FUSES IN SERIES

1. VOLTAGE RATING OF 2 (OR MORE) FUSES IN SERIES

In many applications two fuses in series are involved when a fault occurs. But they do not always share perfectly the fault circuit voltage. Perfect sharing of the voltage depends on the circuit and on the magnitude of the fault current.

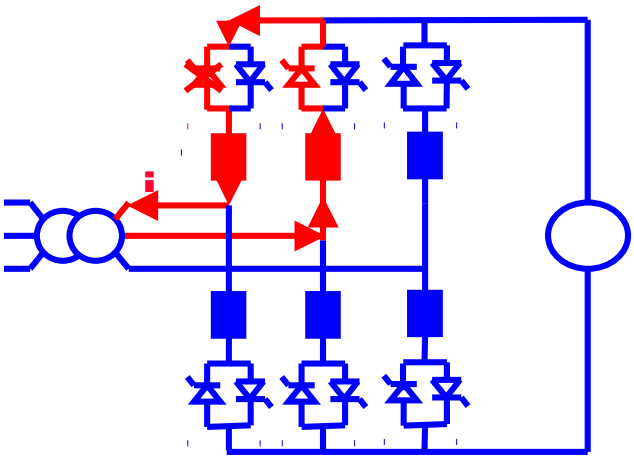

Figure 1 : Internal fault inside a 3 phases bridge

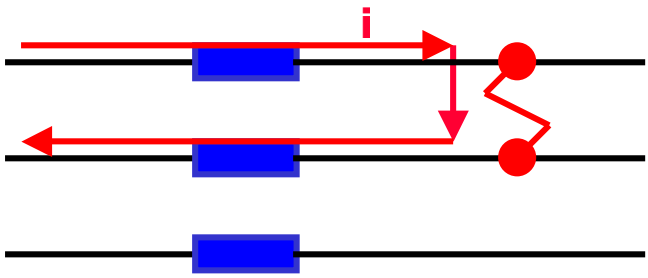

Figure 2 : Line to line fault in a 3 phases feeder

When the fuse needs more than 10 milliseconds to melt there are two possibilities:

a) only one fuse melts (because the prearc time is long): this fuse will see the full voltage of the circuit and must be rated accordingly.

b) one fuse melts several milliseconds before the second one: since the arc duration inside the fuse is typically 5 millisecondes, the fuse that melts first will get most of the interruption energy and may explode or may let go out ionized gases.

Conclusion: the maximum operating voltage of each fuse should be equal to or higher than the maximum circuit voltage.

2. CURRENT RATING

When two fuses are in series the current rating of the assembly is simply the current rating of each fuse. However if two fuses are purposely mounted in series (in order to reduce the I^2t) a derating is may be necessary when there is a very short copper bar between the fuses as shown in figure 3.
The corrective coefficient will depend on the fuse type: it is the C1 coefficient with a special value .

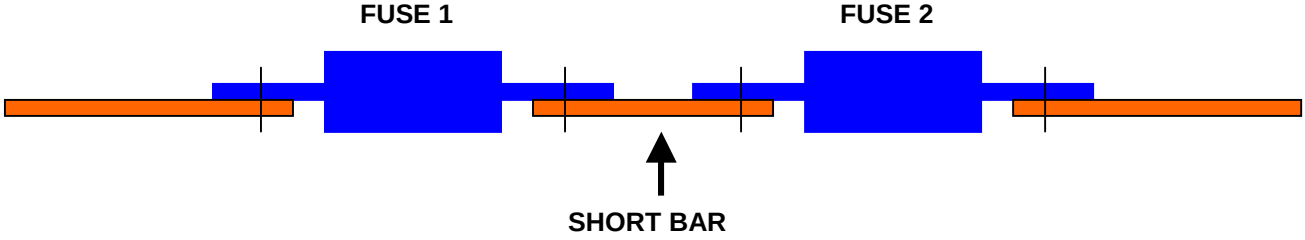

Figure 3 : 2 fuses in series connected close to each other

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3. I²t OF 2 FUSES IN SERIES

The total I²t of a fuse is an essential parameter allowing to check the protection of the Semi Conductor junction (physically the SC silicon die), or the integrity of the SC case (to avoid the case explosion). Furthermore the i²t helps to evaluate the discrimination (selectivity) between different fuses.

When protecting semi conductors the total I²t is considered when the prearc time of the fuse is less than 10 millisecondes. The fault current is then large enough to melt simultaneously (or almost) two identical fuses in series. Each fuse operates under a much lower voltage than the circuit voltage. Then the current is decreasing faster and the I²t of 2 fuses in series is smaller than the I²t of a single fuse .

The curve K = f(U) allows the calculation of the total i²t of the fuse for voltages lower than the rated voltage of the fuse (see figure 4).

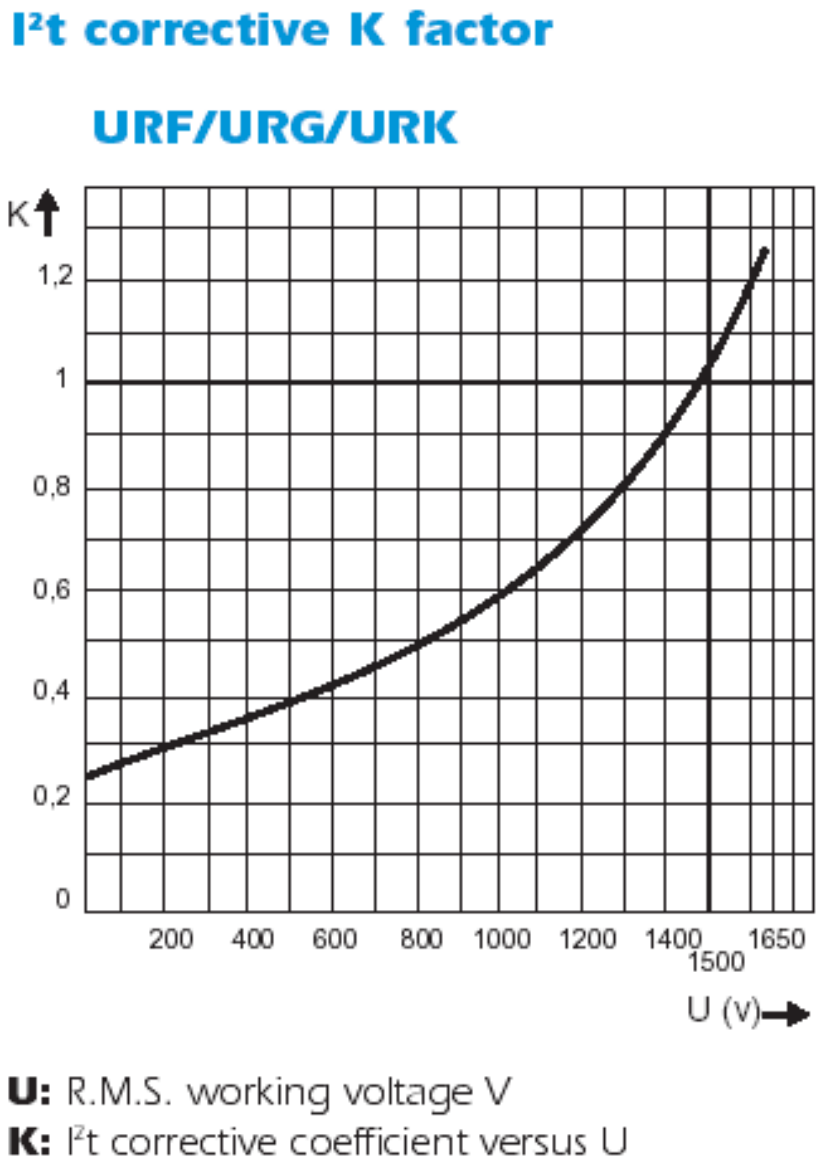

Figure 4 : curve K = f(U) of the 1500 V URF, URG and URK fuses

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3.4. I²t of the fuses when they interrupt a short circuit: case 1

When the fuse is protecting a three phases static current converter, as shown in figure 5, the short circuit starts between line 1 and 2 but may end between line 1 and 3 due to the commutation of the semi conductors.
Then the short circuit current goes partially through fuses F2 and F3 but goes totally through fuse F1. Then the prearcing time of fuse F1 is slightly smaller than the prearcing time of F2 or F3. In such cases the I²t is calculated for **65 %** of the maximum line to line voltage (see example in §3.3.).

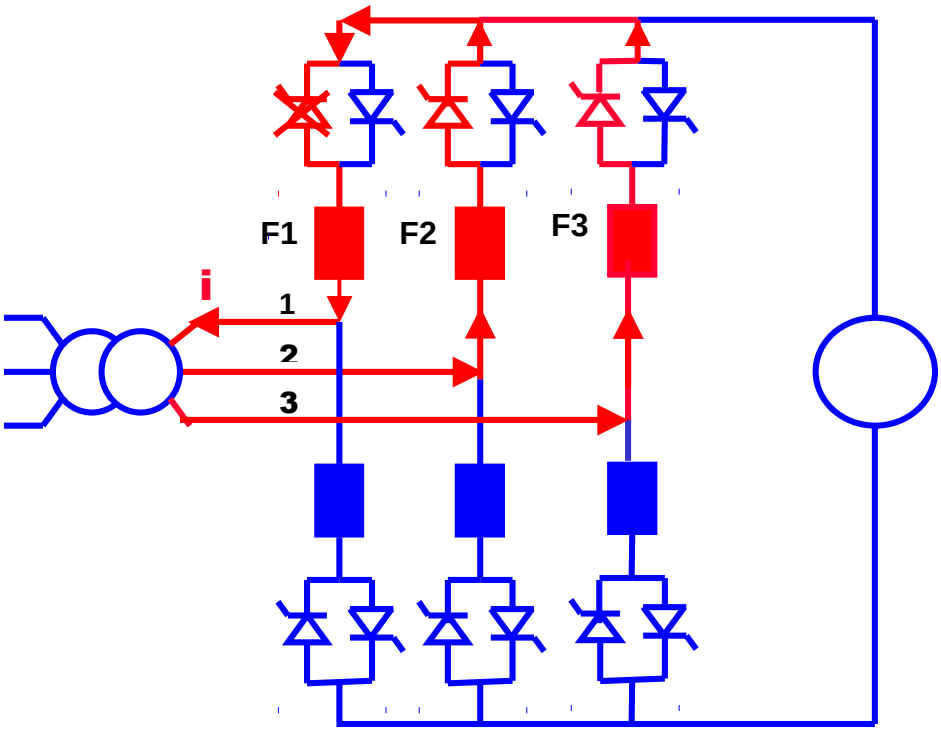

Figure 5 :

3.5. I²t of the fuses when they interrupt a short circuit: case 2

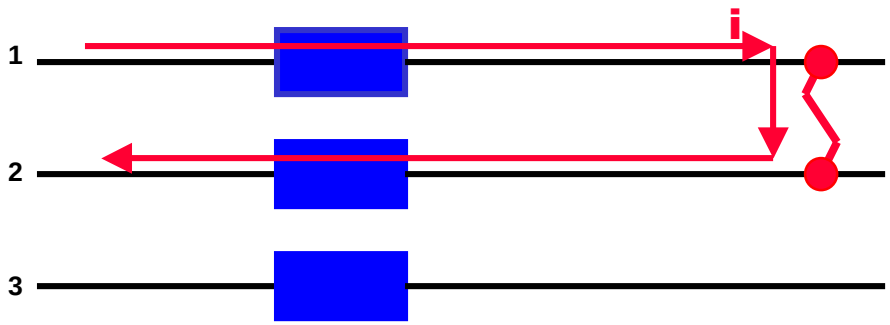

Figure 6

In this case the short circuit current remains in lines 1 and 2 until the end (figure 6).

- Consequently the I²t can be calculated considering the fuses will see only **55%** of the line to line voltage when the prearc time is below 5 ms
- When necessary and when the prearcing time is less than 1 milliseconds the I²t calculation can be calculated for **50 %** of the line to line voltage
- In case of uncertainty on the prearc time the i²t will be calculated considering the fuses will see **65%** of the line to line voltage, as in §3.1.

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3.6. calculation example

Fuse: 1500 V URH 630 A
Working condition: the fuse operates in a circuit rated 1400 + 10% i.e. 1540 V maximum

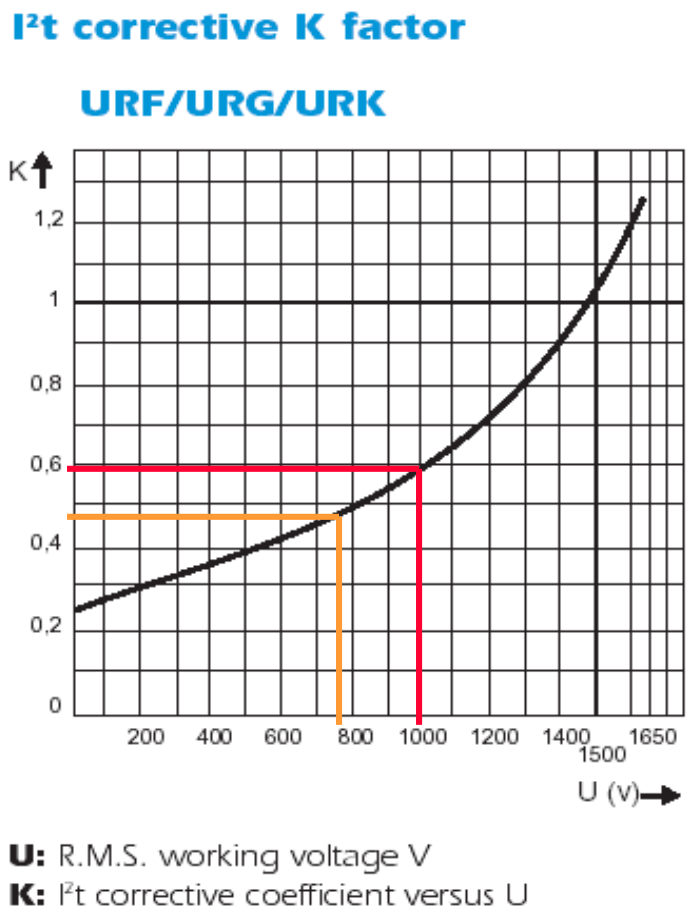

Figure 7 : curve K = f(U) of the 1500 V URF, URG and URK fuses

The short circuit current is such that the fuse prearcing time is only 1 millisecond

The fuse I²t under 1500 V is 1 570 000 A²S

- When the fuse is protecting a 3 phase bridge the i²t of the fuse is calculated for:

  U = 1540 x 0.65 = 1000V
  The curve gives k = 0.59 (see figure 7), then the fuse I²t is:

  1 570 000 x 0.59 = 926 300 A²S i.e. 926 000 A²s

- When the fuse is protecting a 3 phases circuit without static converter bridge the i²t of the fuse is calculated for:

  U = 1540 x 0.50 = 770 V

  The curve gives k = 0.47 (see figure 7) , then the fuse I²t is:

  1 570 000 x 0.47 = 737 900 A²S i.e. 738 000 A²S

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