Parallel connection of fuses

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Introduction

Parallel connection of fuses is a common practice used for the extension of the rated current range of a fuse type. As a result for example the equipment in low-voltage distribution boards can be arranged in a more compact fashion, if two size NH3 fuse-rails in parallel are used on the supply side of the busbar system instead of one size NH4a fuse-rail […]. [1], (Figure 1)

Also for wind turbines it is common practice to use several NH fuse-rails in parallel on the low-voltage supply side […]. [1]

Fig. 1 Parallel connected fuse-rails [2]

Rules of parallel connection of fuses

Generally the following important rules and instructions shall be observed for the parallel connection of fuses:

• *The fuse-links have to be of the same type, size and rating preferably fully identical in construction. [1]* The best is to take fuses of the same production batch.

• *Incoming and outgoing cables shall ensure uniform current distribution. For longer cable lengths it is recommended to perform check-measurements. Alternatively, the cable terminals of the rails are interconnected. […] In this case, however, the connected cables are not protected individually, but only as a bundle. [1]*

• *NH fuse-switches connected in parallel should be equipped with mechanically coupled handles and be capable of being operated without undue effort […]. [1]*

• *The current rating of n fuse-links connected in parallel is always smaller than the sum of the individual fuse current ratings n x I_n due to unequal current distribution. [1]*

• *The pre-arcing I²t of n fuse-links connected in parallel is approximately equal to n^2 x I²t of a single fuse-link. [1]*

• *The cut-off current of n fuse-links connected in parallel is approximately equal to n x I_c of a single fuse-link at a prospective short-circuit current I_p / n. [1]*

• *It has to be assumed that the maximum breaking capacity of the combination is not larger than I_1 of a single fuse. [1]*

• Minimum breaking current*: For […] NH fuses it is not less than n x k_2 I_n. [1]*

• *As it is only one single load circuit, the determination of the temperature rise has to be based on the full operating current for all n switching devices. [1], […]*

Parallel connection of semiconductor fuses

Especially in the range of fuses for semiconductor protection, parallel connection provides certain advantages. Due to the fact these fuses have higher power-loss than standard fuses, temperature rise and cooling is always important. Most of the parallel connected fuses use two single fuses in parallel, very seldom three single fuses in parallel. The rated current of fuses which are assembled in parallel from factory side is always the current of the whole unit of the two or three fuses connected in parallel.

Let’s make a theoretical consideration: the comparison of one single fuse of 2000A with two fuses of each 1000A current rating. Assuming the 2000A needs a bigger body size than the 1000A fuse, but the overall size and especially the surface of two smaller fuses is larger than the single bigger fuse. Thus provides better cooling of the small fuses compared to the big one. But also internal heat transmission inside the small fuses is less critical.

1st experiment

We put in all melting elements from both 1000A fuses into the fuse-body of the big fuse and test the current rating: Theoretically it should be 2000A; but you will discover a current rating below 2000A. In order to reach 2000A you have to increase the cross section of the melting elements or the number of melting elements of the 2000A fuse.

2nd experiment

From the opposite view we take half number of the fuse elements of the 2000A fuse and put them into the fuse-body of the small fuse and test the current rating: you will discover a current rating higher than 1000A. In order to get only 1000A you have to decrease the cross section of the melting elements or the number of melting elements of the 1000A fuse.

3rd experiment

To protect semiconductors the total I^2t-value is a measure of energy limitation and the correspondingly degree of protection. The I^2t-value depends on the fuse design, especially on the cross section of the melting element and its restrictions. We make the short-circuit test of both: one single fuse of 2000A and two fuses of each 1000A current rating in parallel. Due to smaller total cross section of the melting elements of the two 1000A fuses compared to the 2000A fuse the I^2t-values differ significantly.

Let's jump from the theory to real products and tested values.

Table 1 shows values of two 800A DC fuses based on the same basic design, the 1st with normal "single" design, the 2nd with two fuses in parallel. The fuse shown in the 2nd line provides much better current limitation than the fuse in the 1st line.

Order number	I_n	U_n	IR	Char.	number in parallel	Size	I^2t_{melt}	I^2t_{total}@1500V
3NB1 345 4KK11	800A	1250Vdc	100kA	aR	---	size 3L	770.000	1.910.000
3NB2 345 4KK16	800A	1250Vdc	150kA	aR	2x	size 3L	375.000	1.150.000

Table 1 data of examples of DC fuses

Table 2 shows values of two 1700A AC fuses based on the same basic design, the 1st with two fuses in parallel, the 2nd with three fuses in parallel. The fuse shown in the 2nd line provides much better current limitation than the fuse in the 1st line.

Order number	I_n	U_n	IR	Char.	number in parallel	Size	I^2t_{melt}	I^2t_{total}@690V
3NB3 358 1KK26	1700A	690Vac	100kA	gR	2x	size 3	2.370.000	10.000.000
3NB3 358 1KK27	1700A	690Vac	100kA	gR	3x	size 3	1.550.000	6.400.000

Table 2 data of examples of AC fuses

Connection methods
As described above some general rules have to be considered while using single fuses in parallel. Some customers may handle such complex constellations as shown in figure 2.

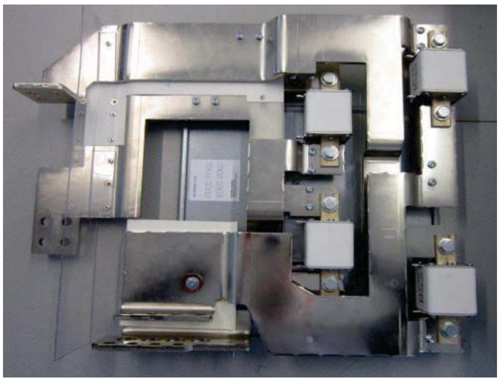


Fig. 2: fuses in parallel, two in plus- and two in minus-path [3]

The best and safest solution is to provide a “double-fuse-unit” which is assembled by the factory. Two versions are on the market: fuses of real parallel-connection (figures 3 and 4) and quasi parallel-connection (figure 5). In most cases the fuses of real parallel connection are not easy to be manufactured because the fuse-body length must be very precise. Expensive grinded fuse-bodies are needed. These fuses provide the electrical connection itself by a common contact part at both sides which simplifies the connection of copper-bars, cable-lugs or as part of a press-pack staple.

Fig. 3 real parallel-connection [4]

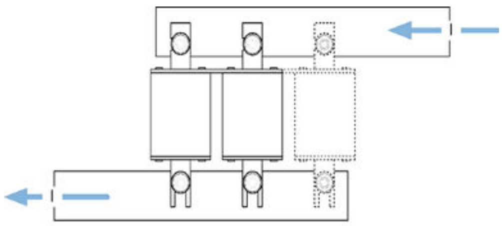
Fig. 4 real parallel-connection [5]

Quasi parallel-connected fuses are available with different designs but all of them need some attention with regard to the connection of copper-bars or cable-lugs.

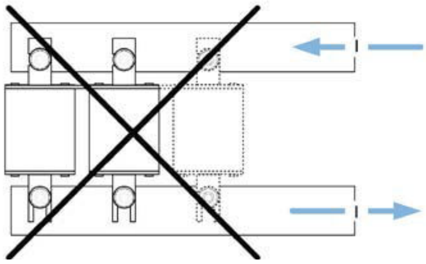
Fig. 5 quasi parallel-connection, electrically connected at the upper contacts [6]

The simplest solution is to make a pure mechanical connection. The electrical connection of the parallel-fuses has to be managed by the customer as shown in following connection scheme.

Connection scheme:



Correct connection



Forbidden connection

These very popular slotted knife-contacts shown in the connection scheme (see also figures 6 and 7) offer adjustment of the connection of copper-bars and do not require very precise positioning of the copper-bars. A further advantage for the fuse factory is the low costs, as the existing fuse-components can be used and the fuse-body length is not critical. The figures 6 and 7 show examples of quasi parallel-connected fuses without any electrical connection.

Fig. 6 Double fuse for AC application [7]

Fig. 7 Triple fuse for DC applications [8]

Requirements of UL-certified fuses

To avoid mistakes or failures while changing fuses, the NEC (National Electrical Code) states in its document 240.8: „Fuses and circuit breakers shall be permitted to be connected in parallel where they are factory assembled in parallel and listed as a unit. Individual fuses, circuit breakers, or combinations thereof shall not otherwise be connected in parallel“ [9].

All different versions of parallel-connected fuses described above fulfill these NEC-requirements.

Summary

Fuses in parallel may be an alternative to single-type fuses to be used in power distribution networks or for semiconductor protection. With respect of the rules those constellations offer safe and cost-saving solutions. Parallel connection of fuses is generally well accepted by the customers in a lot of worldwide markets but use of UL-fuses connected in parallel needs special regard required by a National Electrical Code document.

References

- [1] Dr.-Ing. Herbert Bessei, FUSE MANUAL; 5th edition 2015, ISBN 978-3-931954-86-4
- [2] Fig. 1 Parallel connected fuse-rails, picture provided by company EFEN GmbH, Eltville
- [3] Fig. 2: fuses in parallel, two in plus- and two in minus-path, Copyright Siemens AG
- [4] Fig. 3 real parallel-connection, picture provided by company SIBA GmbH, Lünen
- [5] Fig. 4 real parallel-connection, picture provided by company Eaton Bussmann
- [6] Fig. 5 quasi parallel-connection, picture provided by company SIBA GmbH, Lünen
- [7] Fig. 6 Double fuse for AC application, Copyright Siemens AG
- [8] Fig. 7 Triple fuse for DC applications, Copyright Siemens AG
- [9] National Electrical Code 240.8 Fuses or Breakers in Parallel

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