HIGH-VOLTAGE FUSE-LINKS FOR MOTOR CIRCUITS PROTECTION

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Abstract: There are presented pre-arcing time-current and cut-off characteristics obtained in high-rupturing capacity laboratory, principal technical features and the results of specified withstand test to a cyclic starting of the motor, for a new series of fuse-links with improved characteristics and reduced quantity of silver for fuse elements.

I. INTRODUCTION

High-voltage fuses are basically simple and relatively cheap and because of their features they are used in wide variety of applications, e.g. for distribution transformers, motors and capacitors, as an extremely important mean of protection, [1].

The high-voltage fuse-links for motor circuit protection are used only as short-circuit protection and are connected to the motor in series with an "associated device" wich can be a circuit breaker or a contactor, having its own relaying system that protects the motor against overcurrents due to excesive loads.

Fault energy limitation to minimise damage resulting from electrical faults, ability to co-ordinate precisely with protective system of associated device, together with adequate short-circuit capacity of fuse-links are all essential for safety of entire installation.

The development of the new series of fuse-links with improved characteristics and a reduced quantity of silver for fuse elements it was the purpose of this work.

II. REQUIREMENTS FOR FUSE-LINKS FOR MOTOR CIRCUIT APPLICATIONS

The demands for a typical motor circuit application involving a motor, a protective system against overcurrents based on relays, an associated electrical apparatus, the cable and the fuse-link, regarding their protective characteristics are shown in Fig.1.

The requirements for such an application are:

- the operation should be as rapid as possible on heavy faults (fast operation), that the cut-off current and the let-throught I^2t should be as low as possible, in the region below 0.1 s on the pre-arcing time-current characteristics;
- ability to withstand indefinitely under repeated starting condition (slow operation), than have good pulse withstand ability in the region over 10 s on the pre-arcing time-characteristics;
- improved performances under low overcurrent conditions and ability to interrupt satisfactorily all faults beyond the capability of the associated devices up to maximum fault level of the system.

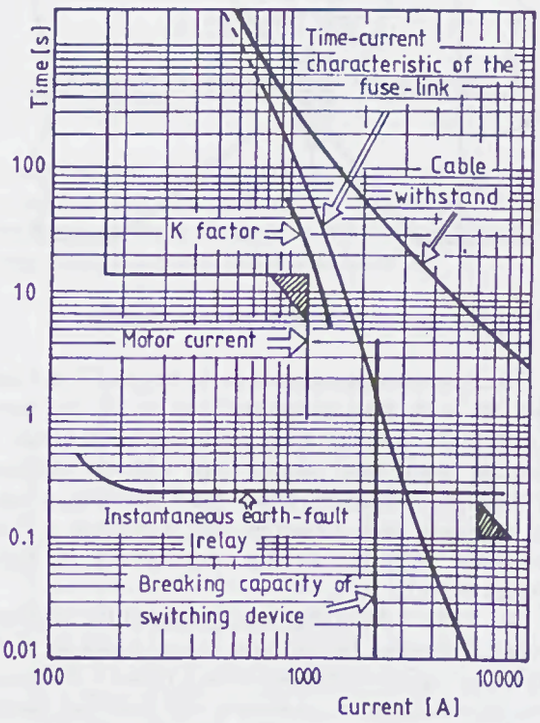

Fig.1 Co-ordination of characteristics relating to the protection of a motor circuit

The pre-arcing time-characteristics of the motor starting fuse-links, for satisfying these requirements, shall be within the limits indicated in [2]. An overload characteristic to which the motor fuse-link may be

repeatedly subjected under specified motor starting conditions without deterioration is obtained by multiplying the current on the pre-arcing characteristics by the K factor, chosen at 10 s, for a frequency of starts up to six per hour and for not more than two consecutive starts, [2].

III. THE NEW SERIES OF FUSE-LINKS 7.2 kV 25-400 A FOR MOTOR PROTECTION

The new series of motor protection fuse-links [3], is in according with IEC Publications 281-1 and 644, regarding overall dimensions and the tests. This type of fuse-links, because their time-current characteristics are relatively "slow" in the region above 10 s can have a small number of elements, of relatively large cross-section area and with uniformly spaced restrictions having particular forms. In Fig.2 is shown a type of restriction, with a small cross-section area, which provides a cooling of this region and a withstand to repeated startings of the motor and a fast operation at the short-circuit currents.

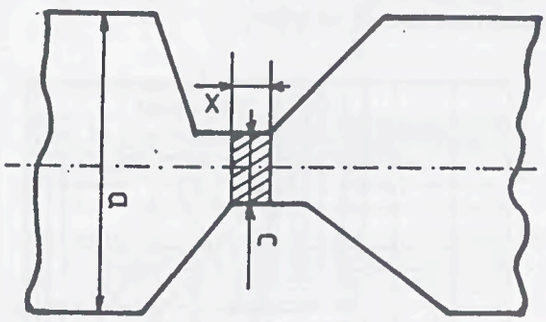

Fig.2 A type of restriction for fuse-element

The number of elements is in the range of 3 to 8 and they are made from silver and can be of the same length as the fuse-link body, with expansion bends at intervals along their length, equal with the distance between the restrictions, to provide a flexibility to take up expansion and contraction due to thermal cycling associated with the starting requirements of high-voltage motors.

In Table 1 and Table 2 are presented the principal technical features for the new series, tested in high-rupturing capacity laboratory from Craiova – Romania, and manufactured in conformity with certified quality assurance system ISO 9001, [4]. The fuse-link bodies are of single resin glass fibre tube for rated currents up to 250 A and of double tubes, mounted in parallel, for rated currents of 315 A (2x160 A) and 400 A (2x200 A). The resin body provides a good withstand to the thermal shock at the test duty 3, the minimum breaking currents being in the range of 3 to 4 times I_n. All fuse-links have striker (type medium) actuated by a spring, for operating associated electrical apparatus, to ensure 3-phase tripping on the blowing of a single fuse-link.

The end caps are mounted on the resin body of the fuse-link using a magnetic forming machine, with a very precise control of energy, then an accurate repeatability of the magnetic forming process. That new unconventional technology provides a great productivity and important economy of materials and energy.

Table 1 Fuse-links for rated currents up to 80 A

Type	MOT 7.2 kV/25 ... 80 A					
Overall dimensions	Ø73/508 mm					
Rated current [A]	25	31.5	40	50	63	80
Rated breaking current [kA_{ef}]	45					

Table no.2 Fuse-links for rated currents up to 250 A

Type	MOT 7.2 kV/100 ... 250 A				
Overall dimensions	Ø88/508 mm				
Rated current [A]	100	125	160	200	250
Rated breaking current [kA_{ef}]	31.5				

The fuse-links for the range 25 ... 80 A and for the range 100 ... 250 A are considered as forming homogeneous series because theirs characteristics comply with the conditions shown in [1]. They may be used in combination with vacuum contactors and another electrical or mechanical switching devices and a precisely co-ordination between their characteristics must be made, to provide a good protection in heavy working conditions (milling, extractive and petroleum industry, etc.).

IV. TEST RESULTS

According to the IEC 282-1 and IEC 644 standards, were tested more than 240 fuse-links, for determining pre-arcing time-current characteristics, cut-off characteristics and test duty 1, test duty 2 and test duty 3 to demonstrate the capability of operation at extreme conditions, for each rated current of the new series.

Fig.3 represents time-current characteristics for fuse-links type MOT 7.2 kV, 100-400 A, obtained in a low voltage test circuit, with a constant value of the test current through the fuse-link. The limits imposed in [2]:

$$I_{f_{10}} / I_n \geq 3 \; for I_n \leq 100A$$

$$I_{f_{10}} / I_n \geq for I_n > 100A$$

$$I_{f_{01}} / I_n \leq 20(I_n / 100)^{0.25} \; for.all.current.ratings$$

provide slow and fast operation of fuse-links in the 10 s region and 0.1 s region respectively, and characteristics of our new series of fuse-links obtained by a great

number of tests in laboratory, are in accordance with these requirements.

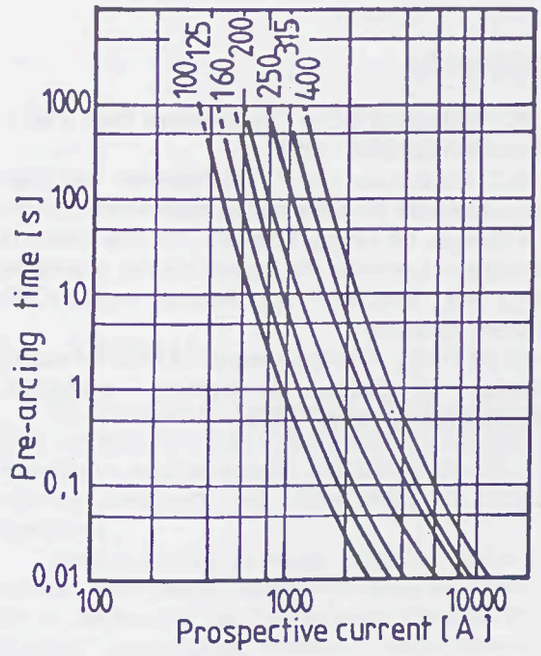

Fig.3 Time-current characteristics for rating curents of 100 – 400 A.

In Fig.4 are represented cut-off characteristics obtained in high-current laboratory, for the same rating currents as above. The new series of fuse-links being a homogeneous series, breaking tests were conducted in accordance with [1], and the results of test duty 1 and test duty 2 are presented in Table 3, for rated currents 100 – 250A. As it was indicated above, the shape of restrictions for fuse-elements, correlated with the number of restrictions, can provide a substantial reduction of the T.R.V. values. The results of tests confirmed that our solution provides reduced values of T.R.V., as can be seen in Table 3.

Table 3 Results of tests for rated currents 100-250 A

Type	MOT 7.2 kV/100 ... 250 A				
Rated current [A]	100	125	160	200	250
Cut-off current [kAmax] – duty 1	13.4	17.7	18.1	23.5	26.5
T.R.V.[kV]	11.7	11.2	10.5	9.4	9.6
Cut-off current [kAmax] – duty 2	8	12.7	13.6	18.8	25.5
T.R.V.[kV]	10.1	10.7	10.7	10.1	10.1

When fuse-links are used for motor circuit protection together with an associate electrical apparatus, like a contactor, the main criterion in choice of current rating of the fuse-link is the ability to withstand repeated

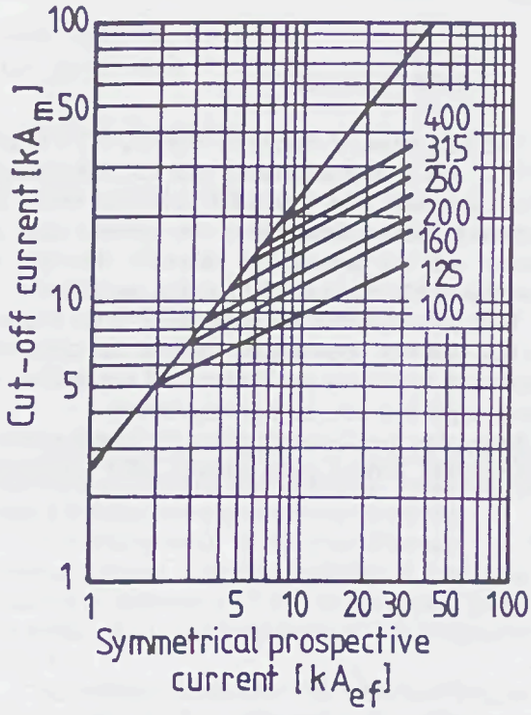

Fig.4 Cut-off characteristics for rating currents of 100-400 A.

starting current surges for the run-up time of the motor, in normal and abnormal service conditions, without deterioration. There are made a gret number of tests for establishing the correct value of K factor, [2].

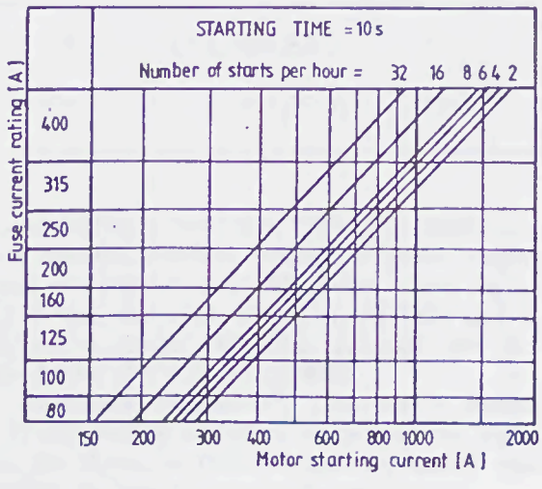

Fig. 5 Fuse-link selection chart, for motors with run-up times not exceeding 10 s

The chart presented in Fig.5 is very useful for an user in selection of fuse-link, correlated with the motor power, his number of starts per hour and the starting time.

V. CONCLUSIONS

The new series of fuse-links with U_n=7.2 kV and I_n=25 ... 400 A is in accordance with IEC Publications 282-1 and 644. The fuse-links have the ability to withstand, without deterioration, the repeated starts of motors and can provide the character slow-fast of operation in 10s region and 0.1 s region, respectively.

Tests have confirmed the good choice of the solution for fuse-elements, regarding the shape of restriction, the number of restrictions per element and the number of elements per fuse-link, for all rating currents.

A design objective, to remain within the bounds of size and economy, without compromising other essential parameters, was obtained and the use of magnetic forming in manufacturing process is an example

The charts obtained are very useful for users of such kind of fuse-links, and are instrumental to the choice of a fuse-link for a concrete application.

REFERENCES

[1] IEC Publication 282-1, "High-voltage Fuse. Part 1: Current-limiting fuses", 1994.

[2] IEC Publication 644, "Specification for high-voltage fuse-links for motor circuit applications", 1979.

[3] V.Giurgiu, Gh.Oarga, S.Purdel, "A new series of high-voltage fuse-links for motor circuits protection, Un=7.2 kV, In=25-400 A", Internal work, ICPE, Bucharest, Romania.

[4] EN ISO 9001, "Quality systems – Model for quality assurance in design, development, production, installation and servicing", 1994.