D.C. circuit protection –a fuse application of growing importance

Fuses are universal protective devices as far as a.c. and d.c. voltage applications are concerned. The ratings are different however, and published a.c. ratings cannot easily be converted to d.c. ratings. Some basic information is therefore required on the principle of fuse operation and has to be born in mind when using fuses in d.c. circuits. Published fuse characteristics and performance data generally concentrate in a.c. 50 Hz or 60 Hz values, representing the public and industrial power supply networks, i.e. the bulk of power fuse applications. However, d.c. performance of fuses are highly depending on the time constant of the circuit to be protected and may deviate significantly from a.c. values. While d.c. fuses have been widely used in low energy, extra low voltage circuits, e.g. electronics and automotive applications, d.c. power applications could be found in some niche markets only, e.g. traction engines, electric magnets and battery powered vehicles such as forklift trucks. In addition to conventional d.c. power applications, a number of new applications have developed in the meantime, requiring a more wide spread knowledge on d.c. behaviour of fuses. Among the new and rapidly growing application fields are. -

- Uninterruptible power supplies
- Base stations for mobile telecommunication
- Solar and fuel cell power generation
- Electric powered cars

The majority of new applications is based on sources of limited short-circuit currents compared with conventional d.c. power taken from rectified a.c. networks, which makes fuse selection more specific.

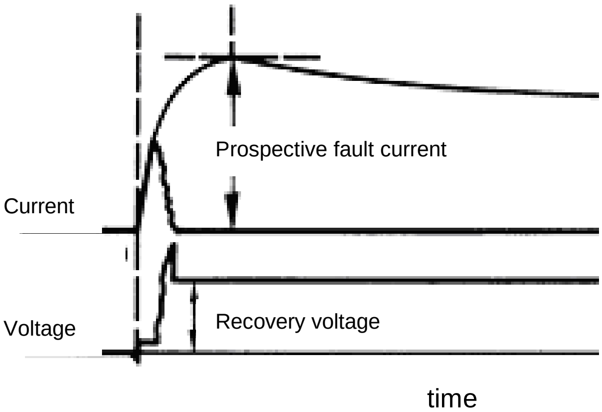

Fig. 1 – Current-limiting d.c. operation

1 D.C. breaking process

Fuses are able to build up a high arcing voltage surpassing the recovery voltage and thus forcing the current to zero (fig. 1). They are therefore generally suited for both a.c. and d.c. current interruption. Under high fault conditions, i.e. in the range of current-limiting operation, the physical process of a.c. and d.c. current interruption is very much alike. Under overload conditions, i.e. non-current-limiting operation the d.c. and a.c. breaking processes are completely different. While periodic current zero (i.e. zero stored magnetic energy) eases arc extinction in a.c. circuits, in d.c. circuits the fuse has to absorb the full stored magnetic energy during arcing time (fig. 2). Consequently, the d.c. breaking capacity of fuses is generally dependant on the stored magnetic energy, i.e. time constant* of the circuit and, as a rule, is below the a.c. breaking capacity.

Low-voltage power fuses (fuses mainly for industrial applications) acc. to IEC 60269-2 have minimum breaking capacities of a.c. 50 kA and d.c. 25 kA respectively. The d.c. rating is based on a conventional time constant of 15 ms and fits most industrial control and load circuits. The breaking capacity of fuses is de-rated in circuits having greater time constants, e.g. large d.c. motors and field supplies, and increased in circuits having smaller time constants, e.g. battery powered installations.

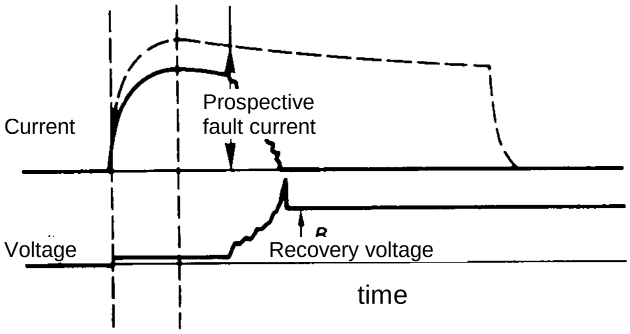

Fig. 2 – Non-current-limiting d.c. operation

<u>The d.c. breaking capacity of a fuse-link should therefore always be seen in conjunction with the associated time constant.</u>

2 Rated d.c. voltage

Fuse-holders marked with a.c. ratings may also be used for d.c. Fuse-links shall be marked separately for a.c. and d.c. If no d.c. ratings are marked on a fuse-link, these ratings may be received from the fuse manufacturer. Though the application range of IEC 60269 comprises fuses rated up to a.c. 1000 V and up to d.c. 1500 V, d.c. ratings of fuse-links are usually lower than their a.c. ratings. This is because of the greater arc energy to be absorbed during breaking process. For a.c. and d.c., the standard rated voltages are different and there is no strict mathematical relationship between. A fuse-link rated a.c. 500 V may be rated d.c. 250 V or d.c. 440 V. As a rule of thumb, 50 % of the a.c. voltage rating may be assumed for the d.c. rating of a general-purpose fuse-link. Reliable d.c. performance data can only be determined by testing and fuse manufacturers should therefore be asked for advice before using standard fuses for d.c. circuit protection.

3 Time-current characteristics

Published virtual time-current characteristics of fuse-links represent r.m.s. values of the melting current, assuming un-delayed appearance of this current. They can be used for d.c. under steady state conditions, i.e. for melting times of about 20 time constants and greater (fig. 3). Under transient (i.e. short-circuit) conditions, the melting time-current characteristic is no intrinsic property of the fuse but dependent on the rise-time of the current, i.e. on the time constant of the faulted circuit. The d.c. melting time-current characteristic in the time range before steady state is reached can be derived from the published characteristics for a specific circuit time constant T as follows.-

- Take the (virtual) melting-time for a specific current (r.m.s. value) from published characteristic.
- Determine the number n of time constants within this melting-time.
- Read conversion factor K = f(n) from r.m.s. curve in fig. 3.
- Divide the r.m.s. value by K to get the corresponding d.c. current value.

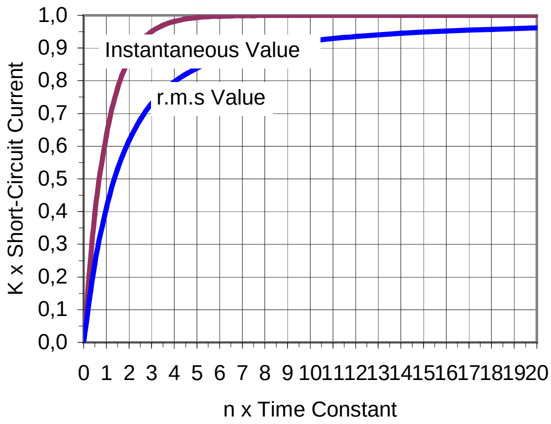

Fig. 3 – Instantaneous d.c. current and r.m.s. values

The results of this procedure, plotted in fig. 4 for time constants of 10 ms and 50 ms illustrate the effect of circuit parameters on the melting time of fuses in d.c. circuits. Different characteristics will be achieved for each circuit time constant.

As this procedure is quite complicated and time consuming, it is recommended for the user of fuses to ask the manufacturers for advice. Competent advice will be given by the manufacturers organized in Pro Fuse International.

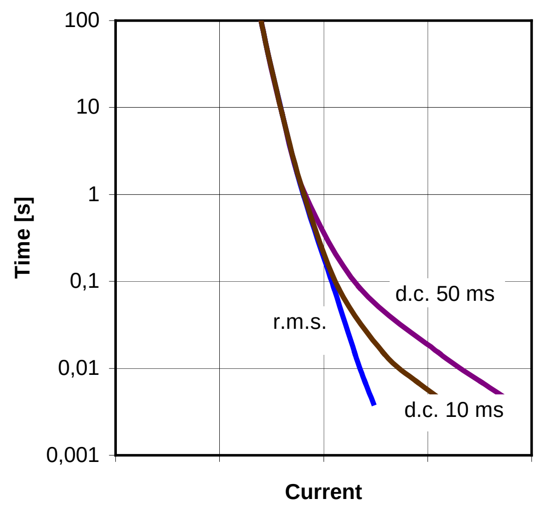

Fig. 4 – D.C. characteristics versus r.m.s. values

* Note – The time constant T is the inductance L divided by the resistance R of a d.c. circuit: T = L / R and is an important d.c. circuit parameter (corresponding to the power factor of a.c. circuits), that dominates fuse operation. It represents the speed of current rise in a d.c. curcuit as well as the stored magnetic energy at fuse operation.