IMPROVED TECHNOLOGY FOR MANUFACTURING OF THE HIGH-VOLTAGE FUSE-LINKS

Valer GIURGIU[1] and Gheorghe OARGA[2]

[1, 2] Electrical Engineering Co.-ICPE SA, 313 Splaiul Unirii, 030138-Bucharest, ROMANIA, hvfuses@icpe.ro

Abstract: **The new patented design solution and corresponding technology for manufacturing high-voltage fuse-links reduces to the minimum the number of parts in the area of the contact between the fuse-elements and the contacts of the fuse-link. The electric contact between these parts is realized on the outer size of the isolating tube, utilising magnetoforming method, that being the base modification in technology, conducting to a great productivity and high savings. As regards the striker construction, there are eliminated tinnering operations and the new solution is simple, cheap and environment-friendly. The tests made on the new fuse-links were conducted only for establishing of the temperature-rise and dissipated power and checking the time-current characteristics. The obtained values are in conformity with the imposed values by the international norms.**

Keywords: **fuse-link, fuse-element, technology, magnetoforming, striker.**

1. Introduction

The time-current characteristics of the high-voltage fuse-links used in motor circuits must have a slow-fast specific feature, that is a relatively high operating current (slow operation) to give maximum withstand against motor starting current and relatively low operating current (fast operation) to give maximum short-circuit protection to associated switching apparatus, cables and motor.
The sizes of the fuse-links are high, therefore any modification in design or in technology can offer important reductions of the production costs, because the demand is of the order of thousand per year.
The new patented design solution and corresponding technology for manufacturing high-voltage fuse-links reduces to the minimum the number of parts in the area of electrical contacts between the fuse-elements and the contacts of the fuse-link.
The tests made on the new fuse-links were conducted only for establishing of the temperature-rise ans dissipated power. The obtained values there are in conformity with the imposed values by the international norms.

2. The present stage in the manufacturing of the HV fuse-links for motor protection

The old technology of the HV fuse-links for motor protection implies many parts, Fig.1, and corresponding a high consumption of materials and electrical energy, a long execution time, therefore a small productivity and an unwholesome medium for execution personnel, because of the tinnering operations, [1].

Contacts of the fuse-links there are executed in two parts: one which it is first assembled on isolating tube and another part, the proper contact which is fixed on the first part through screws.

Fig.1 – Old solution for contacts of the fuse-link

In order to obtain best technical results and an economical efficiency, it was selected the electromagnetic forming technique for assembling the first part of the contact on the isolating tube, which is deformed in high magnetic field, without mechanical contact, on a special device, based on the electromagnetic effect, Fig.2. Based on this technique, there are executed thousand of fuse-links with best results in comparison with another techniques: assembling with epoxy resinns or by rolling. The principal advantages there are: reduced general cost of the assembling operation, minimal operator skill, a high productivity, no clearing or lubricants required (environmentally friendly process), the process can be easily automated and the forming energy can be precisely controlled.
Regarding the striker construction, the solution is expensive and implies many and great parts, assembled by tinnering, which mean an unwholesome medium for operators and a great

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consumption of the electric energy, in comparison with another solution, having smaller parts.

Fig. 2 - Electromagnetic forming equipment

The device for electromagnetic forming have a construction with many possibilities regarding the diameter of the piece which will be deformed, by simple change of the magnetic field concentrator.

3. The new solution for manufacturing of the HV fuse-links for motor protection

Motor type fuse-links [2-3], have the rated voltage of 7,2 kV and the rated currents in the range between 25 A to 250 A. The diameters of the fuse-links are divided in two sizes, according to rated currents:

first diameter is about 74 mm, for rated currents between 25 A to 80 A;

the second diameter is about 88 mm, for rated currents between 100 A to 250 A.

The rated currents of 315 A and 400 A, will be realized by connecting in parallel two fuse-links, two with rated current of 160 A for 315 A, respectively two with rated current of 200 A for 400 A.

The new solution for the manufacturing of the HV fuse-links for motor protection is based on a revision and a re-design of the many fuse-links parts, except the fuse-elements and the isolating tubes.

There were designed tools for manufacturing the new contacts and another new parts necessary for fixing of the fuse-elements by spot welding, to achieve an ensemble which is mounted between the contacts of the fuse-link.

To one end of the fuse-elements ensemble, the fuse-elements are welded on a part which will be pressed on isolated tube by the contact of the fuse-link, deformed by magnetoforming procedure, realizing a good electric contact between these pieces. To the other end of the fuse-elements ensemble, the fuse-elements are welded on a part which will be fixed, by screws, to the same type of the piece as to the first end, over which will be deformed, by magnetoforming procedure, the second contact of the fuse-link, Fig. 3.

Fig.3 – Magnetoforming area

Also, it was re-designed the striker, classified as a medium type, by its mechanical characteristics. The new solution is simple, without tinnering and with simple manufacturing operations.

4. Testing of the new solution and quality assurance

Because the new solution have not changed the fuse-elements, the tests were concentrated only on the measurement of temperature-rises and power dissipation, as well as the checking of some points on the time-current characteristics, to demonstrate that are not exceeded the limits imposed by the norms or by the technical specifications of the products.

The tests were made in conformity with the IEC 60282-1, [2]. Fig. 4 shown a testing circuit for the measurement of the temperature-rises and power dissipation.

Fig. 4 – Testing circuit

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The temperature-rise in the hottest spots (middle of the isolated tubes) and on the contacts of the fuse-links were measured by thermocouples, utilising a Fluke device, and the values of the resistance of the fuse-link, before and after tests, were measured with a Chauvin Arnoux micro-ohmmeter type CA 10.
In Table 1 are presented the results of the tests regarding the temperature-rise for each rated current of the fuse-links.

Table 1 – Measured values for temperature-rises

In [A]	Measured values			Imposed values [K]
	δT_1 [K]	δT_2 [K]	δT_3 [K]	
25	12	30	6	contacts: 65 isolated tube: 115
31.5	17	35	8	
40	19	40	10	
50	24	45	14	
63	29	63	20	
80	34	70	24	
100	22	30	17	
125	26	34	21	
160	34	38	27	
200	43	45	29	
250	59	50	36	

The tests were made with a vertical mounting of the fuse-link, and from the Table 1 it can be seen that the highest temperature-rises are measured approximate at the center of the isolated tube, except the case of the 250 A rated current, at which the highest temperature-rise is at the up contact of the fuse-link. This case can be explained by the fact that the tube reaches its limits regarding heat transfer by convection and radiation, the characteristic dimension being fuse's diameter.

The values measured for power dissipation are presented in Table 2.

Table 2 – Measured values for power dissipation

In [A]	Measured values [W]	Imposed values by technical specifications [W]
25	38	40
31.5	47	50
40	56	60
50	67	70
63	81	85
80	105	110
100	45	50
125	52	55
160	77	80
200	91	100
250	120	120

The value for rated current 250 A confirm the above supposition regarding the touching of the upper limit for heat transmission of the isolating tube.

Time-current characteristics for fuse-links were obtained in a low voltage test circuit, the same as for temperature-rise tests, with a constant value of the test current through the fuse-link.

The limits imposed in [3]:

$$I_{f10} / I_n \geq 3 for I_n \leq 100A$$
$$I_{f10} / I_n \geq for I_n > 100A \qquad (1)$$
$$I_{f0.1} / I_n \leq 20(I_n / 100)^{0.25} \textit{ for all current ratings}$$

provide slow and fast operation of fuse-links in the 10 s region and 0.1 s region respectively, and characteristics of our fuse-links are in accordance with these requirements.
In Table 3 are presented calculated values for these two currents, with equation (1).

Table 3 – Calculated currents with equation (1)

In A]	**25**	**31.5**	**40**	**50**	**63**	**80**
I_{f10} [A]	75	95	120	150	190	240
$I_{f0,1}$ [A]	350	470	630	840	1120	1500

In [A]	**100**	**125**	**160**	**200**	**250**
I_{f10} [A]	300	500	640	800	1000
$I_{f0,1}$ A]	2000	2650	3500	4760	6300

The time-current characteristics were checked for each rated current, by tests made on two fuse-links (two points on the characteristic), with currents for pre-arcing times in the neighbourhood of 10 s.
In Table 4 there are presented the pre-arcing times obtained for the testing currents corresponding to fuse-links with rated currents from 25 A to 80 A, and in Fig. 5 and Fig. 6 are shown examples where there are marked these points on the time-current characteristic for motor type fuse-links with 31.5 A, respectively 250 A rated current.

Table 4 – Measured values for pre-arcing times

In [A]	**25**	**31.5**	**40**	**50**	**63**	**80**
I_1 [A]	100	150	200	200	300	350
t_1 [s]	38	10	30	50	33	60
I_2 [A]	120	180	250	250	350	400
t_2 [s]	6.4	1.5	4	10	4	14

The points marked in Fig.5 and in Fig.6 are in a region of ± 20% for the test current, using mean current values.
The manufacturing of the motor type fuse-links, and another HV fuse-links types (for capacitors or transformer protection), are made in an implemented quality assurance system, which takes in account,

firstly, all the conditions imposed by the international norms and secondly, the mechanical tolerances of the initial material (silver strips, for instance), parts or final assembly of fuse-link and thirdly, the tolerances regarding the electrical resistance of fuse-elements.

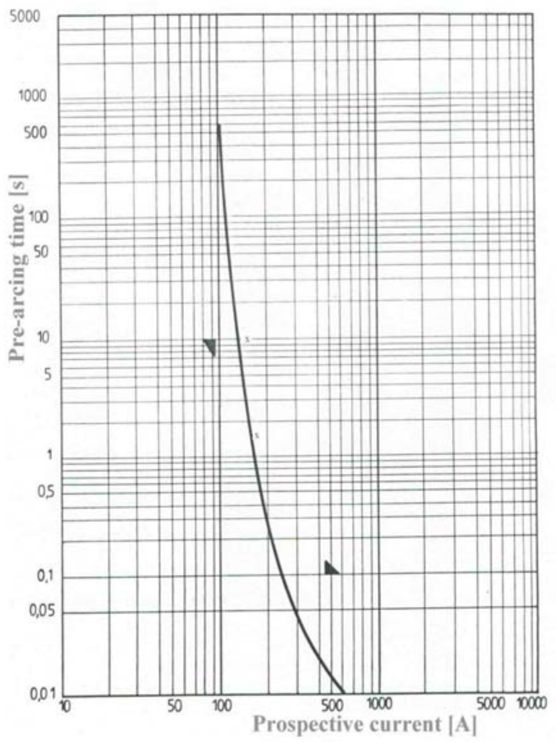

Fig. 5 – Time-current characteristic for a fuse-link with rated current of 31.5 A

There are imposed measurements in various stages of the production flux, to discover some irregularities in execution or assembly processes. The tolerance for electrical resistance is ± 10 % and the resistance is measured and recorded after consecutive execution operations, and naturally before and after the fillig of the fuse-link with the sand, in order to detect any manufacturing influences, for instance damaged fuse-elements or poor welding. Each fuse-link have a serial number, very useful for identification, in case of any irregularities being observed later on.
The fuse-links are marked with labels, having the following identifying dates: manufacturer's name, type of the fuse-link, rated voltage, rated current, rated maximum breaking current, and serial number/year.

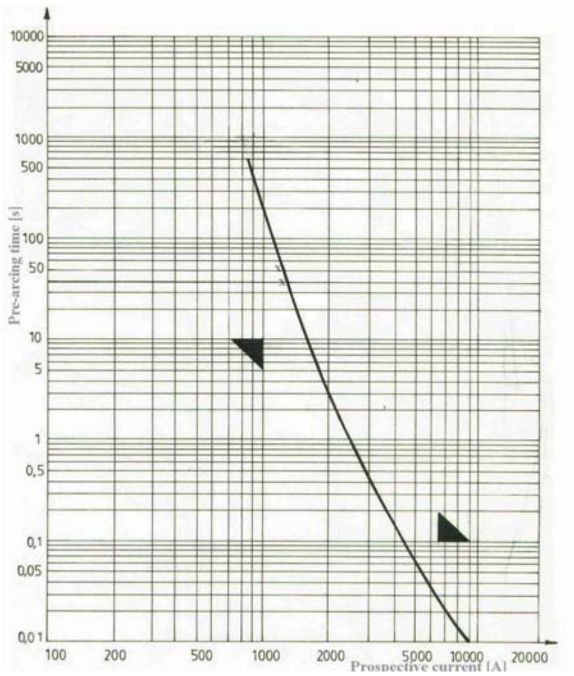

Fig. 6 – Time-current characteristic for a fuse-link with rated current of 250 A

5. Conclusions

The authors describe a new solution for manufacturing of the fuse-links utilised for motor protection, having as a novelty application of a non-conventional technology in final assembling. Theoretically, electrical contacts between the fuse-elements and the contacts of the fuse-link are made by magnetoforming procedure, on the outer surface of the isolating tube, which reduces to the minimum the number of parts, and offer important reductions of the production costs.

The tests were made only for checking the fact that the new technology don't modify significantly the values of the temperature-rises and power dissipation and that there are respected time-current characteristics. The obtained values are in conformity with the imposed values by the technical specification of the fuse-links.

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