



THE USE OF HRC FUSES IN PARALLEL

by: **P.G. Nicholls**
Engineering Manager
IPD Industrial Products

INTRODUCTION

Occasionally, for some low voltage and high voltage applications, it is necessary for two or more fuses to be connected in parallel in each phase of a circuit, usually for the purpose of obtaining sufficient high current rating. It has been the practice for many years to use fuses in parallel without the need for formal testing of such combinations, provided that:

- The paralleled fuses are of the same type and rating
- The individual fuse has been subjected to satisfactory short circuit tests

As higher current rating fuses contain a number of parallel elements (up to 20 in fuses of modern designs), the use of parallel fuses only extends the principle of parallel elements. This article explains various aspects of parallel arrangement of fuses, and shows how technical data for such arrangements can be derived from the data available on single fuses.

MAXIMUM INTERRUPTING CURRENT

In general, our fuses have a substantially flat I^2t prospective current characteristic. Therefore the effect of paralleling fuses is to increase the maximum short circuit capability because fuse performance is dependent on the current density of the elements in concurrent operation. Conversely, for a given prospective short circuit current, the duty on parallel fuses is eased, as the current in each fuse is inversely proportional to the number in parallel.

MAXIMUM ARC ENERGY CONDITION

Single fuses are tested to withstand their maximum arc energy condition, which usually occurs at a level significantly less than maximum interrupting current. For fuses in parallel, the current required for this condition increases directly in proportion to the number of fuses. If, for whatever reason, unequal sharing of this current occurs then the current in each individual fuse moves away from the maximum arc energy condition, and the duty on each fuse is eased.

ARC VOLTAGE

The arc voltage can be considered independent of the number of fuses in parallel, and is that arc voltage associated with a single fuse.

MOUNTING ARRANGEMENT AND RATED CURRENT

For optimum thermal performance, the mounting arrangement needs due consideration (bolted tag fuses offer more certain connection than ferrule types). An ideal parallel arrangement will give equal current sharing, but even if completely balanced paths are not achieved, a small degree of self-compensation will occur.

A full thermal test on the equipment in its intended environment is ideal but usually impractical. Derating is necessary because two fuses in close proximity radiate heat less effectively than single fuses. As a general rule, IPD recommends a minimum reduction in rated current of 10% for 2 fuses in parallel (20% for 3 or 4 fuses in parallel) and the combination assigned a rated current of nearest preferred number from R10 or R20 given in AS2752; for example 2 X 800A fuses in parallel = 2 X 800A X 0.9 = 1440A (= 1400A nearest preferred number).

TIME/CURRENT CHARACTERISTICS

On the basis that equal current sharing occurs between fuses in parallel, the time/ current characteristics can be determined by either of the two following methods:

- (1) Applying a multiplier to the prospective current axis of the published time/ current curve for the single fuse, equal to the ratio of the parallel fuse arrangement assigned rated current (refer above) divided by the single fuse rated current. Corresponding pre-arcing times for the parallel fuse arrangement are then represented by the single fuse curve. This is illustrated by using the above 2 X 800A parallel fuse example, and for say 3500A load current, then:

$$\text{Multiplier for 2 X 800A parallel fuses} = 1400 \div 800 = 1.75$$

$$\text{Equivalent current for each fuse} = 3500 \div 1.75 = 2000\text{A}$$

$$\text{Therefore pre-arcing time for parallel arrangement} = 650 \text{ sec.}$$

By comparison, for 800A single fuse with 3500A load current, pre-arcing time is 60 sec.

- (2) Alternatively, another time/current curve is plotted parallel to the single fuse published time/current curve, by applying the same multiplier as (1) above to various points on the single fuse curve. The pre-arcing time and prospective current axis remain unchanged. For example, using the same 2 X 800A parallel fuses, then:

Pre-arcing time on published 800A T/C curve	Corresponding current for 800A fuse	Corresponding current for 2 X 800A fuses
10000 sec.	1400A	2450A (say 2500A)
1000 sec.	1800A	3150A (say 3200A)
1000 sec.	3100A	5425A (say 5400A)
10 sec.	5500A	9625A (say 9600A)
1.0 sec.	10000A	17500A (say 18000A)
0.1 sec.	18000A	31500A (say 32000A)
0.01 sec.	29000A	50750A (say 51000A)

PRE-ARCING AND TOTAL OPERATING I²t VALUES

In general, for fuses that have a substantially flat I²t/prospective current characteristic, the minimum pre-arcing I²t and the maximum total operating I²t are proportional to the square of the number of fuses in parallel. For the same example of 2 X 800A parallel fuses, I²t values are:

800A single fuse:

- Published pre-arcing I²t = 4400 X 10³ A² sec.
- Published total I²t (at 415V) = 9600 X 10³ A² sec.

2 X 800A parallel fuses:

- Pre-arcing I²t = 2² X 4400 X 10³ = 17600 X 10³ A² sec.
- Total I²t (at 415V) = 2² X 9600 X 10³ = 38400 X 10³ A² sec.

CUT-OFF CURRENT

The cut-off current for two or more parallel fuses is determined by the following method:

- The short circuit prospective rms current I_F is divided by number of single fuses in parallel N , giving I_F/N .
- For this value of I_F/N , the cut-off current peak for the single fuse is found from the published cut-off current characteristic.
- This value of cut-off current peak is multiplied by the number of single fuses in parallel N , giving the cut-off current peak for the parallel fuses.

As an example, for 2 X 800 parallel fuses and 50kA rms prospective current, the cut-off current peak is:

Fault current per fuse = $I_F/N = 50\text{kA}/2 = 25\text{kA rms}$

For 800A single fuse at 25kA rms, published $I_{CO} = 54\text{kA peak}$

Therefore 2 X 800A parallel fuses at 50kA, $I_{CO} = 2 \times 54\text{kA} = 108\text{kA peak}$

By comparison, for the 800A single fuse at 50kA, the published I_{CO} is 64kA. Also, the threshold for exhibiting cut-off for the 800A single fuse is 24kA rms prospective, compared to 48kA rms prospective for 2 X 800A parallel fuses.

CONCLUSION

The foregoing information is based on known principles applicable to the paralleling of fuses, and the examples given are relevant to GE Redspot type 'T' 660 volt HRC fuses.