OPERATING TIMES AT LOW SHORT-CIRCUIT CURRENTS

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ABSTRACT According to IEC 269-1 the breaking capacity of fuses is verified in the range of small over-currents, near the fusing current, and for relative high over-currents in the range of 50 times the rated current of the fuse and higher. In practice, however, short circuit currents may appear in the range of 15-20 times the rated current of the fuse. Tests have shown that the operating times in that region can be much longer than what is stated in the manufacturer's time/current characteristic for the fuse. This may become a problem when fuses are used for short-circuit protection of motor starters and the starters (contactors) are damaged because of the longer exposure to short-circuit currents.

COORDINATION WITH CONTACTORS According to IEC standard 158-1 for contactors the manufacturer shall state the maximum prospective short-circuit current and the type and characteristics of the short-circuit protective device, for instance a fuse, to be used in order to achieve a given type of protection. Two tests shall be made to verify the ability of the contactor to withstand short-circuit currents.

The first coordination test shall be made with a test current equal to the maximum prospective short-circuit current, usually 50 kA. The operating times of fuses are in this case very short and the Joule integrals, I^2t, are limited to relatively low values. Normally there are no difficulties for contactors to withstand this test.

The second coordination test is to be made with a test current, I_r, equal to 30 times the rated current of the contactor. (The rated current of the contactor is here assumed to be equal to the maximum operational current for utilization category AC-3.) One of the most important applications of contactors is motor control. Here thermal overload relays are used for overload protection. For proper coordination the overload relay shall trip and not the fuse at heavy starts, locked rotor or jam. Thus the fuse characteristics must be selected such that the current, I_c, at the cross-point, between the time/current characteristics of the relay and fuse, is greater than the actual starting current, I_{st} (see figure 1).

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As an example a 22 kW motor with the rated current 43 A has a starting current of 300 A. A recommended fuse size is 100 A and contactor size 50 A. The test current mentioned above corresponding to 30 times the rated current of the contactor is then 1500 A. Related to the 100 A fuse consequently the test current, I_r, is 15 times the rated current of the fuse (see figure 1).

When coordinating motor, overload relay, contactor and fuse as described above, the second test current 30 times the rated current of the contactor, will be in the range of 15-20 times the rated current of the fuse. In this range the operating times of fuses are in general relative long. But the current is also still so high that the contactor contacts may separate and give rise to arcing because of the current forces. If the operating times of the fuses then are too long there is a risk of heavy contact burning, flash-over between phases or to earth and damage to the contactor.

SHORT-CIRCUITS IN INDUSTRIAL PLANTS Industrial plants are generally equipped with high power transformers and assemblies of switchgear and controlgear are often located near the transformer. Thus short-circuits inside or close to the controlgear result in high short-circuit currents and the problem with fault currents in the range of 15-20 times the rated current of the fuse do not arise in this case. However there is a trend to concentrate the assemblies of switchgear and controlgear to one place even if the plant is extended over a large area. The cables from the controlgear to the motors are for that reason often very long and the short-circuit current in case of a fault on the cable at the motor side or on the motor terminals, may be relatively small (see figure 2). The probability of a fault occurring in this case is greater than for a fault inside or near the assembly. Table 1 shows the calculated short-circuit current for different motor sizes in relation to the rated current of the fuse. The calculated maximum cable length is based on a voltage drop of 15 % at the motor terminals during start.

Table 1

Motor	Cable		Fuse	Short-circuit current	
Rated power [kW]	Area [mm^2]	L_{max} [m]	I_n [A]	I_{sc} [kA]	I_{sc}/I_n
18,5	10	99	80	0,88	11
22	10	77	100	1,1	11
30	16	59	125	1,9	15
37	25	105	160	1,7	11
45	35	103	200	2,1	11
55	35	83	200	3,0	15
75	70	121	250	4,5	18
90	95	112	315	5,8	19
110	120	99	355	7,1	20
132	150	132	400	8,3	21
160	185	102	500	11,4	23

L_{max} = cable length that gives 15 % voltage drop on the motor terminals during start
I_n = rated current of the fuse
I_{sc} = short-circuit current with a cable of length L_{max} to the fault.

The coordination of contactor and fuse according to IEC 158-1 is verified by the conventional test current, I_r, which for motor application lies in the critical range of 15-20 times the rated current of the fuse. Table 1 confirm that current of that magnitude also may appear in practice.

OPERATING TIMES Tests on fuses with currents in the range of 15-20 times the rated current of the fuses have shown that the operating times can be much longer than what is stated in the manufacturer's time/current characteristic for the fuses. In figure 3 the result of four tests on gL(gI)-fuses of different manufacturers is shown. The first fuse to clear in each test has an operating time that is about 2-6 times the nominell stated operating time. The second fuse to clear in each test usually has a pronounced longer operating time mainly due to the fact that the current is decreased to 87 % of the 3-phase short-circuit current when the first fuse has interrupted one phase.

CONCLUSION The operating time of a fuse at low short-circuit currents in the range of 15-20 times the rated current of the fuse, is a critical parameter for design of contactors and for dimensioning of controlgear and cables in motor circuits. Tests have shown that the operating times in that region can be much longer than what is stated in the time/current characteristic of the fuse, a fact which is videly unknown inspite of it's great significanse. The reduction of operating times at low short-circuit currents should be made a target for future research on fuses.

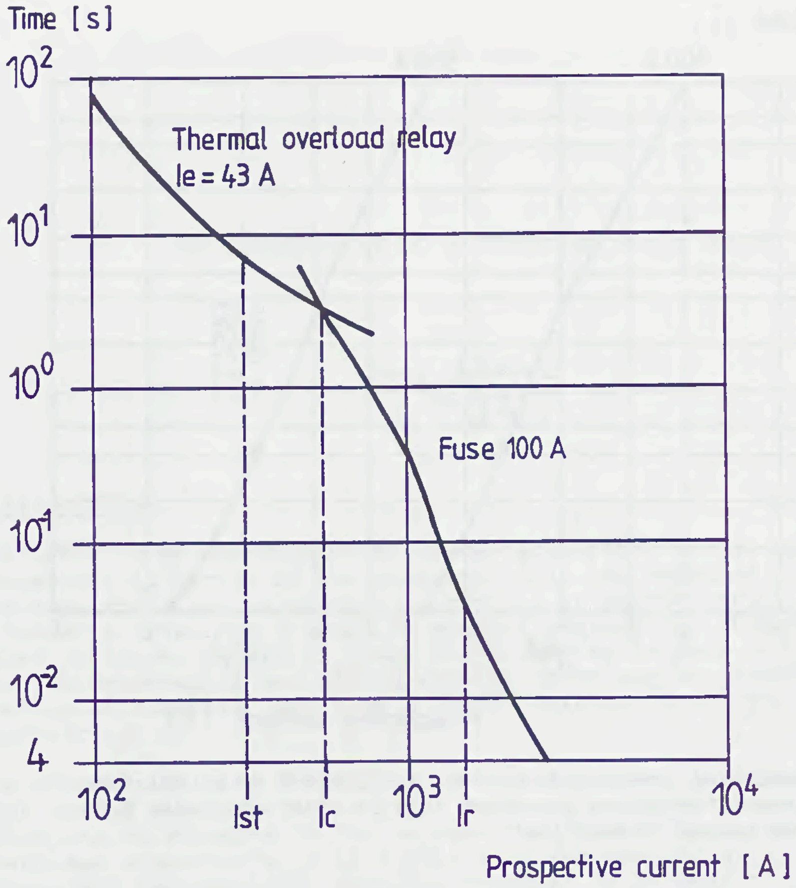

Figure 1 Time/current characteristic coordinating thermal overload relay and fuse

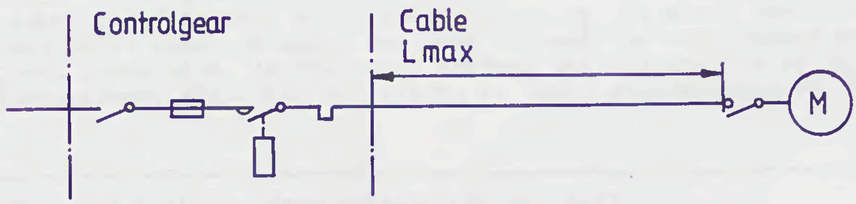

Figure 2 Coordination of controlgear and cable. L_{max} is the cable length that gives 15 % voltage drop on the motor terminals during start.

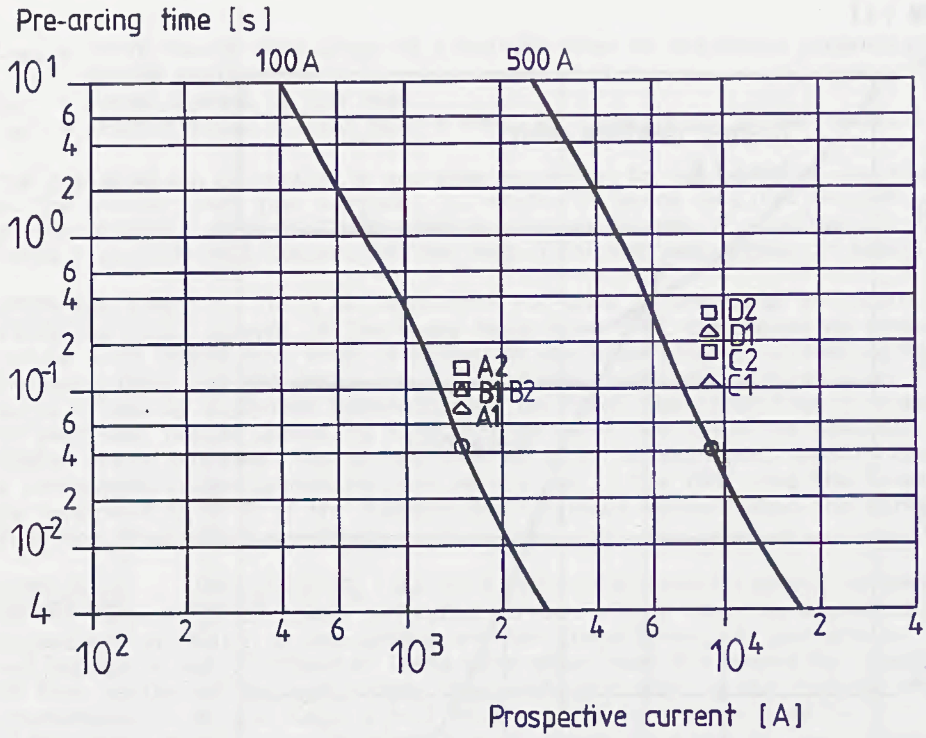

Figure 3 Operating times in four test, A,B,C and D on gL(gI)-fuses. Index 1 refers to the first fuse to clear and index 2 to the second in each test.