INFLUENCE OF LOAD CURRENT ON THE OPERATING CHARACTERISTIC OF FUSES

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Abstract*:* Aim of the paper is to determine the influence of the initial thermal conditions of the fuse element on the operating time and the let trough energy of fuses. An experimental investigation on two types of fuses has been performed starting from different thermal steady state conditions and in particular the cases of no load current and fuse rated currents are compared by evaluating pre-arcing and time-current characteristics for fuses rated 125 and 250 A. The effects of making angle for different prospective currents on operating characteristics are evaluated and final comments are given on possible influence on the selectivity of the intervention in case of fault.

I. INTRODUCTION

Operating characteristics of low voltage fuses are usually determined by laboratory tests starting with the fuse element at ambient temperature. In practice complex loading cycles can vary over a wide range [1] when the over current begins. Aim of the paper is to evaluate the influence of the initial thermal conditions of the fuse element on the operating time and let trough energy of the fuses, that are expected lower than the value obtained with a test without load current. In fact, as it was shown in [2], pre-arcing Joule integral is influenced by test current amplitude and making angle which modify the heating process of the fuse element and its behaviour. A significant influence is also expected by initial thermal conditions that means initial loading current.

To this end an experimental investigation has been performed on two different types of fuses (125 and 250 A rated currents) starting with thermal steady state conditions obtained by loading the fuse with its rated current and without current before the beginning of the short-circuit.

The test circuit has been arranged in order:

- to get a known preliminary heating (that means a initial known load current);
- to maintain initial thermal state;
- to state a short circuit condition by a suitable making angle.

It is essential to avoid absence of current trough the fuse during the transition from the rated load current to the one of fault in order to ensure repetitive test conditions, because the thermal behaviour of fuse elements quickly modifies when the current flowing changes. The case of an electrical distribution system will be analysed. Fuses usually employed in substations, with rated current of 125 and 250 A, are investigated in order to verify the effects on the operating characteristic and the influence on the selectivity of the intervention in case of fault. The power distribution system, used by AEM in Milan (Italy) and in 14 smaller towns of the surrounding area, can be split into typical radial structures which includes one transformer supplying some primary lines with secondary branches for users protected by fuses.

The test circuit is detailed in section II and the experimental results are discussed in section III. The practical consequences of the present investigation on fuse behaviour and on protection selectivity are discussed. Section IV gives final conclusions.

II. EXPERIMENTAL ANALYSIS

II.1 Test Circuit

The test circuit is represented in Fig. 1. The fuse under test is loaded by its initial load current (the rated current in our cases) until the steady state condition is reached. This is done by means of a low voltage transformer. A measure of the fuse temperature by a thermocouple placed on the fuse body verifies that the steady state condition is actually achieved. After this initial fuse heating the supply circuit is commutated from the low voltage source (less than 12 V at 50 Hz) to the test voltage (420 V at 50 Hz) by opening the contactor C_1 and immediately closing the contactor C_2.

In these conditions the fuse continues to be loaded by its rated current. The current amplitude is controlled both by the impedance Z (adjusted for the short circuit current) and by a resistor R_2 suitable to obtain the rated current of the fuse in the circuit.

After a time of about 20 seconds, sufficient to recover the thermal steady state conditions of the fuse, altered by the commutation operation, the resistor R_2 is short-circuited by an electronic device which makes the short circuit current. The making instant of the short circuit test, from which the fuse interruption behaviour depends [2], is varied at each test in order to verify the behaviour of the fuse in all closing conditions. By means of a data acquisition system the test current and the supply voltage are recorded and the main test quantities are evaluated.

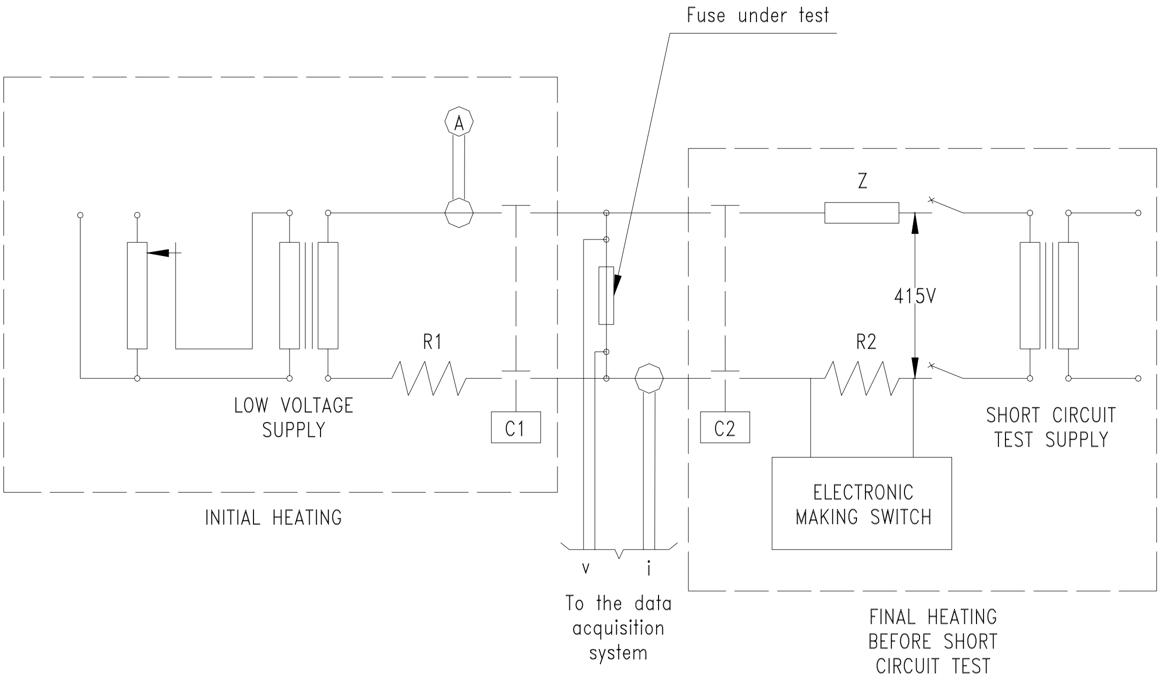
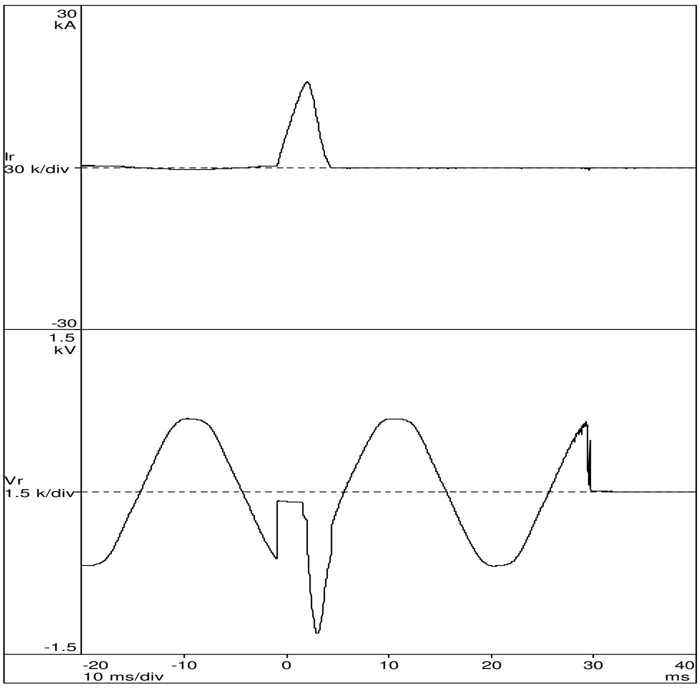
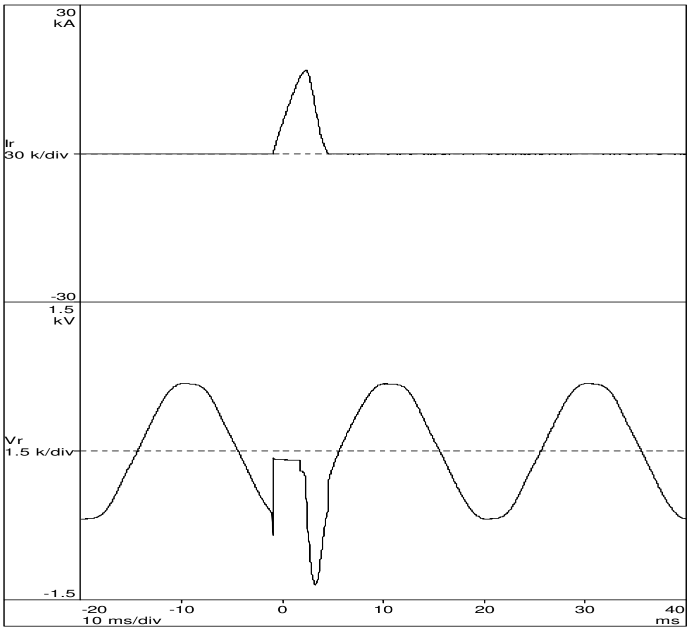


Fig. 1 Test circuit



Max peak current	15,92 kA
Prearc time	2,48 ms
Total duration	5,30 ms
I^2i prearc	193,0 kA^2s
I^2total	506,3 kA^2s

Fig. 2 Currents and voltages on a hot 250 A fuse tested at 15 kA.



Max peak current	16,94 kA
Prearc time	2,66 ms
Total duration	5,52 ms
I²i prearc	277,9 kA²s
I²total	608,2 kA²s

Fig. 3 Currents and voltages on a cold 250 A fuse tested at 15 kA.

The tests have been repeated also without the pre-heating of the fuse before the short-circuit test. In these cases the contactor C_2 is always kept closed and the resistor R_2 is excluded from the test circuit.

II.2 Test conditions

The analysis has been applied to fuse types most frequently used by AEM in the distribution network of Milan. In particular two values of rated currents are considered: 250 A and 125 A. Usually fuses having 250 A protect main low voltage distribution lines and these lines frequently supply secondary lines with 125 A fuses at their starting points. The fault current examined have been 5, 10 e 15 kA with a power factor equal to 0,2.

The initial load conditions compared are the case of rated current and the one of no load . The fuse behaviour is analysed by recording test current and voltage and evaluating pre-arcing, total Joule integrals and arc energy.

III. RESULTS

Some typical test results are reported in Fig. 2 and 3. In particular Fig. 2 shows fuse voltage and currents for the 250 A fuse tested at 15 kA with initial load current equal to the fuse rated current; approximately 1 h is needed to reach the thermal steady state.

Fig. 3 includes plots of current and voltage of a fuse tested at 15 kA when the short circuit test starts without initial load and with the fuse at ambient temperature.

The recorded voltage is the supply one.

Of course some differences are found in waveforms of currents and voltages because of the effects of initial load on the pre-arcing and total Joule integral. As well known and justified in [2] pre-arcing and total Joule integral are influenced by making angle which modifies current waveform and this effect is more evident in the cases of relatively low short circuit currents.

This phenomenon, during the pre-arcing time, seems due mainly to the thermal conduction along fuse element and fuse terminals, being very low the heat transferred to the sand for short time as those we are considering. Therefore the initial load modifies the initial thermal state of fuse elements and it causes a reduction of pre-arcing Joule integral. As a consequence of the different starting instant of the arc, also arcing and consequently total Joule integrals change.

The results are reported in the following figures 4, 5, 6, 7, 8 and 9 which report the results obtained for the two sizes of fuses with 3 values of short circuit current.

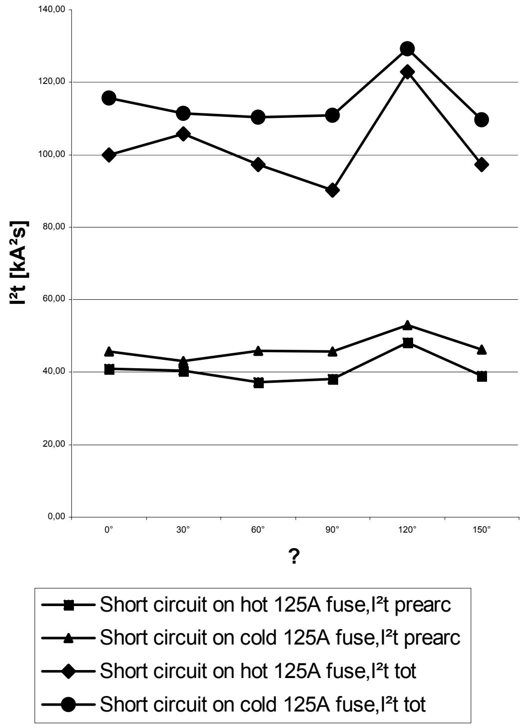


Fig. 4 Joule integrals for a 125 A fuse at 5 kA

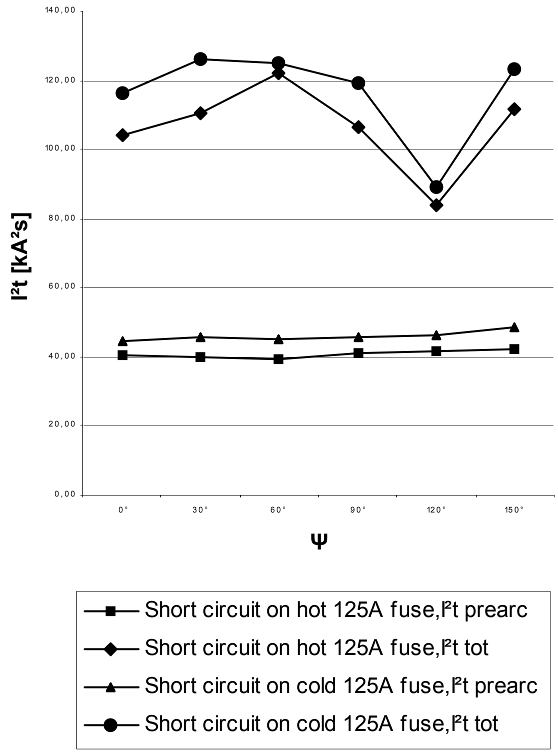


Fig. 6 Joule integrals for a 125 A fuse at 15 kA

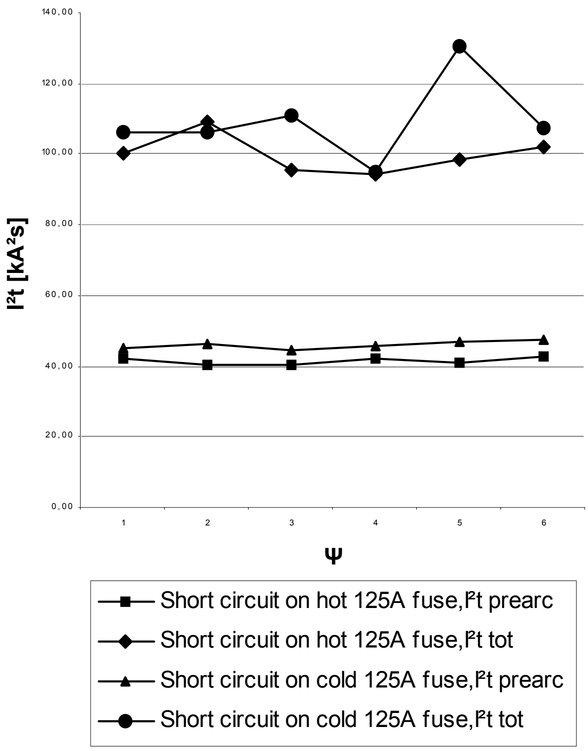


Fig. 5 Joule integrals for a 125 A fuse at 10 kA

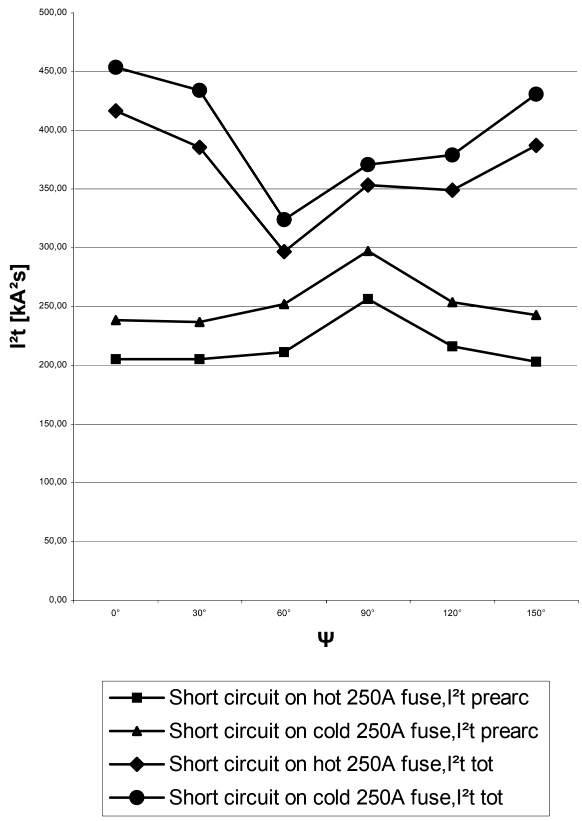


Fig. 7 Joule integrals for a 250 A fuse at 5 kA

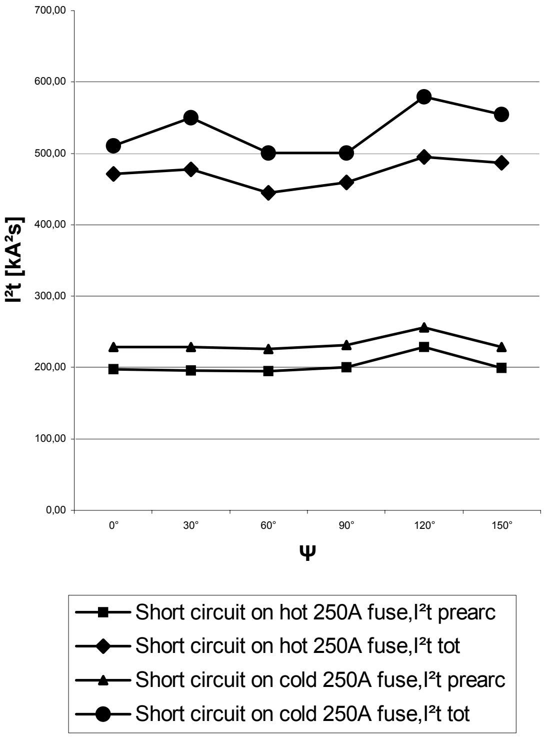


Fig. 8 Joule integrals for a 250 A fuse at 10 kA

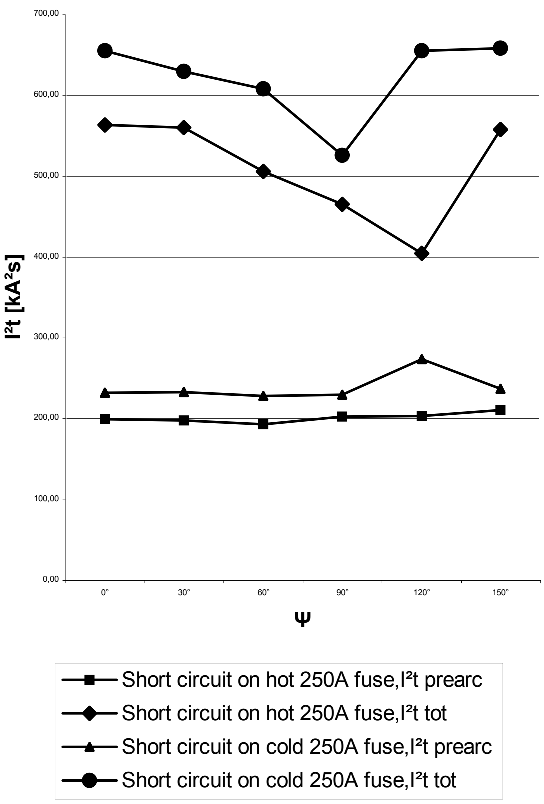


Fig. 9 Joule integrals for a 250 A fuse at 15 kA

The experimental results point out the differences on the operating characteristics due to the initial thermal state of the fuse. These differences consist in a reduction of the Joule integral with an initial load which are found in the order of 10% for all tests.

IV. CONCLUSIONS

In this paper the effects on an initial load current on the operating characteristics of fuses have been experimentally investigated. As expected the effects of an initial load give a reduction of pre-arcing and total Joule integral. However these reductions seem to be relatively weak because their amplitude (about 10%) lays within the uncertainty of an industrial product. Moreover, the effect is a reduction of specific energy let-through in the protected circuit that means a reduction of circuit thermal and mechanical stresses. In conclusion, for the limited selection of fuse analyzed, one can use the operating characteristics obtained on fuses without any initial load current and the results are approximated according a small security factor because of the actual values found when an initial condition is considered.

REFERENCES

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[3] IEC Standard 60269-1 (1998-12) "*Low voltage fuses – Part 1: General requirements*".

[4] IEC Standard 60909 (1992-09) "*Short-circuit current calculations in three-phase ac systems*".