BREAKING TEST REQUIREMENTS FOR SAND-FILLED HBC MINIATURE FUSE-LINKS

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1 Abstract

The first and third authors of this paper contributed to the Fourth International conference on Electric Fuses and their Applications a paper [1] on the breaking performance of lbc (low-breaking capacity) cartridge fuse-links covered by IEC 127-2 [3].

In this paper, they clarified that the failures of these fuse-links in breaking overcurrent were attributable to the excessive arc-energy dispersed in the fuse-envelope and that this energy depended strongly on the arc-initiation angle on the source voltage wave. Based on these findings, they raised a question to the present IEC specification [2] that requires for all miniature fuse-links a fixed value of 30 degrees as the making angle of the test circuit for breaking capacity.

They also reported that the arc-energy fell steadily with decreasing breaking current, and suggested that the breaking tests of the lbc fuse-links at their rated voltage for the lower current levels than their rated breaking capacity should be deleted as useless.

In the present paper, the authors describe the results of their various tests on the breaking performance of the sand-filled hbc (high-breaking capacity) miniature fuse-links covered by IEC 127-2, and conclude that the breaking failures of these fuse-links are closely associated with the high arc-energy.

Based on this conclusion, they suggest that the arc-initiation angle on the source voltage wave should be specified for the test of hbc fuse-links instead of making angle, in line with the IEC requirement for low- and high-voltage current-limiting fuses [4][5].

The fall of arc-energy with decreasing breaking current — found to be more conspicuous than for the lbc cartridge fuse-links — is also reported, and it is suggested that the breaking tests at lower current levels should be deleted for the hbc fuse-links rated 250V and below.

2. Arc-energy and arc-initiation angle

Since the sand-filled cartridge fuse-link is a current-limiting fuse-link in the principle of current interruption, it is most likely that their breaking performance is strongly affected by the arc-initiation angle on the voltage wave just like for the high- and low-voltage current-limiting fuse-links [4][5].

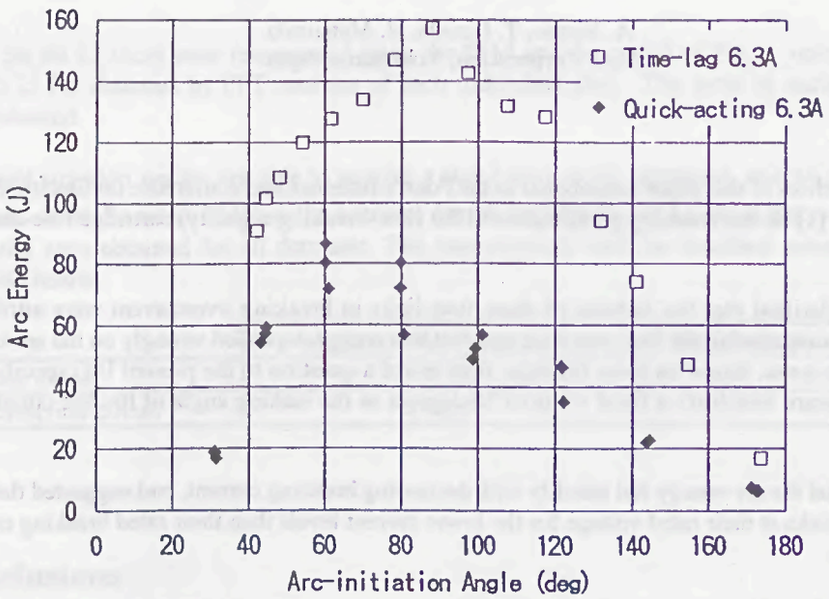
To verify this presumption, the arc-energy of some hbc miniature fuse-links were tested at their rated voltage for their rated breaking capacity, i.e. for 1,500A/250V at power factor 0.75, with the making angle of the test circuit distributed evenly over one half cycle. All the test samples were products of a single manufacturer.

Fig. 1 (a) indicates the arc-energy of 6.3A/250V hbc cartridge fuse-links both of the time-lag and quick-acting types according to IEC 127-2, taking the arc-initiation angle as abscissa. For both types of fuse-links, the arc-energy reached maximum for the arc-initiation angle between 50 and 110 degrees. Fig. 1 also indicates that the arc-energy for the time-lag fuse-links is appreciably higher than for the quick-acting fuse-links.

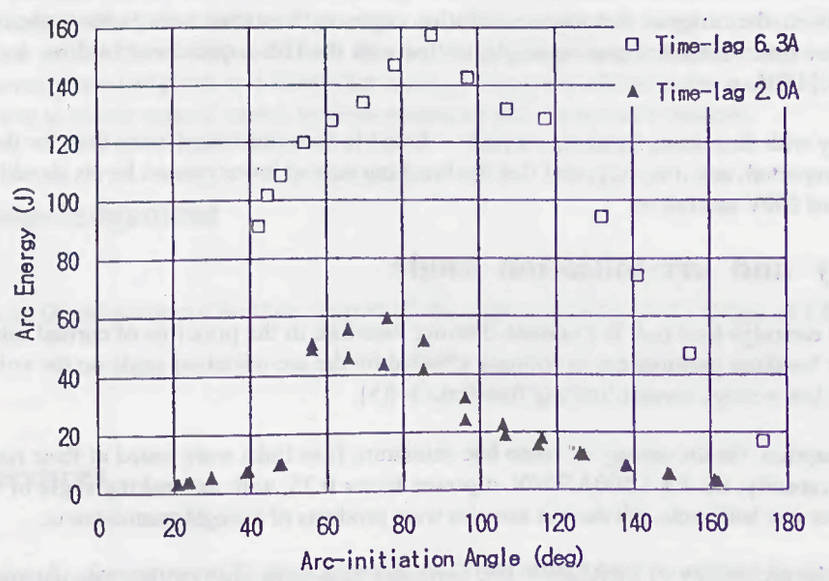
The fact, that the arc-initiation angle between 50 and 110 degrees provides the highest arc-energy, holds true irrespective of the current rating of the hbc fuse-links. Fig. 1 (b) indicates one example.

It also indicates that the arc-energy of 6.3A/250V fuse-links is appreciably higher than that of 2.0A/250V fuse-links. The rule of higher arc-energy for fuse-links of higher rated current on the same Standard Sheet generally prevails for the hbc fuse-links. For the lbc fuse-links, however, this rule does not always hold true [1].

In our tests for Fig. 1, it was found that the arc-energy for a given making angle scattered more widely for the hbc fuse-links than for the lbc fuse-links. This fact could be attributed to the filling of the sand into the fuse-envelope, and it implies that higher attention must be paid in the production of the hbc fuse-links than the lbc fuse-links.



(a) Compared with 6.3A quick-acting fuse-links



(b) Compared with 2.0A time-lag fuse-links

Fig.1 Arc-energy of 6.3A time-lag fuse-links

Fig. 2 shows typical oscillograms illustrating the interruption of 1,500A under the circuit power factor of 0.75 by the hbc fuse-links. The abrupt cutting-off of the current, accompanied by a high voltage spike, is characteristic of the current-limiting fuse-links.

In the oscillograms (a) of Fig. 2, the arcing lasts for several milli-seconds: in (b), however, the arcing is unstable and the current is cut off very quickly, due to the poor supply of metal vapour from the fuse-element at the instant of fusion. The latter mode of interruption is characteristic of the fuse-links of smaller ratings, especially of the quick-acting type.

Although the tests for Fig. 1 showed no breaking failures, the test results suggested that, of all the hbc fuse-links covered by IEC 127-2, the interruption of the rated breaking capacity was hardest for 6.3A time-lag fuse-links specified by Standard Sheet 5.

To define the most rigorous test conditions for the hbc cartridge fuse-links, 6.3A/250V time-lag fuse-links of various designs, produced by four manufacturers, were tested under extremely onerous conditions.

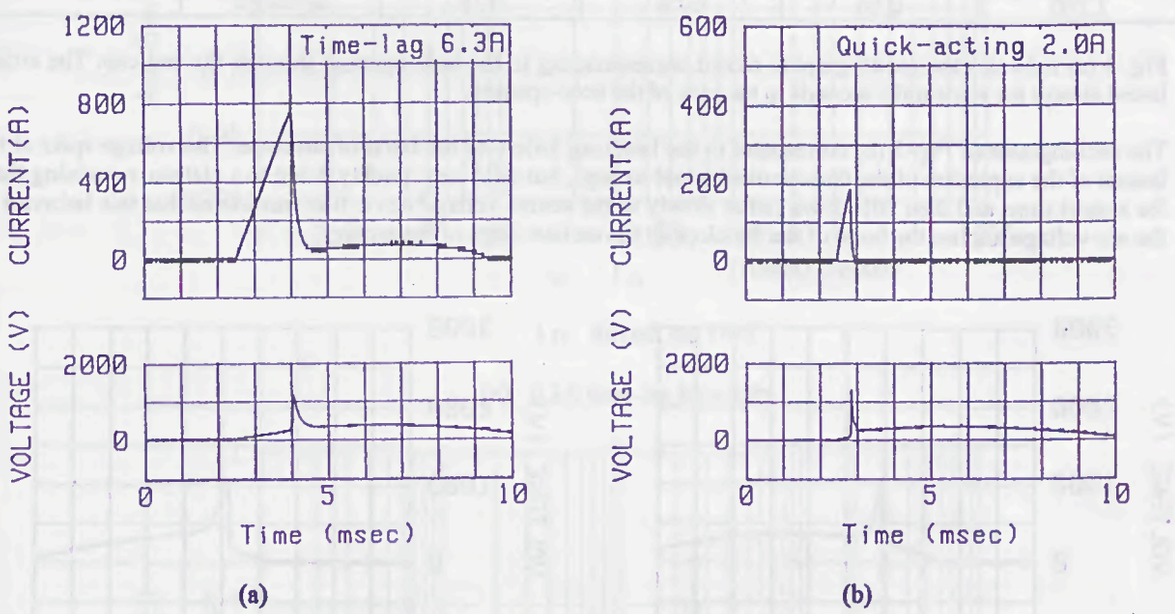


Fig.2 Interruption of overcurrent by the hbc cartridge fuse-links

Table 1 records all the failures obtained in the onerous tests, where the power factor of the test circuit was lowered down to 0.26. The material of fuse-envelope for most fuse-links were ceramics, but some were glass.

The Table indicates that the breaking failures are due either to the breakage, including cracking and burst, of the fuse-envelope or to the opening of a hole through the end-cap. This implies that the failures were closely associated with the high arc-energy dissipated in the fuse-envelope just like in the case of lbc cartridge fuse-links [1].

The Table also indicates that all of the failures occurred for the arc-initiation between 50 to 90 degrees on the voltage wave, except for one case. This reminds us of the requirement for the arc-initiation angle — in one test between 40 and 65 degrees, in two tests between 65 and 90 degrees — given by IEC 269-1 and IEC 282-1 for the low- and high-voltage current-limiting fuse-links, respectively.

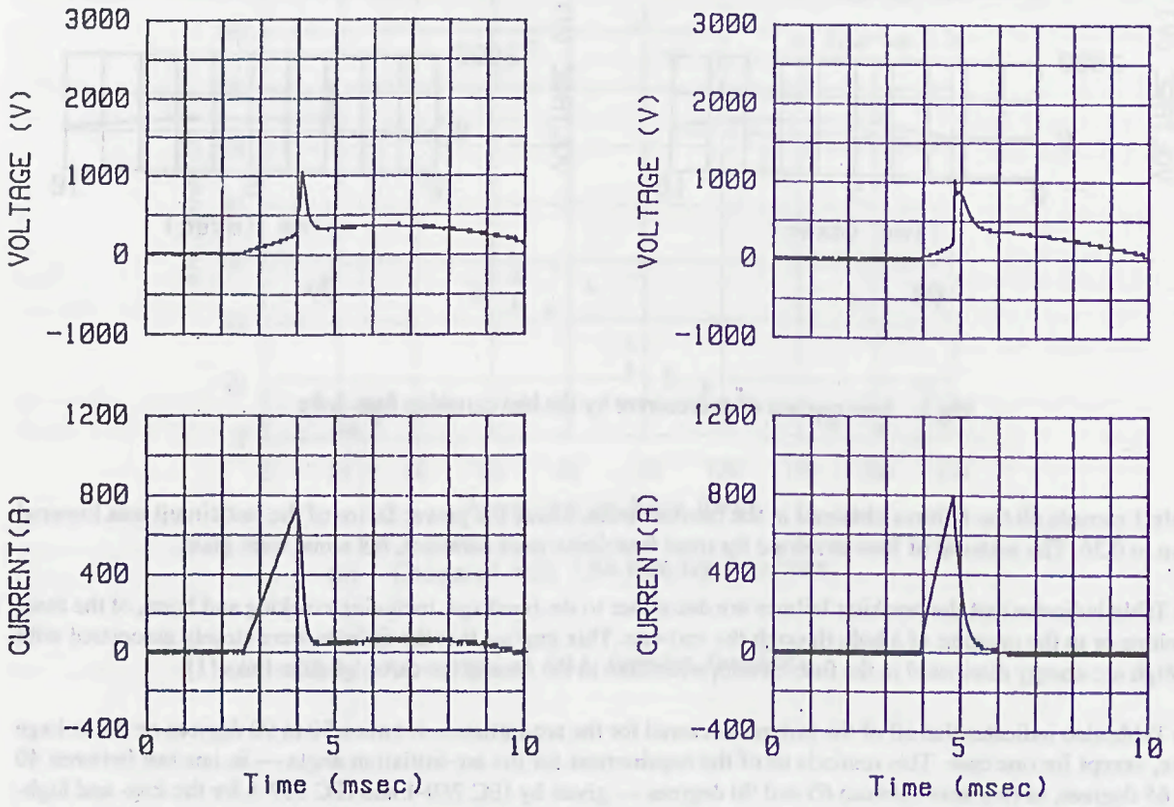
Taking these into consideration, the authors of this paper propose to specify 50 to 90 degrees for the arc-initiation angle in the test of the rated breaking capacity for the hbc cartridge fuse-links to IEC 127-2.

Table 1 Breaking failures under onerous test conditions

Test current (A)	Power factor	Arcing angle (deg)	Arc-energy (J)	Failure location	Remarks
1,500	0.42	64.4	169	end-cap	
1,600	0.26	51.4	270	end-cap	
1,700	0.56	54.1	115	end-cap	
1,700	0.56	86.5	185	envelope	
1,700	0.56	77.0	181	envelope	
1,700	0.56	77.9	163	envelope	
1,700	0.56	68.9	150	envelope	
1,700	0.56	53.2	206	end-cap	
1,700	0.56	52.5	149	end-cap	Fig. 3 (a)
1,700	0.56	117.0	130	envelope	
1,700	0.56	86.5	151	envelope	
1,700	0.56	77.6	131	end-cap	
1,700	0.56	77.4	153	envelope	
1,700	0.56	77.5	143	envelope	Fig. 3 (b)
1,700	0.56	67.6	121	envelope	

Fig. 3 (a) indicates the oscillographic record corresponding to the hole-opening through the end-cap. The arcing lasted always for some milli-seconds in the case of the hole-opening.

The oscillograms of Fig. 3 (b) correspond to the breaking failure of the burst of envelope. The voltage spike at the instant of the explosion of the fuse-element is not so high, but falls very quickly down to a plateau, remaining there for a short time, and then falls down rather slowly to the source voltage wave. It is considered that this behavior of the arc-voltage implies the burst of the envelope at the earliest stage of the arcing.



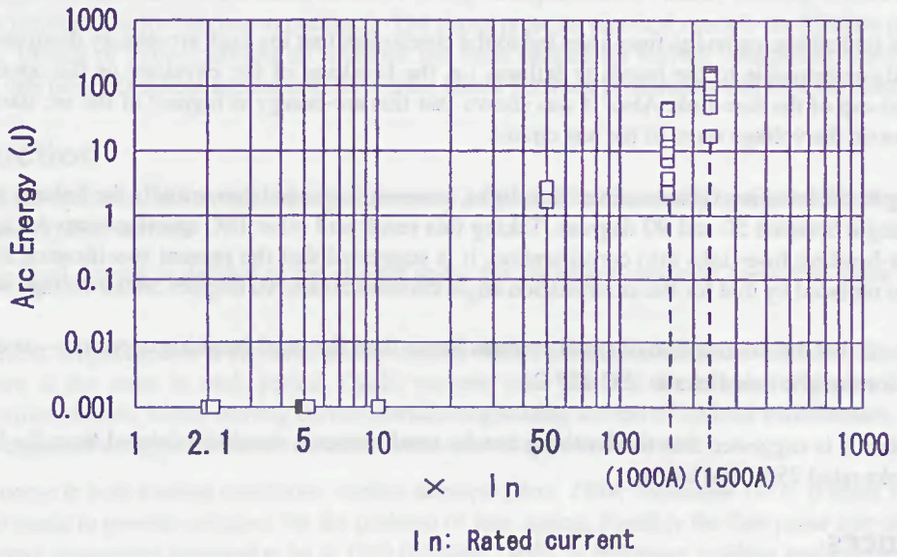
(a) Hole opening (b) Burst of envelope

Fig.3 Failed interrupions by 6.3A time-lag fuse-links

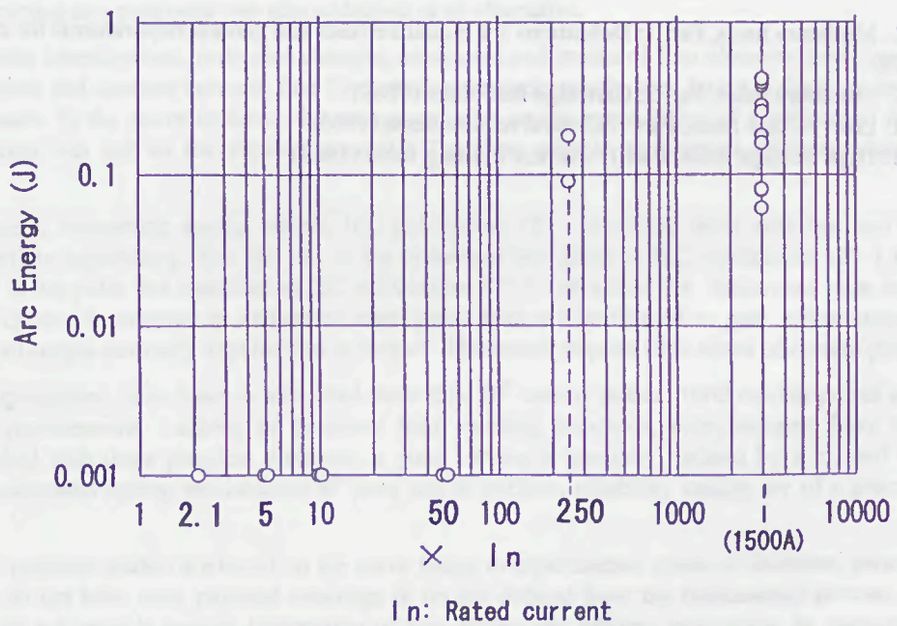
3 Breaking tests at lower current levels

In the present IEC 127-1, breaking tests at lower current levels, i.e. at 5, 10, 50 and 250 times the rated current (I_n) of the fuse-links not exceeding their rated breaking capacity, are specified for all miniature fuse-links. This specification, however, could hardly be justified for the hbc fuse-links with rated voltage not exceeding 250V.

Fig. 4 (a) indicates the arc-energy of 6.3A/250V time-lag cartridge fuse-links for the test currents 2.1, 5, 10, 50 I_n and also for 1,000A and the breaking capacity 1,500A. The lowest current, 2.1 I_n, corresponds to the conventional fusing current for this fuse-link, which might be most difficult to interrupt. The test current 1,000A has been chosen as an intermediate current between 50 I_n and the rated breaking capacity.



(a) 6.3A time-lag fuse-links



(b) 0.5A quick-acting fuse-links

Fig.4 Arc-energy for the interruption of small current

Fig. 4 (b) relates to 0.5A/250V quick-acting fuse-links, for which tests were made at 2.1, 5, 10, 50 and 250 I_n and the rated breaking capacity 1,500A.

For high-voltage current-limiting fuse-links, the interruption of small overcurrent, such as one-hour fusing current, is not easy and the test for the rated minimum breaking current is specified [5]. In the case of the hbc miniature fuse-links rated 250V, however, no breaking failures occurred even in the test for 2.1 I_n as indicated in Fig. 4.

Based on these facts, the breaking tests of lower current levels specified for miniature fuse-links by IEC 127-1 should be deleted at least for the hbc fuse-links rated not higher than 250V.

4 Conclusions

The tests of the typical hbc cartridge fuse-links led to the conclusion that the high arc-energy dissipated in the fuse-link is primarily responsible to the breaking failures i.e. the breakage of the envelope or the opening of a hole through the end-cap of the fuse-link. Also, it was shown that this arc-energy is highest of the arc starts between 50 and 110 degrees on the voltage wave of the test circuit.

The test leading to the breaking failures of hbc fuse-links, however, indicated that actually the failures occurred at the arc-initiation angle between 50 and 90 degrees. Taking this result and other IEC specifications for low- and high-voltage current-limiting fuse-links into consideration, it is suggested that the present specification for the making angle should be replaced by that for the arc-initiation angle between 50 and 90 degrees on the voltage wave.

It was also shown that the interruption of small currents lower than the rated breaking capacity — even of 2.1 I_n — is no problem for the hbc fuse-links to IEC 127-2.

Based on this fact it is suggested that the breaking test for small currents should be deleted from the list of tests for the hbc fuse-links rated 250V and below.

5 References

[1] Hirose A, Matsuzaki H: Breaking tests of low breaking capacity miniature fuse-links, ICEFA/1991, pp 103 - 106.
[2] IEC 127-1: Miniature fuses, Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links (1988)
[3] IEC 127-2: Miniature fuses, Part 2: Cartridge fuse-links (1989)
[4] IEC 269-1: Low-voltage fuses, Part 1: General requirements (1986)
[5] IEC 282-1: High-voltage fuses, Part 1: Current-limiting fuses (1985)