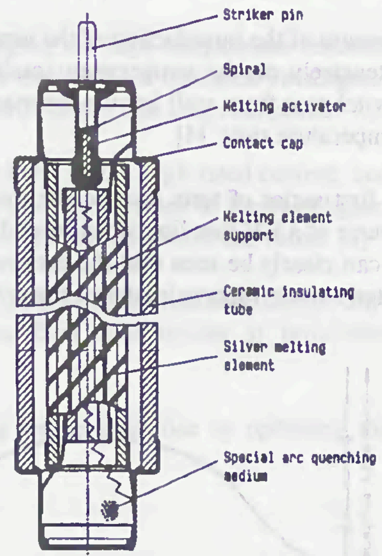
Fig. 5
Fuse link 24kV 63A
load current 126A



Max. values of temperature at standard fuse link

Reduced values of temperature with melting activator

Fig. 6
Current- and temperature limiting HV fuse link



Now it is especially advantageous that the temperature of the fuse enclosure, measured in the switchgear with the smallest volume, is just 100°C. This is a temperature value which, even with 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 **Figure 6** this newly developed tripping device requires no more space than the original. Use is made of the free space available within the pressure spring. This still gives sufficient space between it and the source of heat, the fuse elements. The activator gives the system the necessary delay in order to avoid the tripping device responding immediately to a temporary current increase.

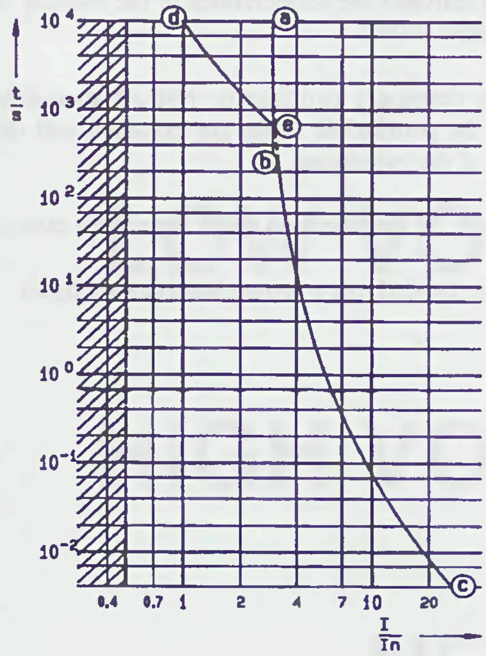
The power part of the fuse link remains unchanged when using the temperature limiter. The fuse element design and its arrangement correspond to the design tested and certified. The auxiliary melting element, the electrical contact of the tripping device, has not been changed either.

The function as a back-up fuse is therefore enhanced. Up to the rated current, and from the minimum breaking current, this new fuse link development corresponds to the conventional one. It is 100% compatible and can be directly 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 DIN VDE 0670 Part 402.

4 Operating points of the temperature limiter

Figure 7 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 the breaking range and the range a-b as the prohibited range where the fuse link must not operate. At point b, the crossing of the broken line with the straight line, is the minimum breaking current, and at point a the minimum melting current.

Fig. 7
Time/current characteristic
of a current and temperature limiting fuse link



The operating range of the temperature limiter is within the area between the points a-d-e. The exact operating point will vary according to the type of swithgear used, ambient temperatures and instalation conditions. It is even possible that a fuse will operate at its rated current if the prescribed temperatures are exceeded.

This gives the best possible protection for the switchgear. Random tripping is stopped as there is sufficient margin 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 rises can occur as a result of the following conditions:

- Faults between windings in the transformer cause a long lasting fault current.
- The transformer is operated considerably above its capacity limit.
- The fuse rated current chosen for transformer protection is too small.
- An prohibitively high temperature caused by poor contact is experienced by the fuse link.
- Fuse links experiences a fault current below the minimum breaking current.
- The fuse link carrying capacity will be reduced because of transient influences damaging individual elements of the element system.

During the last fault example, a situation would arise when only one or two fuse elements open though the fuse link is equipped with a total of six melting elements. As the fuse links, according to the classification tables, are only loaded up to half their rated current, the developing temperature is eventually not sufficient to activate the temperature limitation. Only when the additional elements open and consequent prohibitively high temperatures occur, will the temperature limitation become 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 overcome prohibitively high temperatures (regardless of the cause) in gas insulated or narrow enclosed air insulated switchgear. By the use of a melting activator the temperatures in the housing of the fuse link container have been reduced from more than 180°C to below 100°C.

Here special importance has been given to power supply safety in customers switchgears. Not all short-time overcurrents lead immediately to response by the fuse. Only when the permissible limits are exceeded will the release system of the new fuse link activate and act on the trip release of the switchgear.

The new fuse links are fully compatible with conventional back-up fuses; all classification tables remain the same.

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

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 1kV

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

LOW VOLTAGE FUSES,

HIGH VOLTAGE FUSES,

NEW TYPES