NEW LINE IN THE H.B.C. FUSES DEVELOPMENT

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1. INTRODUCTION

The vast majority of nowadays fuses are the h.b.c. and gas-expulsion fuses. H.B.C. fuses are the short-circuit current-limiting devices. From the short-circuit current-limiting ability point of view a typical h.b.c. fuse-element shall fulfil two requirements: first is to keep its cross-section as small as possible in order to have the smallest pre-arcing time and the second one,- to create an as high as possible arc-voltage using quite reasonable fuse-link length. That's why in comparison with the gas-expulsion fuses, which are not current-limiting ones, the h.b.c. fuses do indicate several times larger watt-losses. This is the price paid for the current-limiting ability.

For instance, a 15kV h.b.c. fuse has the element-length of order 100cm, whereas a 15kV gas-expulsion one,- few cm only. So the h.b.c. fuses are very much electrical energy consuming devices. Some general purpose h.b.c. fuses of 10kV rated voltage and 100A rated current for example indicate abt 200W rated power-losses. Or a h.b.c. fuse for protection of diodes and thyristors of 1000V a.c. rated voltage and 100A rated current shows abt 20W, but of 500A rated current,- abt 100W. This is a waste energy, which specifically in the case of large power semiconductor invertors shall be artificially removed.

An/other drawback of such fuses is their relatively large fuse-element cross-sectional area which by given rated current is dictated by the heat transfer ability into the fuse-terminals and, especially for high voltage fuses, into direction of the sand. In result the h.b.c. fuses in prior art do demonstrate comparatively great pre-arcing and in cosequence great total I^2t. It makes difficult the economic solution of the proper protection for instance of the power semiconductor equipment.

Besides, the substantial power-losses yield the hot running fuse-links. In consequence the thermal stresses of fuse-element are very likely, resulting in the eventual damage of that element. This is a factor that also deteriorates the operating characteristics of the fuse and renders it unfit for further use.

Obviously, there are manufactured several h.b.c. fuses in which is visible an effort to diminish of the mentioned drawbacks. But the general principle of operation remains still this same, which does limit the further improvement.

One of the possible way of the drastic avoiding of those inco-

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nviniences are h.b.c. fuses based on the new principle described further.

2. PRINCIPLE OF NEW H.B.C. FUSES

In all existing h.b.c. fuses the fuse-element does play two roles: it fits the current-carrying ability for long period and it assures the correct interruption of the overload currents. While according to the new idea these roles are divided between the two independent fuse-elements. Hence the name of new fuses is the two-path h.b.c. fuses[1/]. In here a fuse comprises (Fig.1) : the basic fuse-element manufactured of a good conducting metal, placed in an open casing or in a casing within good dielectric gas, or in vacuum or dielectric liquid, and the arcing fuse-element placed in a casing filled up within quartz-sand or another arc-quenching means. Both mentioned fuse-elements are connected in parallel to terminal contacts. The length of basic fuse-element is many times smaller than the length of arcing fuse-element. It could be in the range of 0.5 to 10mm, whereas the length of arcing fuse-link has to be selected to the correct current breaking ability at fuse rated voltage.

Due to entire heat conduction to the contact terminals the cross-sectional area of so short basic fuse-element largely depends upon its length. For instance, the minimun fusing current (MFC) density of a silver element of the 2mm length is 3.5 times greater than that of the 7mm length [1] . That's why a long silver fuse-element of the same MFC indicates a larger cross-section than that of the short fuse-link. An example, loaned also from reference [1] , gives MFC of 44.5A for 0.2mm dia. Ag wire of 5mm length, while a long wire of this same MFC should have appr. 0.475mm dia.

A fuse agreed with the new idea does operate as follows: under normal working conditions practically the entire current is flowing along the basic fuse-element, meanwhile the arcing fuse-element is practically free of the current. The latter then in steady state conditions practically does reach the temperature rise of the terminal contacts only. That's why the casings 5 and 6 (Fig.1) can be manufactured even from a cheap insulating material say of the heat-resistance class A.

But at an overcurrent in relatively short time the basic fuse-element does interrupt without the arc-ignition, because the current in this instant is turning-over into the arcing fuse-element surrounded by an arc-quenching medium such as the quartz-sand. After a defined time the latter also does operate, but in this case, say in the constrictions af arcing fuse-element, if any, the arcs do ignite and then they are finally extinguished as soon as current interruption has take place.

Generally, to obtain the correct operation two fundamental conditions should be fulfilled:

i the current turn-over from the basic fuse-element into the arcing fuse-element must be free of the arc-ignition in

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1/ Polish patent application P.245953, 27.01.84

that basic element,

ii the recovery strength of the gap which arise in the basic fuse-element as result of turn-over process shall be sufficient to withstand of the recovery voltage.

The first condition one can consider generally using the following relations (Fig.2)

$$L_B \frac{di_B}{dt} + R_B i_B = L_A \frac{di_A}{dt} + R_A i_A \qquad (1)$$

$$i_B + i_A = i_t \qquad (2)$$

In here the turn-over current i_t over the turn-over period t_t is practically constant because the time constant L/R in comparison with the time t_t is very large one. A short-circuit current due to the rapid adiabatic heating yields the instant increasing of the basic fuse-element resistance. Hence the current i_B is forced to decaying, but the inductivity L_B does oppose to that. On the other hand, the forced increasing of the current i_A in the arcing-element has been delayed due to the inductivity L_A. The magnitude of the fuse terminal voltage u_t, which appears in very turn-over instant, shall be lower than a defined value. Otherwise an elctric arc does ignite in place of the disrupted basic fuse-element. Such a case would be disastrous for described arrangement. To avoid this the ratios R_A/R_B and L_B/L_A shall be kept in certain limits. Some particular data of those ratios are given in the next chapter.

The second condition one could stress as follows: neither the maximum arc-voltage nor arc-extinction voltage generated by fuse-element shall exceed the recovery strength of the gap arising in the place of the basic fuse-element.

To satisfy above given conditions, generally speaking, the cross-sectional area of arcing fuse-element shall be rather large one.

From the general point of view, this "new idea" is well known from the switchgear technology. Already very old circuit-breakers have got the basic- and arcing-contacts. Again, the short-circuit current-limiting devices such as I_s-limiters manufactured already several decades by Calor Emag (GFR) or e.g. ULTRUP-Fuse made by Fuji (Japan) are only some examples of application of this same idea. But the consistent difference is that the suggested h.b.c. fuse is a parallel combination of two fuse-elements. On the contrary, I_s-limiters of ULTRUP-Fuse and others instead of a basic fuse-element have the basic contact driven by an explosive detonator or by use of the electrodynamic Thomson principle or have basic current carrying path of a large cross-sectional area interrupted also by an explosive means. To that they shall have a special control system in order to fire on of the detonator in an appropriate instant.

Already ab.20 years ago we have endeavoured to create a h.b.c. fuse agreed with the described principle, but we did'nt succeed due to failures during the short-circuit interruption. Recently we did new approach and overcame them. The technical data of a representative of the improved h.b.c. fuses for protection of semiconductor devices will be demonstrated below.

3. AN EXAMPLE OF NEW H.B.C. FUSES

An exaple of new fuses for diodes and thyristors is of the following rated data (Fig.3) : rated current,- I_n = 315A; rated voltage,- 500V; rated power-losses,- 30W; rated breaking capacity,- 110kA at 500V, p.f.= 0.15 (Fig.4) ; ability of interrupting of the small overcurrent,- not lower than $3I_n$ (Fig.5) ; clearing I^2t,- abt 120000 A^2s; upper terminal temperature rise,- 62°C; casing temperature rise,- 62°C; very steep time-current characteristic.

Some internal data of that fuse are: the ratio R_B/R_A = 1:15 (0.16mΩ : 2.4mΩ) ; again the ratio L_A/L_B = 1 and shall be as small as possible; the ratio of the fuse element cross-sections S_A/S_B = abt 6. It exists a close relationship between the required cross-sectional area and the inductivity of the arcing fuse-element. The greater inductivity needs the larger cross-sectional area in order to reach the correct turning-over.

4. CONCLUSIONS

Thereinbefore described two-path fuses do create a new possible line in the h.b.c. fuses development. This line does characterize by the following advantages:

- Drastical diminishing of the rated power-losses. Given example indicates abt 2 times smaller losses than that of a comparable present days h.b.c. fuses destined for diodes and thyristors.
- Substantial lowering of the temperature rises at the rated current. As result the fuse insulating body could be manufactured from an insulating materia even of the heat resistance class A.
- Sharp diminishing of the silver consuption, from which is made the very short basic fuse-element only.
  The cold running arcing fuse-element makes possible to manufacture it from any kind of metal.
- Because the very short basic fuse-element, the time-current characteristic is rather a very steep one. It predistinate them to use as the protective means for semiconductor devices.

Logically, there are also several drawbacks of new fuses:

- The small insulating gap arising in the basic fuse-element during the turn-over period can have too small recovery withstand, needed to keep the recovery voltage. One could improve that withstand placing this element e.g. in vacuum, or in a good insulating gas, or liquid.
- Above given drawback may take place specifically at smaller overcurrents.
- In order to get an exact length of the basic fuse-elements during the mass manufacturing rather a precise manufacturing process has to be applied.

5. REFERENCE

[1] Vermij L., Short fuse elements enclosed in a small slit, 'Switching Arc Phenomena' Int.Symp.Łódź, Poland, 1970, p.247.

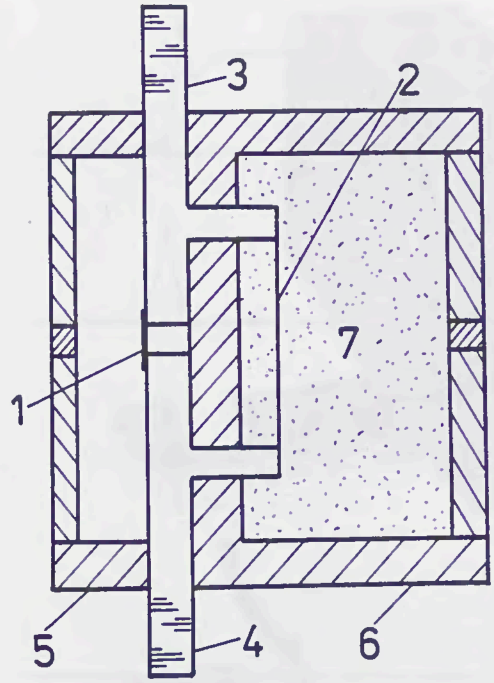

Fig.1
Partial cross-sectional view of a fuse-link assembly acc. to the new idea 1-basic fuse-element; 2-arcing fuse-element; 3,4-contact terminals; 5-casing of basic fuse-element; 6-casing of arcing fuse-element; 7-arc-quenching medium /e.g. quartz-sand/

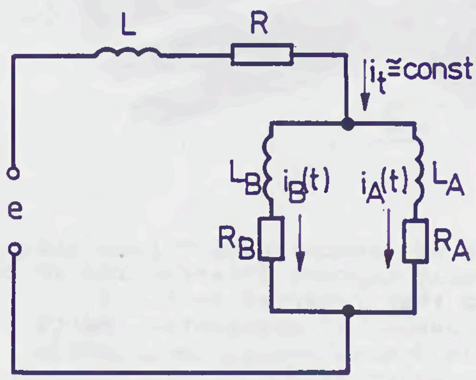

Fig.2
A scheme of the current turn-over indeces: B-basic fuse-element; A-arcing fuse-element

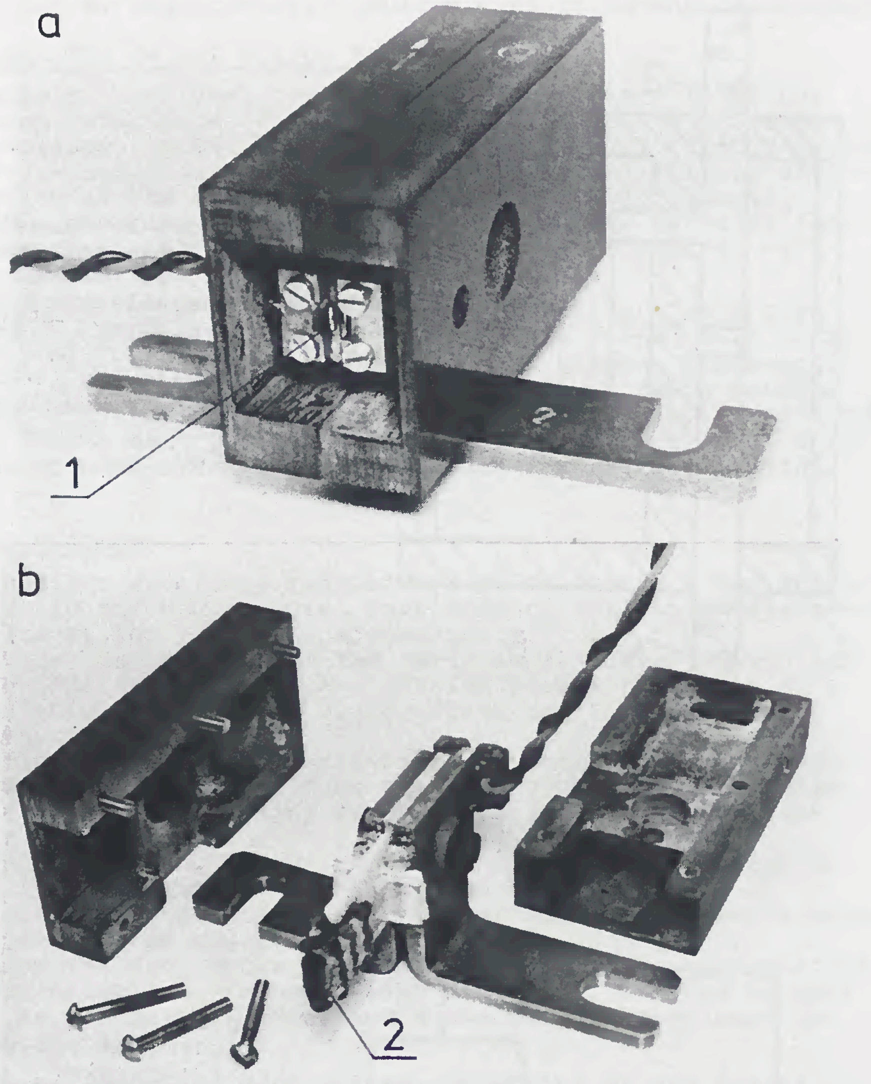

Fig.3 Photographs of a new semiconductor fuse 315A, 500V after short-circuit current interruption in conditions similar to that recorded in Fig.3
a-general view, b-view of substantial parts
1-disrupted basic fuse-element, 2-fulgurite after arcing fuse-element

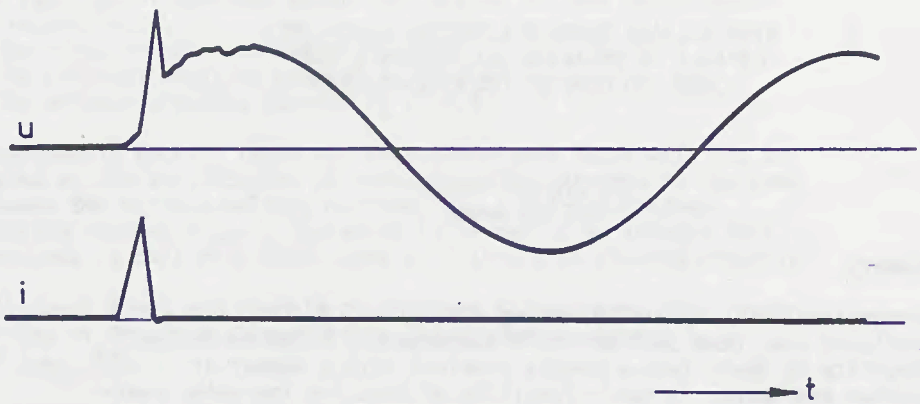

Fig.4 A loop record of the interrupting of 110kA, 550V, 50Hz, p.f.$\leqslant$0.15 by a new semiconductor fuse of 315A, 500V

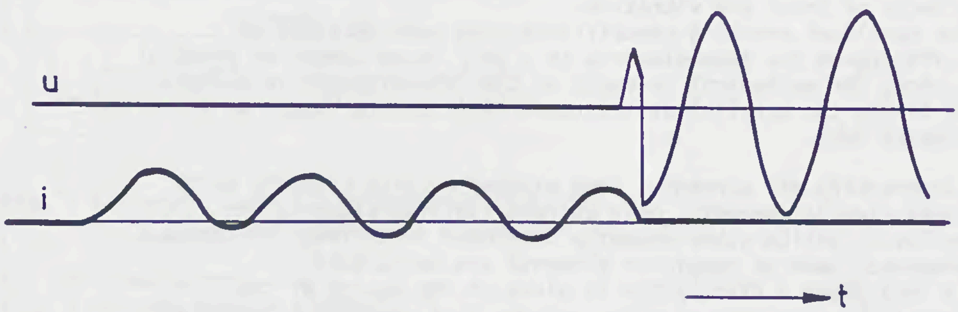

Fig.5 A loop record of the interrupting of abt 1kA, 550V, 50Hz, p.f.$\leqslant$0.15 by a new semiconductor fuse of 315A, 500V