OPTIMISATION OF H.V. FUSE-LINK CONTACTOR COMBINATIONS BY STUDY OF THE EFFECTS OF CIRCUIT CONDITIONS AND FUSE-LINK MANUFACTURING TOLERANCES ON TIME-CURRENT CURVES FOR TIMES LESS THAN 0.1 SECONDS.

A J CRANSHAW

ABSTRACT

Industry has seen a significant change from the use of H.V. circuit breakers to fuse-link/ contactor combinations. The inherent advantages in the use of fuse-links for short circuit protection can be fully exploited in minimising the cost of the total installation, due to reduction in maximum current and energy. To give maximum economic benefit, the contactor capability must be matched to the highest possible fuse-link rating. This requires a better understanding of the way in which circuit conditions and manufacturing tolerances affect nominal time/current curves of fuse-links.

A computer programme has been used to predict the effect of power factor, point on wave, and manufacturing tolerances on the nominal time/current curve of a particular high voltage fuse-link, for operating times less than .1 seconds. The results allow certain general comments to be made, and are also used to examine a particular fuse-link-vacuum switch combination.

GEC INSTALLATION EQUIPMENT LTD
EAST LANCASHIRE ROAD,
LIVERPOOL L10 5HB
ENGLAND.

OPTIMISATION OF H.V. FUSE-LINK CONTACTOR COMBINATIONS BY STUDY OF THE EFFECTS OF CIRCUIT CONDITIONS AND FUSE-LINK MANUFACTURING TOLERANCES ON TIME-CURRENT CURVES FOR TIMES LESS THAN 0.1 SECONDS.

INTRODUCTION

This investigation arose from a desire to show that a particular 3.6kV 250A fuse-link could be satisfactorily used in conjunction with a vacuum switch with an interrupting rating of 5.5kA to BS.5311 Duties 4 and 5. The latched opening time of the vacuum switch is 25mS and the time current point of 5.5kA/25mS is close to the nominal time/current curve of the 250A fuse-link. Whilst IEC.282-1 allows a tolerance of ±20% on the current ordinate of the curve most manufacturers claim a maximum tolerance of ±10% for currents giving operating times down to 0.1 seconds. Below this level the effects of current asymmetry may be expected to increase the tolerance, but even the use of +10% would result in the proposed fuse-link/vacuum switch combination being declared unsatisfactory. It was thus decided to conduct a study on the variations in time/current characteristics which would be brought about both by the effects of manufacturing tolerances and current asymmetry for operating times less than 0.1 seconds. Virtual time/current curves have been used to take account of the latter but their accuracy is in some doubt and virtual time cannot be related to real time situations.

METHOD OF INVESTIGATION

A computer programme for fuse-link performance prediction was used to obtain actual time/current points for a 250A fuse-link. Circuit conditions were 3.3kV applied voltage, 50 HZ, and differing values of prospective current, power factor and making angle. Manufacturing tolerances for both element and element material were also taken into account to provide the longest and shortest operating times for given circuit conditions. The computer predicted pre-arcing times are based upon evaluating fuse-link element temperature rise from a nominal 20°C ambient. The pre-arcing time is that required to reach 940°C rise for the silver elements in use in the particular fuse-link. For each combination of prospective current and power factor the range of making angle from O° to 180° was covered. The computer predicted time/current points were plotted against the nominal time/current curve as published.

RESULTS

Figures 1 to 6 show the computer predicted time/current points for power factors of .15, .6 and .99 for maximum and minimum manufacturing tolerances. It is clear that at .15 power factor the time zones of operation at a given current are discontinuous when pre-arcing extends beyond 17 milliseconds. The phenomena reduces as power factor increases and is not evident at all at .99 power factor. The individual time zones have been highlighted by joining together the appropriate points with a vertical line. The reasons for such discontinuities can be better understood by examination of a typical temperature-time graph and the associated instantaneous current-time graph as shown in Figures 7 and 8. These are for a current of 3.7kA with making angles of 9° and 10° respectively. For the latter, when the melting temperature is missed at the first peak of an asyymetric current waveform it is a further 50 milliseconds before melting point is reached. The condition is of course dependent upon element temperature at onset of fault current.

-

Although the position of the time step in relation to making angle will alter with 'pre-conditions' the phenomena will still be evident.

In considering computer predicted time/current point tolerances based upon a current variation from the curve as drawn, and for times between 20 milliseconds and 100 milliseconds, the following is arrived at:-

POWER FACTOR	MAXIMUM TOLERANCE	MINIMUM TOLERANCE
.15	+6%	-21%
.60	+6%	-12½%
.99	+10%	-12½%

TABLE 1.

Since time/current curves are usually determined from Laboratory tests carried out at low voltage and high power factor the computer predicted points for .99 power factor are in close agreement with the generally accept ±10% tolerance. This gives credance to the accuracy of both the computer programme used and the time/current curve as published. The computer predicted results then indicate that as power factor reduces the operating time of the fuse-link becomes faster. However a positive tolerance on the curve is still evident at .15 power factor but then only 6%.

SPECIFIC COMMENT ON THE PARTICULAR FUSE-LINK - VACUUM SWITCH COMBINATION.

Further examination of Figure 1 indicates a positive gap in the pre-arcing time, roughly centred around 20 milliseconds and being at its minimum at 5.5kA with a gap from 17 milliseconds up to 25 milliseconds. Hence if specific computer predicted pre-arcing times are examined for 5.5kA a different picture energes to that of Table 1. This can be seen in Figure 9, which shows that the pre-arcing time of 25 milliseconds is only exceeded where the fuse-link is manufactured to worst case conditions and the power factor is .6 or higher. At .6 power factor the maximum time is 26 milliseconds and at .99 power factor the maximum time is 31 milliseconds.

Thus for the particular combination of fuse-link and vacuum switch it cannot be said that the fuse-link will always operate with a pre-arcing time of less than the required 25 milliseconds under all conditions. However for practical purposes the combination could be deemed acceptable.

Without the use of a computer study, and a lesser understanding of the way tolerances on time/current characteristics vary with manufacturing tolerances and circuit parameters, it would be necessary to adopt a more conservative approach to this type of co-ordination problem. Such action would result in either the use of a more expensive vacuum switch with higher breaking capability, or downrating of the equipment by the use of a fuse-link of lower current rating.

REFERENCES

1. A suite of interactive programs for fuse design and development.
R. Wilkins, S Wade, J. S. Floyd. INT CONF. on Electric fuses - Trondheim 1984.

2. Operating times at low short circuit currents - Sven Lindgren
INT. CONF. on Electric fuses - Trondheim 1984.

COMPUTER PREDICTED TIME-CURRENT POINTS – 3·6KV; 250A FUSELINK

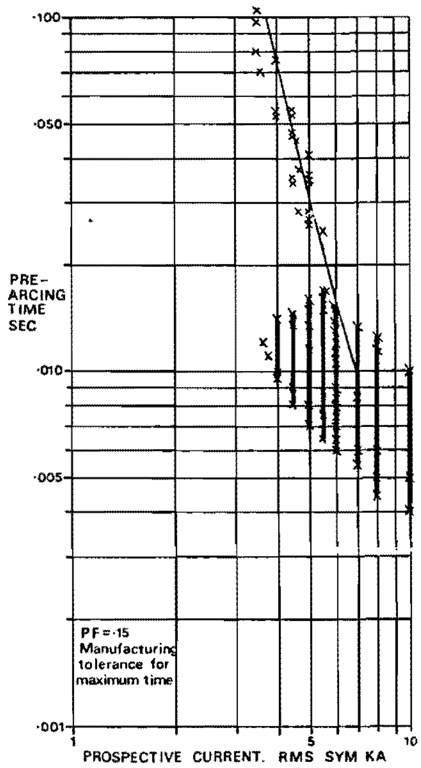


FIGURE 1

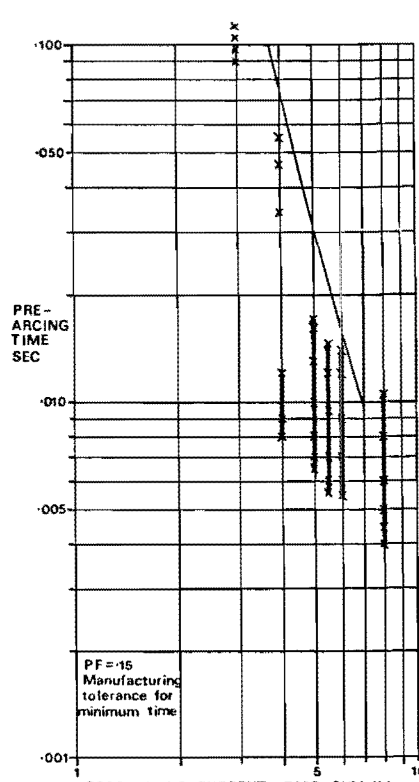


FIGURE 2

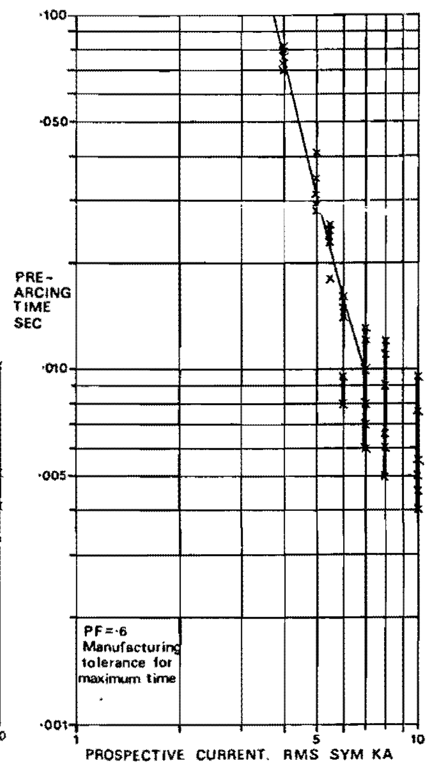


FIGURE 3

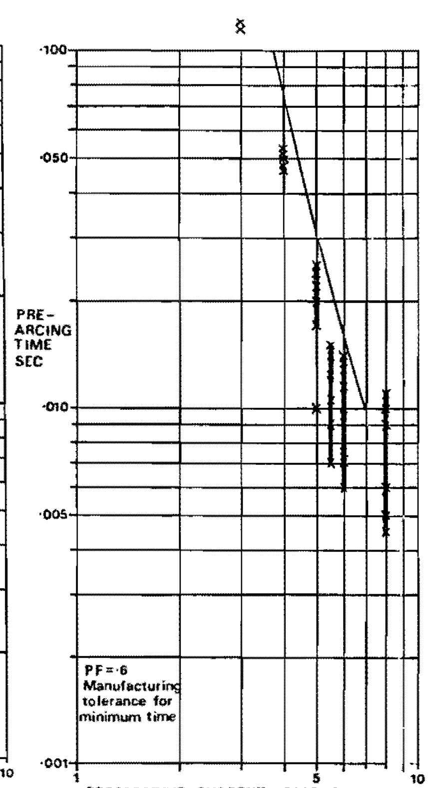


FIGURE 4

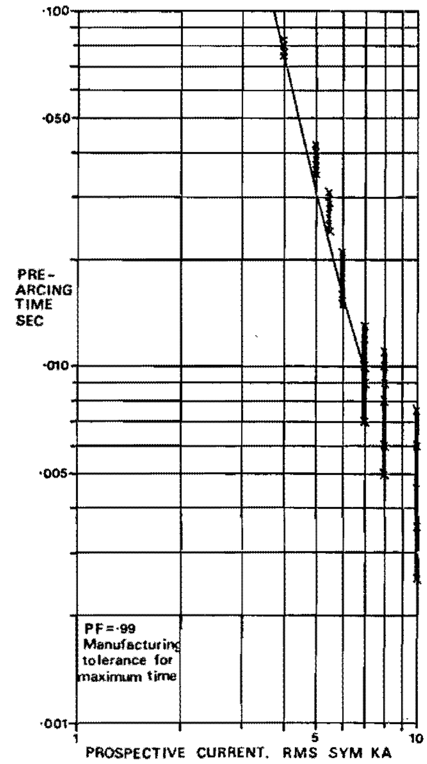


FIGURE 5

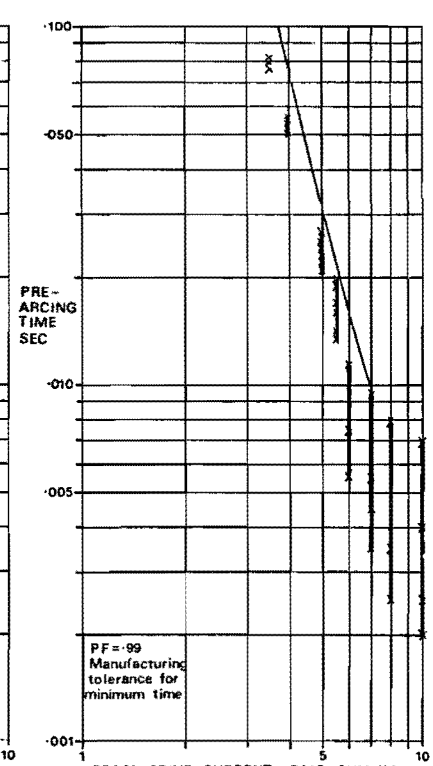


FIGURE 6

CURRENT/TIME AND TEMPERATURE/TIME GRAPHS
3.6kV/250A FUSE-LINK 3.7kA RMS SYM./.15 P.F.

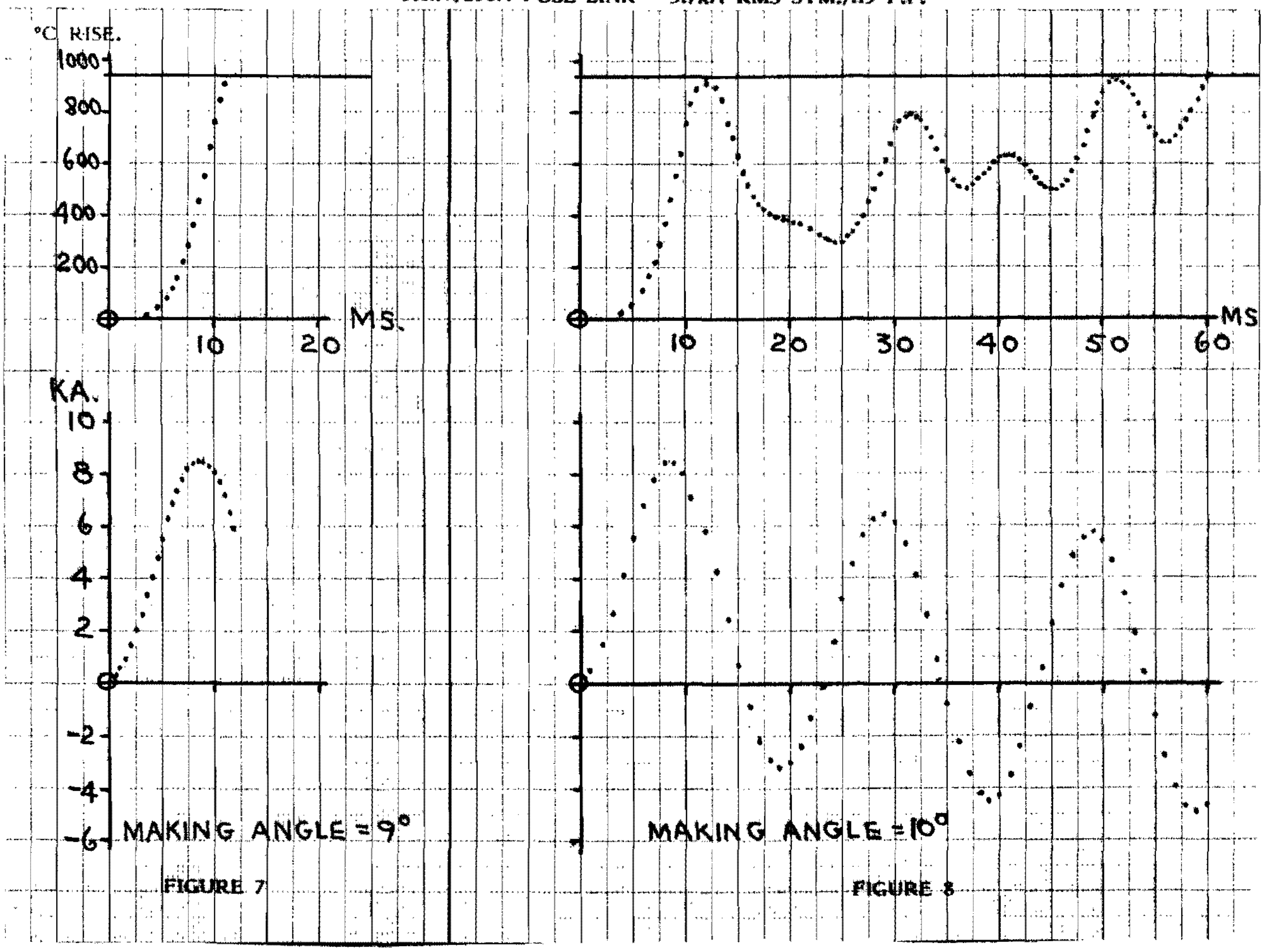
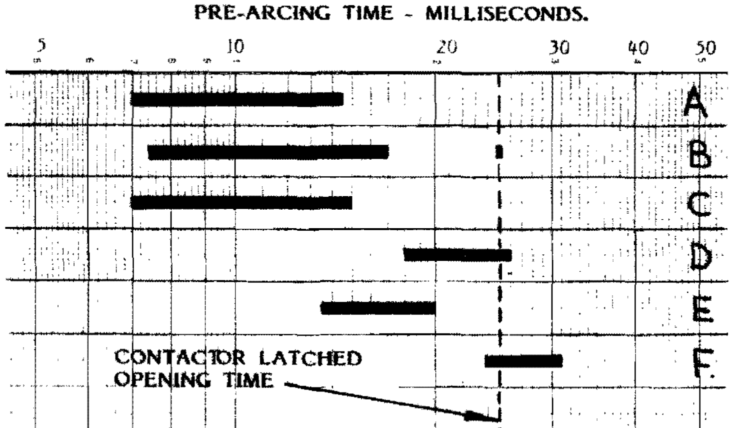


FIGURE 7 FIGURE 8

COMPUTER PREDICTED OPERATING BANDS AT 5.5kA.

PRE-ARCING TIME - MILLISECONDS.



	POWER FACTOR	MANUFACTURING TOLERANCES
A	.15	MINIMUM
B	.15	MAXIMUM
C	.60	MINIMUM
D	.60	MAXIMUM
E	.99	MINIMUM
F	.99	MAXIMUM

FIGURE 9.