"aM" FUSE AND ITS COORDINATION WITH STARTERS

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ABSTRACT

The coordination between fuses and contactors/motor starters requires a full knowledge of the behaviour of all components so that the contactor and its relay are not damaged during fault conditions.

The new IEC 947-4-1 Publication deals with contactors/motor-starters and the IEC 269-1 and 2 deal with "aM" fuses used in combination with them. In fact, these two documents are not correctly harmonized.

This paper emphasizes the lack of assets of the International Standardization in the field of "aM" fuses. On one hand the information given by IEC 269-1 and 2 Publications do not allow a good assessment of the coordination between starters and fuses. On the other hand the electrical characteristics of these fuses are not up to date.

This leads the author to advise new tests to verify "aM" fuse characteristics, mainly I^2t and peak let through current, and to suggest new values for them. Moreover it is shown that these actual characteristics are good enough to get the best coordination with starters.

INTRODUCTION

When a motor starts, a peak current appears, which can reach 25 times the load continuous r.m.s current during the first sinusoidal half-wave.

It is followed by a starting time of around 6 times the normal current of motor. When the speed has reached a steady state, the current recovers its normal value.

The protective device must stand these overloads without operating or ageing. Moreover, when these overloads last longer than the normal starting time or when there is a fault creating higher overcurrents, it must ensure the protection of cables, motor and starter.

To meet these requirements, one combines with the contactor a relay or a release that operates in case of an overload or phase loss, and a short-circuit protective device (SCPD) which operates above the breaking capacity of contactor.

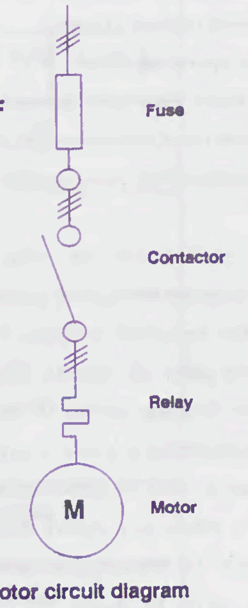


Figure 1 : Motor circuit diagram

When the short-circuit protective device is a fuse, diagram fig. 1 is achieved.

FUSE-STARTER COORDINATION

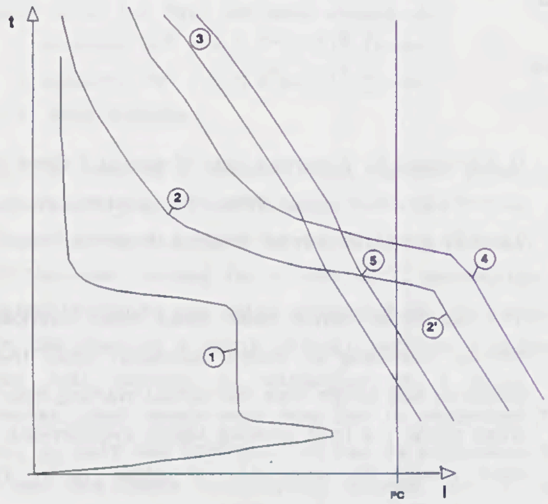


Figure 2 : Coordination of protections

Fig. 2 illustrates the combination between fuse-contactor-relay where the various curves represent :

(1) starting current of motor

(2) relay operating curve

(2') maximum admissible thermal stress of relay

(3) time/current characteristics of fuse

(4) protective limit of bus-conductors

In this combination the relay protects the circuit against overcurrents lower than the breaking capacity (Pc) of the contactor. Actually, it operates for currents below the point (5) absciss. For example, it must let the motor starting current (1) pass through, but has to limit the duration in order to protect the cables, motor and fuses in case of rotor blocking. It is the same in case of a phase loss. Above point (5) fuse (3) breaks the circuit by limiting the peak current and I^2t of current wave to avoid the damage of contactor contacts by excessive energy (repulsion with arc) and of relay and cable by thermal effect (I^2t).

COORDINATION TESTS

IEC 947-4-1 Publication on low voltage motor starters has foreseen some tests to check the coordination of the protections of starter-fuse assembly.

Two types or levels of coordination are considered :

- Type "1" admits that the starter, after a short-circuit, may not be capable of operating without repair or replacement of parts. However, it must not cause any danger to people or installations.

- Type "2" requires that in short-circuit condition the equipment does not cause any danger to people or installations and be capable of ensuring its function afterwards.

The risk of contact soldering is admitted. In this case the manufacturer must stipulate the measures to be taken as far as the equipment maintenance is concerned.

Two tests are foreseen to check this coordination :

- One test at the conventional current "r" precised in the table 3 hereafter, corresponding to a condition often severe for the contactor.

Fig. 3 : Prospective current "r"

Rated operational current (A)	Prospective current "r" (kA)	Power Factor
0 < Ie ≤ 16	1	0,95
16 < Ie ≤ 63	3	0,9
63 < Ie ≤ 125	5	0,7
125 < Ie ≤ 315	10	0,5
315 < Ie ≤ 630	18	0,3
630 < Ie ≤ 1000	30	0,25
1000 < Ie ≤ 1600	42	0,25
1600 < Ie	Agreement of manufacturer/ user	

- One test at the prospective short-circuit current "Iq" if it is higher than "r". "Iq" is the combination conditional short-circuit current, i.e. the value of the prospective current that the starter combined with its SCPD can withstand satisfactorily.

During these two tests at currents "r" and "Iq" the fuse operates before the relay. We are far above point (5) of Fig. 2 in an overcurrent zone where the fuse acts as a limiting device. The behaviour of the contactor and the relay depends on its limiting speed and the values of the cut-off current and the operating I^2t of fuse are of first importance in the result.

If the starter manufacturer wishes to foresee the chance of the starter-fuse combination good operation he needs to know the fuse performances (operating I^2t and cut-off current) in the same operating conditions as above.

OPERATING CHARACTERISTICS OF "aM" FUSE

Publications 269-1 and 2 define the test conditions and characteristics to be respected or to be issued for "aM" type fuses generally combined with starters.

However, these performances cannot be used to study the bahaviour of contactor because they are too far from these of starters.

As a matter of fact, the current "I_1" of Table XII A of Publication 269-1 (Fig. 4) must be compared with the current "I_q" defined above. However, the combination test which is carried out in three-phase conditions leads to very favourable results (I^2t, peak current) in comparison with these of single-phase fuse test. Besides, the current "I_2" of the same table is close to current "r" but the power factor differs a lot, which cannot be justified in a technical point of view because both devices are combined on the same circuit to be protected.

At last, for the same reasons as above, one can also have a favourable behaviour of fuse in three-phase conditions.

Fig. 4 TABLE XII A of IEC 269-1 Publication

Values for breaking-capacity tests on a.c. fuses

		Test according to Sub-clause 8.5.5.1.				
		No. 1	No. 2	No. 3	No. 4	No. 5
Power frequency recovery voltage		110^{+5}_{-0} % of the rated voltage				
Prospective test current	For "g" fuse-links	I_1	I_2	$I_3 = 3.2\ I_f$	$I_4 = 2.0\ I_f$	$I_5 = 1.25\ I_f$
	For "a" fuse-links			$I_3 = 2.5\ k_2\ I_n$	$I_4 = 1.6\ k_2\ I_n$	$I_5 = k_2\ I_n$
Tolerance on current		$^{+10}_{-0}$ %	Not applicable	± 20 %	$^{+20}_{-0}$ %	
Power factor		0.2-0.3 for prospective current up to and including 20 kA 0.1-0.2 for prospective current above 20 kA	Same range as used for test No. 1	0.3-0.5		
Making angle after voltage zero		Not applicable	$0^{+20°}_{-0}$	Not specified		
Initiation of arcing after voltage zero		For one test : 40° - 65 ° For two more tests : 65° - 90 °	Not applicable	Not applicable		

NEW PROPOSALS FOR IEC 269-2 PUBLICATION

It seems then necessary to plan some tests for fuses, enabling a comparison of the operating I^2t characteristics and cut-off current of fuses with the values wished for the contactors. For this, the tests already prescribed should be completed or modified as follows :

- a test should be prescribed at a current corresponding to the rated breaking capacity of fuse but at a voltage equal to the voltage between phases x 3 : 2 = 0.866 x U between phases.

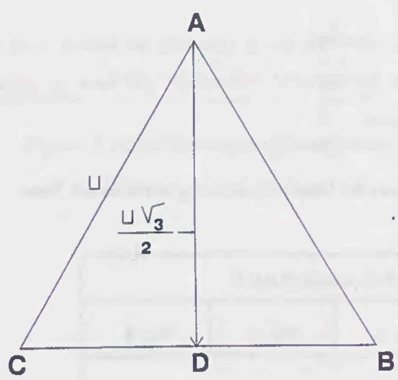


Figure 5 : Applied voltage during a three phase fault

D = middle point of BC

This value is generally admitted as the maximum voltage that a single fuse has to break during a high current three-phase fault (Fig. 5).

As most of these fuses are used under a three-phase voltage close to 400 V, the test voltage would be : 440 x 0.866 = 380 V. For a fuse with a rated voltage of 690V, the test voltage would be : 760 x 0.866 = 660 V.

The operating I^2t achieved during these tests will be useful for the study of coordination with contactor.

- in the same way, the fuse must be tested at the current "r" with the power factor of table Fig. 3 and under a voltage of 0.866 time the voltage applied between phases.

The values achieved of total operating I^2t and cut-off current shall be used for the study of coordination with contactor.

RESULTS ACHIEVED WITH "aM" FUSES TESTED IN THE ABOVE CONDITIONS

Test of current "r"

We have tested "aM" fuses 500 V designed in accordance with the present IEC 269-2 Publication under a voltage of 380 V corresponding to the maximum value of the voltage applied to a fuse in case of a three-phase fault, in a 400 V network.

A rating has been tested in each rating range precised in the first column ot table Fig. 3, at the specified current "r" and power factor. I^2t values and cut-off current have then been extrapolated to achieve the values corresponding to the other ratings of the range as follows :

$$I^2t \text{ for } I_{N1} \text{ rating} = I^2t \text{ for } I_{N2} \text{ rating} \left(\frac{I_{N1}}{I_{N2}}\right)^{2}$$

$$Im \text{ for } I_{N1} \text{ rating} = Im \text{ for } I_{N2} \text{ rating} \left(\frac{I_{N1}}{I_{N2}}\right)^{\frac{2}{3}}$$

thus considering that each range is homogenous.

The results have then been plotted on the graph Fig. 6 (see annex) in comparison with the withstand capabilities of contactors and overload-relays extracted from the document ref. n° 3.

One can thus check that the "aM" type fuses protect perfectly the contactors of the same rating to which they are combined because the cut-off currents and operating I^2t of fuses are always lower than the withstand capabilities of contactors. The most critical device seems to be the 63 A rating for which the fuse performances reach exactly the withstand capabilities of contactors.

Test of current "Iq"

Likewise we have tested these "aM" fuses 500 V at the prospective current "Iq" we have selected at 50 kA, which corresponds to the maximum current achieved in most applications. Under a voltage of 380 V and at a power factor of 0.2, the results achieved are as follows:

$I^2t = 10 \times I_N^2$

$Im = 600\ (I_N)^{2/3}$

Where :

I_N = Fuse rated current

I^2t = Operating I^2t under the specified conditions

Im = Cut-off current

These values are plotted on graph Fig. 7 (see annex) together with the withstand capabilities of contactors and overload-relays (document ref. N°3). This graph shows that the protection of contactors is well ensured on all the rating range.

"aM" FUSE MELTING CURVE

One must also examine the selection of the gates of the "aM" fuse time-current characteristics.

If one observes Fig. 2, one notices that the fuses has to withstand the motor starting, i.e a first half sinusoidal wave with a peak value that can reach 25 times the rated current, or the r.m.s value 18 times the rated current, for around 15 ms (symmetrical wave), followed by the starting current, 6 times approximately the rated current for 10 seconds.

The fuse must also operate before the relay above the breaking capacity of contactor. To respect this condition, the gate 12.5 I_N within 0.5 second maximum is suitable.

Besides, in case of relay failure, the upper gate 6.3 I_N has to be maintained for 60 seconds maximum.

We thus get the gates of figure 8 which we consider satisfying for most applications.

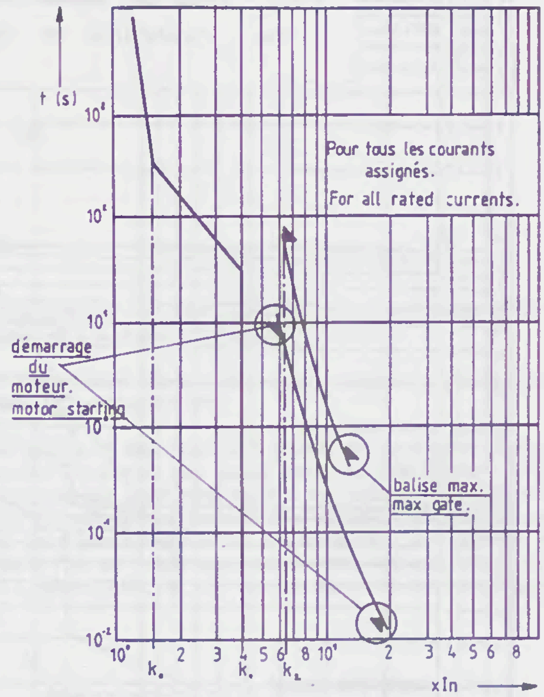


Fig.8 - Zone temps-courant "aM"
Time-current zone "aM"

CONCLUSIONS

The "aM" type fuse ensures an efficient coordination with the contactors and relays to which it is combined, which confirms the current practive. The combination rule is very simple as the fuse rated current is equal to the rated operational current of contactor.

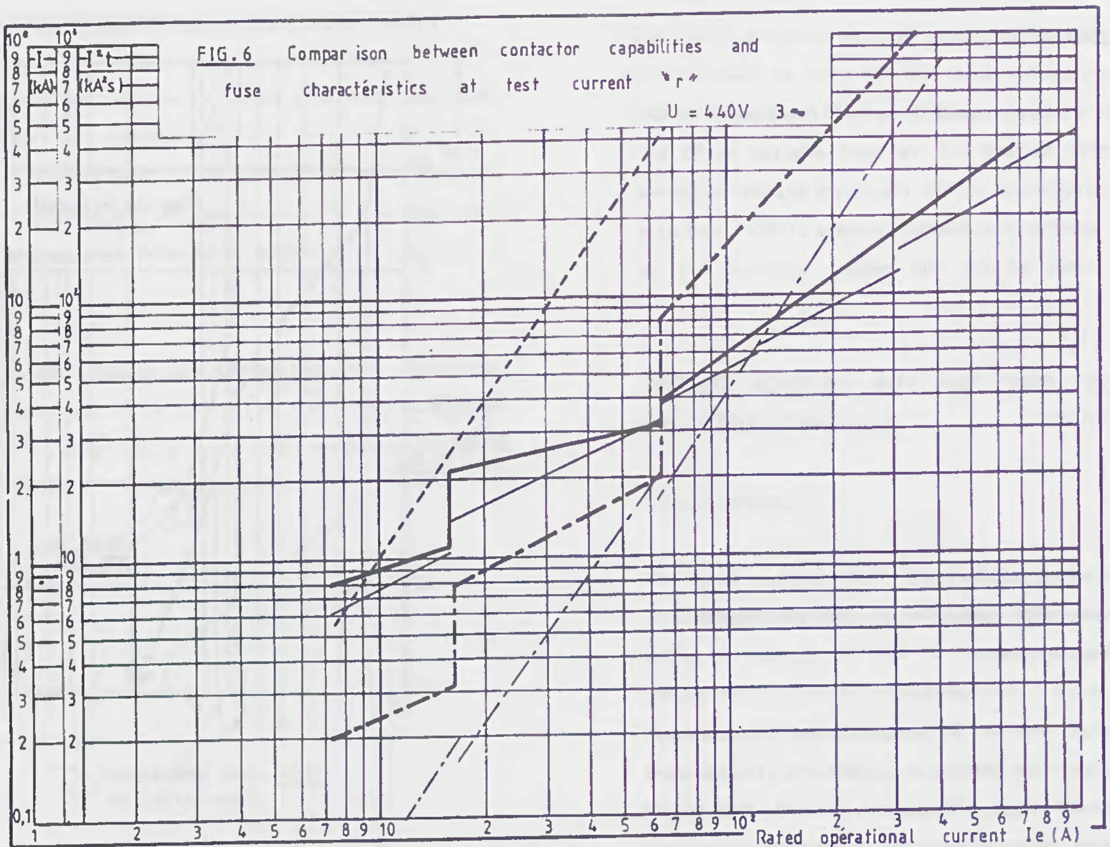
However, a modification of the 269-2 Publication of IEC is required in order to line up the test conditions of fuses with those of contactors and to take into account the actual performances of fuses that are now found on the market and that are appreciably better than these required by the current standards.

References

1/ IEC 947-4-1

2/ IEC 269-1 and 2

3/ IEC 32 B - Ad Hoc Group - Toronto Metting - French Experts document (May June 1988).



- - - - - - - - Overload-relay I²t (100 Ie²).
— - — - — Contactor : total I²t withstand.
———————— Contactor : max peak current withstand.
———————— Fuse : peak let-through current.
— — — — — Fuse : max. operating I²t.