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APPENDIX G

MODELLING OF FUSE CHARACTERISTICS

A specific model to represent the fuse time-current characteristics was employed. The polynomial function used for relays proved to be inadequate for the application, mainly because of the wide variety of curve shapes found in fuses. Also, in the representation of fuse performance, both the pre-arcing times and the operation (pre-arcing + arcing) times has to be considered.

Furthermore, the model must be capable of providing two degrees of approximation. For studies to be done at the preliminary design stage of a project, for instance, time-current zone representation can be adequate. In this case the exact parameters of the system are not known, a fuse of any make may be specified. A 'time-current zone' contains all the time-current characteristics for a give rating: the upper limit corresponds to the highest operating time, and the lower to the minimum pre-arcing time.

On the other hand, the analysis of an existing system or a study at its final stage, when the exact specification are known the more accurate representation of on particular manufacturer's fuse may be required.

The model implemented is general, and entirely based a data normally supplied by the manufacturers. Their published information provide the pre-arcing time-current characteristics and the pre - arcing and operating (or total I2T values, and these have been used to determine the required model. The above characteristic gives the virtual pre-arcing time as a function of the prospective symmetrical current under specified conditions of operation. The virtual time is the I2T integral divided by the square of the rms prospective current. Usually standards allow a maximum deviation of 10% current, from the published curves.

Regarding the I2T values, standards require the manufacturers to state the minimum recorded value for the pre-arcing I2T, whilst for the operating I2T the maximum must be given.

The model represents the pre-arcing time- current characteristic using up to three lines (on log-log scales as shown in figure G.1 for TCC1. The coordinates of a number of points on this curve must be entered, conveniently grouped in either 1, 2 or 3 sets. From these data the coefficients for the corresponding lines are calculated using a least squares routine. Note in this figure that
The validity of line 'a' is limited to currents higher than the minimum fusing current (MFC).

The coefficients Ao and A1 calculated for line 'a', displayed on fuses 4 together with those for lines 'b' and 'c' correspond to the equation

log(T) = A0 + A1 log(I)..(G.1)

Where:

T = pre-arcing time, in sec., and
I = current expressed in p.u. based on the rating of the 'reference fuse'; (REF - AMPs in fuses1).

The model obtained for curve TCC1 (corresponding to a 'reference fuse rating') can be extrapolated to represent any other similar curve such as TCC2. This curve may be the upper limit for a time-current zone, or the pre-arcing TCC for another rating. This extrapolation is achieved by specifying, for example, the currents for p1 and p3 for a given t1. Then, the ratio between these two currents can be used to calculate any current on TCC2 from the corresponding value on TCC1, for the same pre-arcing time. On log-log scales this extrapolation is reflected as the horizontal displacement of TCC1 a distance P1-P3 to represent TCC2.

However, if another set of currents for a time T2 is available, then a uniform convergence rate determined from T1, T2 and the current for P1, P3, P2 and P4 is assumed, only for the times greater than T1. By the appropriate choice of T1 and T2 the user can obtain a better representation of a family of fuse characteristics. This representation can provide the pre-arcing time for any given fault current.

The operating time (i.e., pre-arcing + arcing) can be determined in two ways. If a 'time-current zone ' representation is being used, the operating time is taken directly from the upper curve that limits the zone. On the other hand, if a particular fuse is being represented, an arcing time is obtained from pre-arcing and operating I2T given by the manufacturer. It is assumed that the difference between these two values (i.e., the árcing energy') is constant for the different fault currents. Hence, the arcing time is estimated as the arcing i2t divided by the square of the current, and it is finally added to the pre-arcing time to obtain the operating time. This result is likely to be pessimistic, since it is based on the worst possible arcing I2T. However, this adds-up to the security margins required for protection coordination.

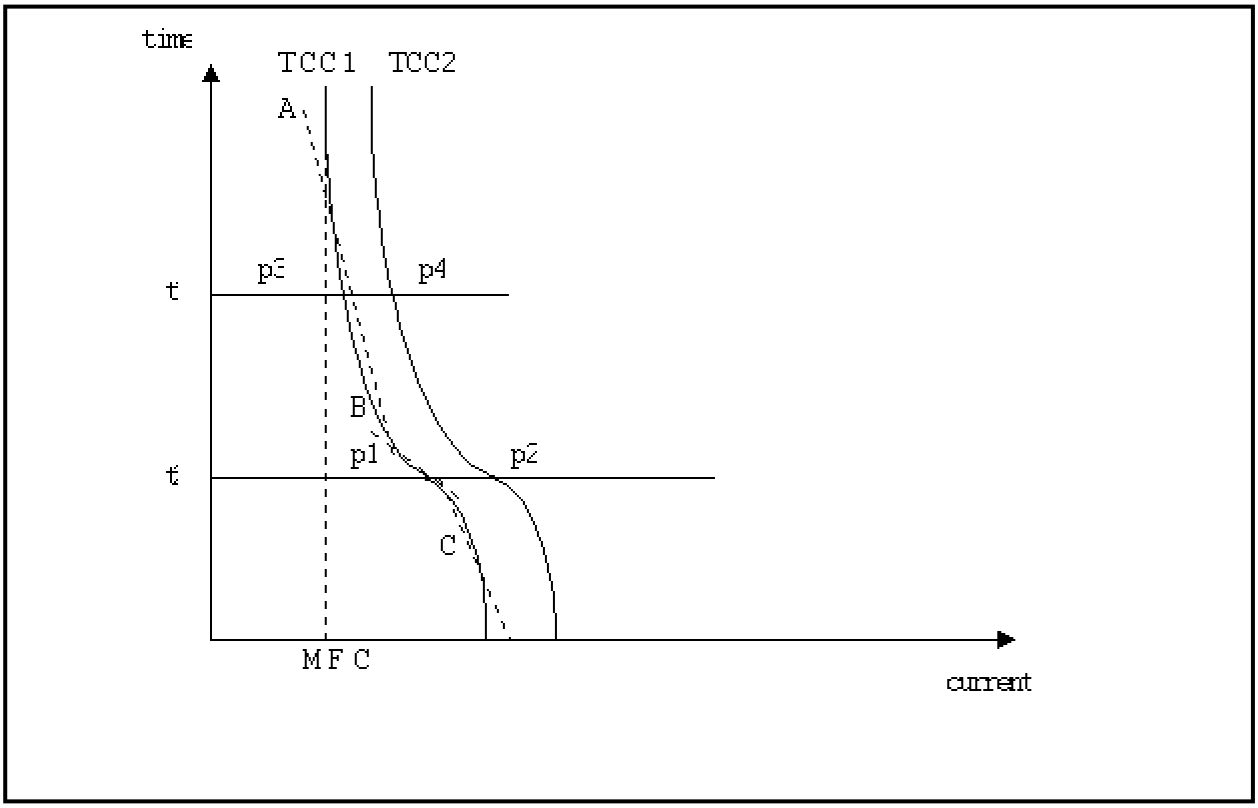

Figure G.1