Application Note

Choice of Prefuses

VLT® 5000
VLT® 6000 HVAC
FCM 300

■ Choice of Prefuses for VLT 5000/6000 HVAC/FCM 300

This statement are only valid for installations, which are made according to IEC 364 (Electrical installations of buildings) and the harmonized documents in the HD 384 series (colloquially according to European standards). UL and NEC standards are not discussed in this note.

Fuses in front of a VLT must consider more different purposes:

1) Limit the heat generation inside the VLT at unit fault.
2) Protection of the mains cable.
3) Protection at ground fault, combined with unit fault in VLT.

In the following the melt fuses will be indicated as follows:

Operation class

In terms of DIN VDE 0636 (IEC 60 269), low-voltage high rupturing-capacity fuse links are classified in terms of their function and operating characteristics (also see Function class). The operation class of an LV HRC fuse link is indicated by letters, whereby the first letter is used to identify the function class and the subsequent letters to identify the object to be protected. The following list includes a number of standardized identifying letters:

G General purpose, i.e. cables and insulated wires, (previously L)
M Switching devices
R Semiconductors
B Mining equipment
Tr Transformers

These result in the following operation classes:

gG/gL Wide-range general-purpose protection for cables, conductors and wires
aM Partial range accompanied protection for switching devices
aR Partial range accompanied protection for semiconductors
gR Wide range general-purpose protection for semiconductors
gB Wide range general-purpose protection for mining installations
gTr Wide-range general-purpose protection for transformers

Further operation classes include:
“träg” or “time delay” and
“flink” or “quick response”

which are both offered as original DIAZED fuse links for cable and wiring circuit protection.

I^2t. The integral of the square of the current over an given time

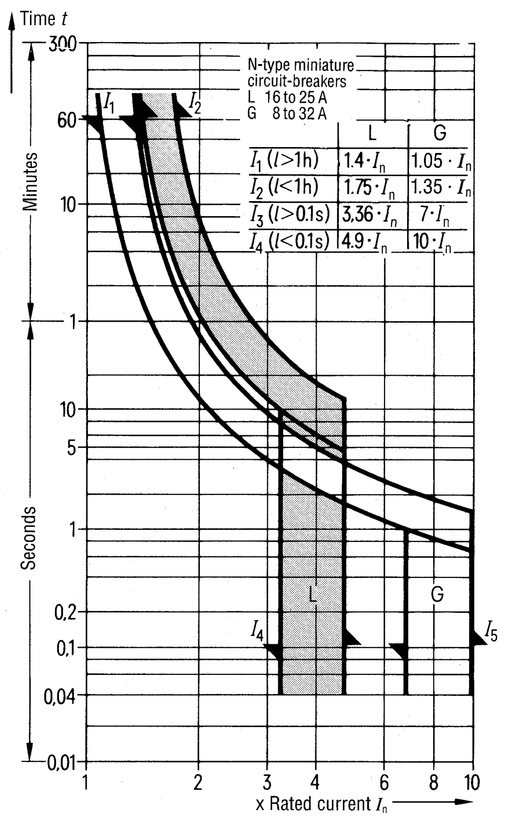
$$I^2t = \int_{t_0}^{t_1} i_1 \, dt$$

The energy in joule (WS) released in a 1Ω of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in A^2s.

Instead of fuses, the use of „circuit breakers“ makes progress.

NOTE:
Circuit breakers are not to be used betweed motor and VLT motor-terminals.
The high frequency harmonic in the current can heat the bimetal windings and the trip release windings in the circuitbreakers.

Fig. 1a and 1b show the tripping characteristics which are normally marketed.



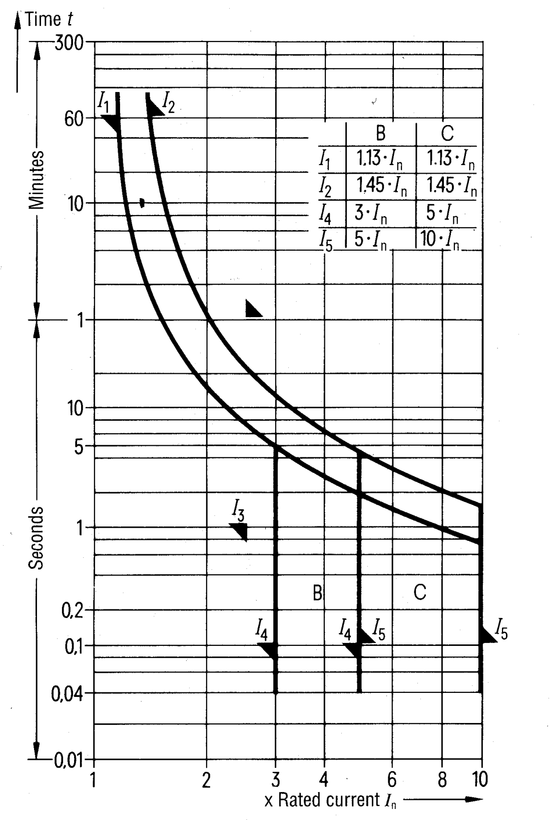
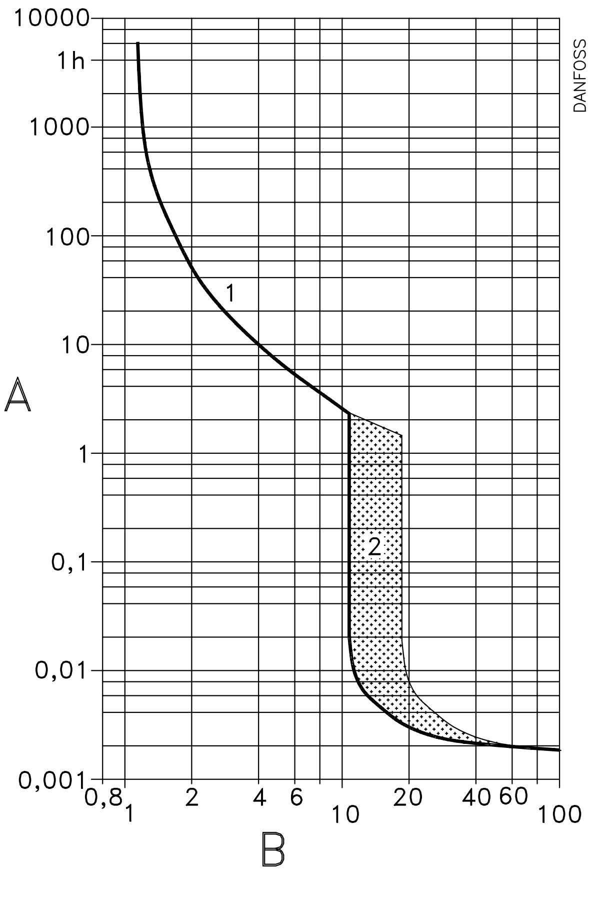
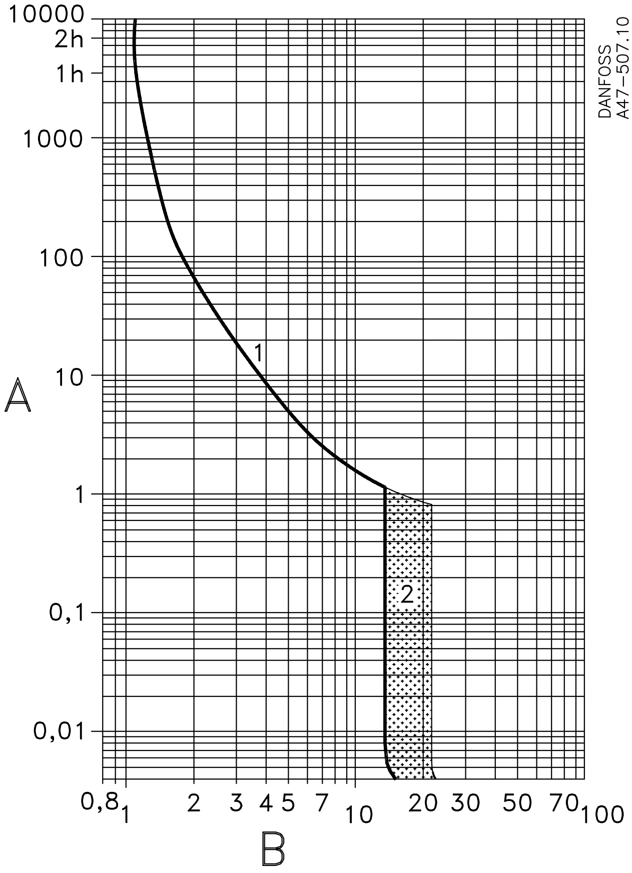


Fig. 1a. *Previously valid*: L and G characteristic curves in accordance with DIN VDE 0641, 6.78 or CEE 19/1.

Fig. 1b: *New:* B and C characteristic curves in accordance with DIN VDE 0641 A4, 11.88 and part 11, 08.92 or IEC 898/1987.

Fig. 2 shows typical tripping characteristics for "circuit breakers", which are used for motor protection.





1. Thermal release current
The adjustable, current-dependent, delayed bimetal breakers guarantee motor overload protection.
The graph gives the average value at 20°C ambient temperature, from the cold condition. When the unit has warmed up, the release time is less or equal to the release time in the cold condition.
The accurate adjustment ensures motor protection even in the event of phase failure.

2. Magnetic trip release current
The electromagnetic, instantaneous high-speed trips react at a fixed response current. At the highest setting value this corresponds to 11 times the set current for CTI 25 and 13 times for CTI 100. At a lower setting it is correspondingly higher.

Re. 1: Limitation of heat generation inside the unit

“Max. prefuses” are stated under “technical data” in the enclosed “Operating Instructions” and “Design Guide”. If nothing special is mentioned, a fuse with characteristic gL/gG/”flink” can be used (alternatively circuit breakers with characteristic G and C, fig. 1 or fig. 2.

If fuses according to abovementioned are chosen, eventually damages on the unit will mainly be limited to damages inside the unit, as the demand in EN 50178.

If a better protection of VLT® against damages caused by misuse or component failure is wanted, gG/”flink” fuse or circuit breaker G/C can be combined with a semi-conductor fuse with characteristic aR/gR. See besides example, fig. 3.

aR/gR fuses are characterized by a low I^2t. This means that the heat which is generated at short circuit or ground fault will be minimized, see table 1.

Normally a aR/gR fuse is dimensioned according to next oversize according to the max. continuous rated input current. If the fuses are placed in high ambient temperature (> 35° C), two oversizes are used.
„Circuit brakers“ normally have a high I^2t, therefore you obtain the best protection if you combine with gG/gL fuses or- even better- a gR/aR fuse.

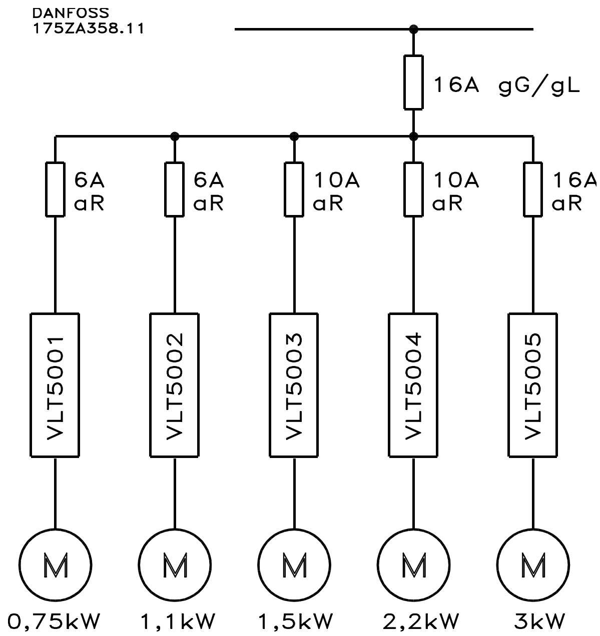


Fig 3A
Example on installation with semi-conductor fuses (aR) and melt fuses (gG or “flink”).
Please note that aR fuses shall be combined with gG/”flink” fuse or a circuit breaker.

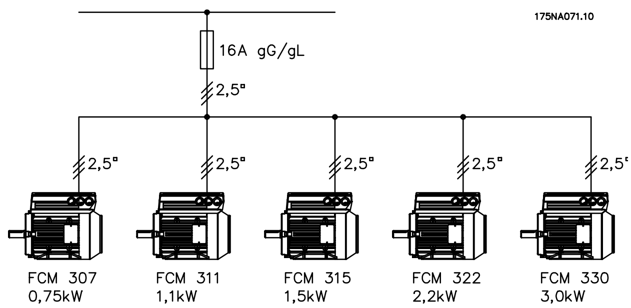


Fig 3B

Table 1
Pre-arcing I^2t values at 0.01 s for “gG” and “gM” fuse-links

	gG and 1gM		aR and gR	
I_n for gG I_{ch} for gM* (A)	I^2t_{min} 10^3 x (A^2s)	I^2t_{max} 10^3 x (A^2s)	I^2t_{min} 10^3 x (A^2s)	I^2t_{max} 10^3x (A^2s)
6	0,3	1,0	0,0012	0,048
20	0,5	1,8	0,0115	0,078
25	1,0	3,0	0,0190	0,130
32	1,8	5,0	0,0400	0,270
40	3,0	9,0	0,0690	0,480
50	5,0	16,0	0,1150	0,770
63	9,0	27,0	0,2150	1,450
80	16,0	46,0	0,3800	2,255
100	27,0	86,0	0,6950	4,650
125	46,0	140,0	1,2000	8,500
160	86,0	250,0	2,3000	16,000
200	140,0	400,0	4,2000	28,000
250	250,0	760,0	7,7500	51,500
315	400,0	1300,0	12,0000	80,500
400	760,0	2250,0	18,0000	125,000
500	1300,0	3800,0	27,0000	180,000
630	2250,0	7500,0	48,5000	325,000
800	3800,0	13600,0	105,0000	725,000
1000	7840,0	25000,0	180,0000	1250,000
1250	13700,0	47000,0	365,0000	2400,000

* For „gM“, see Sub-clause 5.7.1.

Overcurrent discrimination of „gG“ and „gM“ fuselinks according to IEC 60269-1.

Colum 4 and 5 aR/gR fuses type ZILOX.
manufacture BUSSMANN®

Re. 2 Protection of Mains Wire

If the square of a wire for a group VLT is chosen, you want of course to minimize the square to minimize consumption of copper. How much current a certain square must carry, is dependend on many factors. The most sure will always be to follow the national rules.

Fig. 4 shows an example on a combination of melt fuses and circuit breakers type CTI (make Danfoss). The cable square is chosen according to table 2. The wire between CTI circuit breakers and VLT is 1.5 square. 1.5 square is chosen because the installation is fixed. 1.5 square is used, even though it must carry 12A (typical). 2.5 square is chosen between 16A fuse and CTI, because it is protected with 16A melt fuse (gL).

Between VLT and 1.5 kW motor 0.5 square is chosen, because it must have 8A when it is protected with a CTI circuit breaker and a flexible type.

Short-circuit protection of wiring

Type	Max. setting	Protected min. cross-section (mm²) at 380/415 v. 50 HZ						
		10	6	4	2,5	1,5	1	0,75
CTI 25	4,0		•	•	•	•	•	•
	6,3		•	•	•	•	•	•
	10,0		•	•	•	•	•	
	16,0		•	•	•	•		
	20,0		•	•	•			
	25,0		•	•	•			
CTI 100	25	•	•	•	•			
	40	•	•	•				
	63	•	•					
	90	•						

Table 2

Protection of PVC insulated wires against overload and short-circuiting, in accordance with IEC and CENELEC harmonizing documents 384-3 and 384-4.
Overload protection is given by the adjustable thermal circuit breakers in CTI motor starters.
e highest possible release current is therefore significantly lower than with overload protection by fuses. The magnetic trips with fixed setting that rapidly open the main contacts, take over protection in the event of short-circuiting. The low realease time ensures that heating generated in leads by short-cuirting is limited to a minimum. Further information is contained in national regulations.

Setting in short-circuiting protection application
In many cases, CTI 25 or CTI 100 are used exclusively for short-circuit protection - overload protection being provided by thermal overload relays, e.g. in multi stage motors or star-delta starters with heavy start, and/or in reducing motor lead crosssection. Here, the current value can be set 20% higher than the operating current so that only the thermal overload relays release when overload occurs.

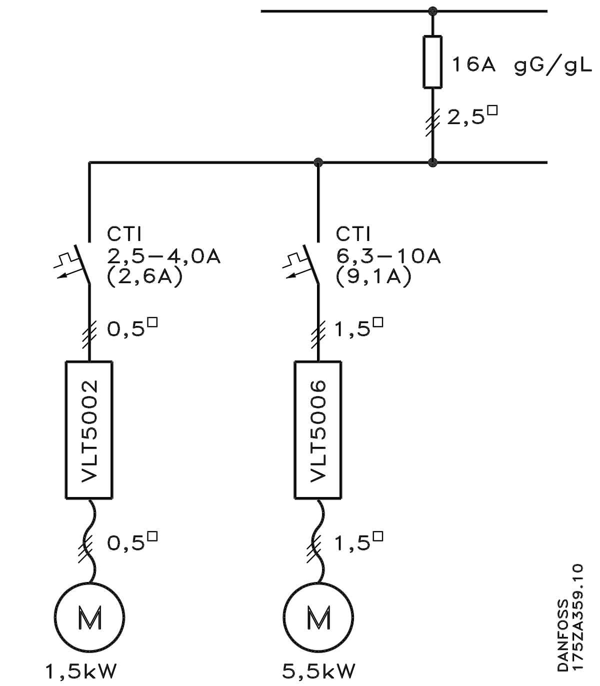


Fig 4A

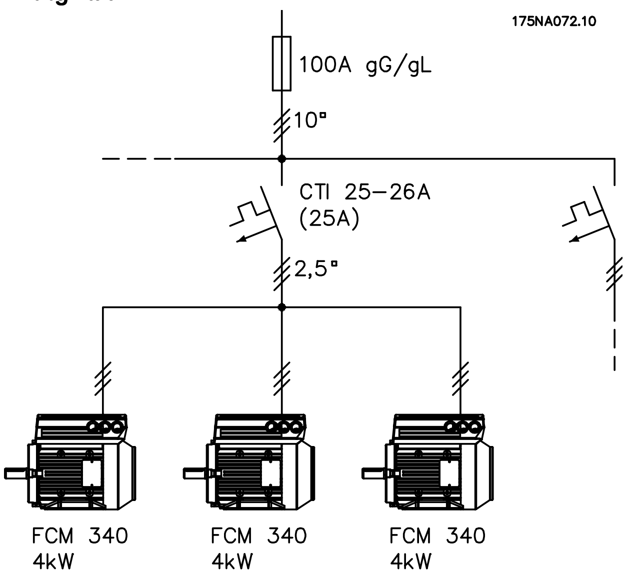


Fig 4B

Combination of melt fuses and "circuit breakers" type CTI.
VLT is from the factory supplied with commutation reactors, therefore Cos φ is @1 and the power factor 0.9 seen from the mains supply. This means in practice that the mains current is never higher than the motor's actual current. This means that the "circuit breaker's" trip current I_1 according to fig. 1 and 2 can be set equal to the motor's rated current. If the motor is oversize combined with the recommended size for VLT, you can choose I_1 according to "rated input current" for VLT.

Protection of ground fault, combined with unit fault
The fuses which are mounted in front of a VLT can also have the purpose to interrupt the current, if ground faults occur. According to IEC 364-4-41, the current - at a ground fault of minimal impedance - must be interrupted within 5 s in TN supply mains.

This demand can claim demands to the max. fuse which can be used in a certain installation.

At most ground faults and control circuits, a VLT will register ground fault of low impedance and limit the current or trip. However, this is except the wires for an eventual external braking resistor. If a ground fault occurs in the brake resistor, the drive would not be able to limit the current.

The ground fault current (I_{GF}) is calculated as follows:

$$I_{GF} = \frac{U_L / \sqrt{3}}{Z_U + Z_{VLT} + Z_{MC} + Z_G} \ (in\ general)$$

If the rectifier in the VLT still works, the current caused by a ground fault will be equaly distributed in all three phases. Therefore the current in each phase will be √3 smaller than the ground fault current. Z_U, seen from VLT, will also be √3 smaller, because all three motor phases lead a part (√3) of the ground fault current. See fig. 5. These two conditions are the reason why the formula is to be modified as follows:

$$I_{GRF} = \frac{U_L / \sqrt{3}}{(Z_U / \sqrt{3} + Z_{VLT} + Z_{MC} + Z_G) \times \sqrt{3}} = \frac{U_L}{Z_U \times \sqrt{3} + 3(Z_{VLT} + Z_{MC} + Z_G)}$$

I_{GFR}: Ground fault current in a mains phase at working B6 rectifier

U_L: Phase-phase voltage

Z_U: Mains impedance seen from VLT

Z_{VLT}: Impedances in VLT at ground fault and short circuited IGBTs

Z_{MC}: The impedance in the motor cable

Z_G: The impedance in the PE connection between VLT and supply transformer (typical 2 Ω).

Gates for specified pre-arcing times of“gG“ and „gM“
fuse links
Ref.IEC 60269-1

I_n for gG I_{ch} for gM* (A)	I_{min} (10 s)*** (A)	I_{max} (5 s)*** (A)	I_{min} (0,1 s) (A)	I_{max} (0,1 s) (A)
16	33	65	85	150
20	42	85	110	200
25	52	10	150	260
32	75	150	200	350
40	95	190	260	450
50	125	250	350	610
63	160	320	450	820
80	215	425	610	1100
100	290	580	820	1450
125	355	715	1100	1910
160	460	950	1450	2590
200	1780	1250	1910	3420
250	7500	1650	2590	4500
315	1050	2200	3420	6000
400	1420	2840	4500	8060
500	1780	3800	6000	10600
630	2200	5100	8060	14140
800	3060	7000	10600	19000
1000	4000	9500	14140	24000
1250	5000	13000	19000	35000

Table 3

*) Values for fuses with rated vurrent less than 16 A are under consideration.
**) For “gM” fuse-links see Sub-clause 5.7.1.
***) I_{min} (10 s) is the minimum value of current for which the pre-arcing time is not less than 10 s.
I_{max} (5 s) is the maximum value of current for which the operating time is not more than 5 s.

The calculation can pass in three steps.

Step I: Choose cable square according to table 2 or other relevant material.

Step IIa: Calculate Z_{MC} according to choise under “I” at mains frequency and max. cable length. Use encl. 2 or other relevant material.

Step IIb: Set Z_U to relevant value. Z_U includes transformer impedance and impedance of power cable for VLT. I suggest that it is set to $Z_{MC} = Z_U$, because often you do not have access to such kind of information.

Step IIc: Calculate Z_{VLT} during the earlier mentioned limits (see table 4)

Step IId: Choose U_L. Worst case will be the lowest rated voltage.

Step IIe: Choose Z_{GRF} (in Denmark typical 2 Ω).

Step III: Add I_{GFR} in the arching curve in fig 5 or table 3 for fuse and read the pre-arching time

VLT type	Voltage	Impedance in VLT by shortid IGBT (Ω)
VLT 5000/ 6000 HVAC/ FCM 300	All	Z_{VLT} 0,1

Table 4

Impedance in VLT at ground fault and a short circuited IGBT.

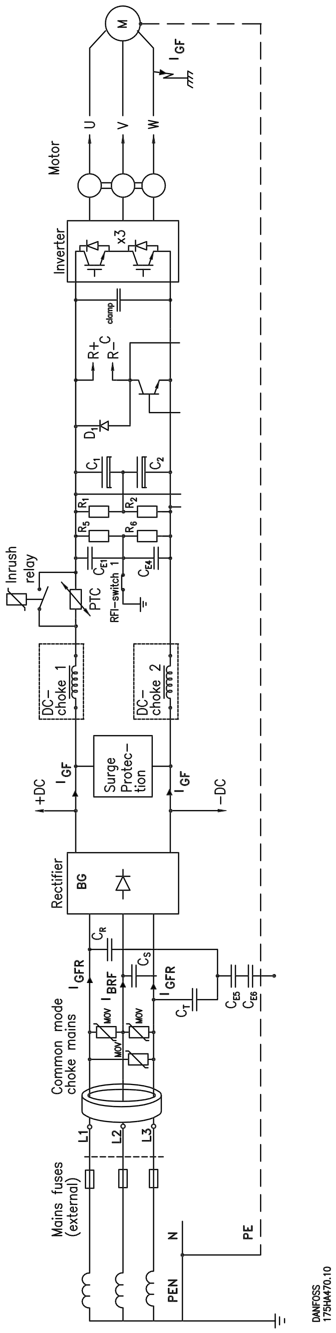


Fig.5

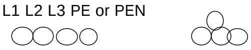
Ground fault current flow in a VLT

Table **5.** Resistance values of PVC insulted connecting cables with copper conductors at 55 C (cable temperature) [1)]
For PVC insulated cables with *Aluminium* conducture, the resistance value R must be multiplied by the factor 1,7.

a) 4 and 5 core cable

Core number x rated Cross-section mm²	R [2)] mΩ/m	X′ [3)] mΩ/m	Z′ mΩ/m
4 x 0,5	81,90	0,23	81,90
4 x 0,75	55,74	0,23	55,74
4 x 1	41,18	0,23	41,18
4 x 1,5	27,53	0,23	27,53
4 x2,5	16,86	0,22	16,86
4 x 4	10,49	0,21	10,49
4 x 6	7,01	0,20	7,01
4 x 10	4,16	0,19	4,16
4 x 16	2,62	0,18	2,62
4 x 35	1,192	0,160	1,203
4 x 50	0,880	0,159	0,894
4 x 70	0,610	0,155	0,629
4 x 95	0,440	0,154	0,466
4 x 120	0,348	0,151	0,379
4 x 150	0,282	0,151	0,320
4 x 185	0,226	0,151	0,272
4 x 240	0,172	0,149	0,228
4 x 300	0,136	0,149	0,202

c) Single core cable

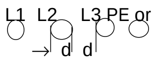


Core number x rated cross-section Main conductor/PEN mm²	R′ [2)] mΩ/m	X′ [3)] mΩ/m	Z′ mΩ/m
1 x 25/16	2,135	0,390	2,170
1 x 35/16	1,904	0,377	1,941
1 x 50/25	1,267	0,373	1,321
1 x 70/35	0,901	0,366	0,973
1 x 95/50	0,660	0,333	0,739
1 x 120/70	0,479	0,330	0,582
1 x 150/70	0,4446	0,327	0,553
1 x 185/95	0,333	0,326	0,466
1 x 240/120	0,260	0,320	0,412
1 x 300/150	0,209	0,328	0,381

b) 3½ and 4½ core cable

Core number x rated cross-section mm²	R′ [2)] mΩ/m	X′ [3)] mΩ/m	Z′ mΩ/m
3 x 25/16	2,135	0,182	2,143
3 x 35/16	1,904	0,183	1,913
3x 50/25	1,267	0,179	1,279
3 x 70/35	0,901	0,174	0,918
3 x 95/50	0,660	0,168	0,681
3 X 120/70	0,479	0,160	0,505
3 X 150/70	0,446	0,167	0,476
3 X 185/95	0,333	0,163	0,371
3 X 240/120	0,260	0,164	0,307
3 X 300/150	0,209	0,162	0,264

1) For resistance values at other temperature, refer to Section 9.4.5, page 529
2) Base values for outgoing and return conductor (i.e. loop values); in accordance with DIN VDE 0295, Tables 14 and 2 as well as with DIN VDE 0102. Based on average conductor temperature of 55 C
3) Base values from „Kabel und Leitungen für starkstrom“, 4th edition, Siemens AG, in accordance with DIN VDE 0102 (loop values).



d) Single core cable

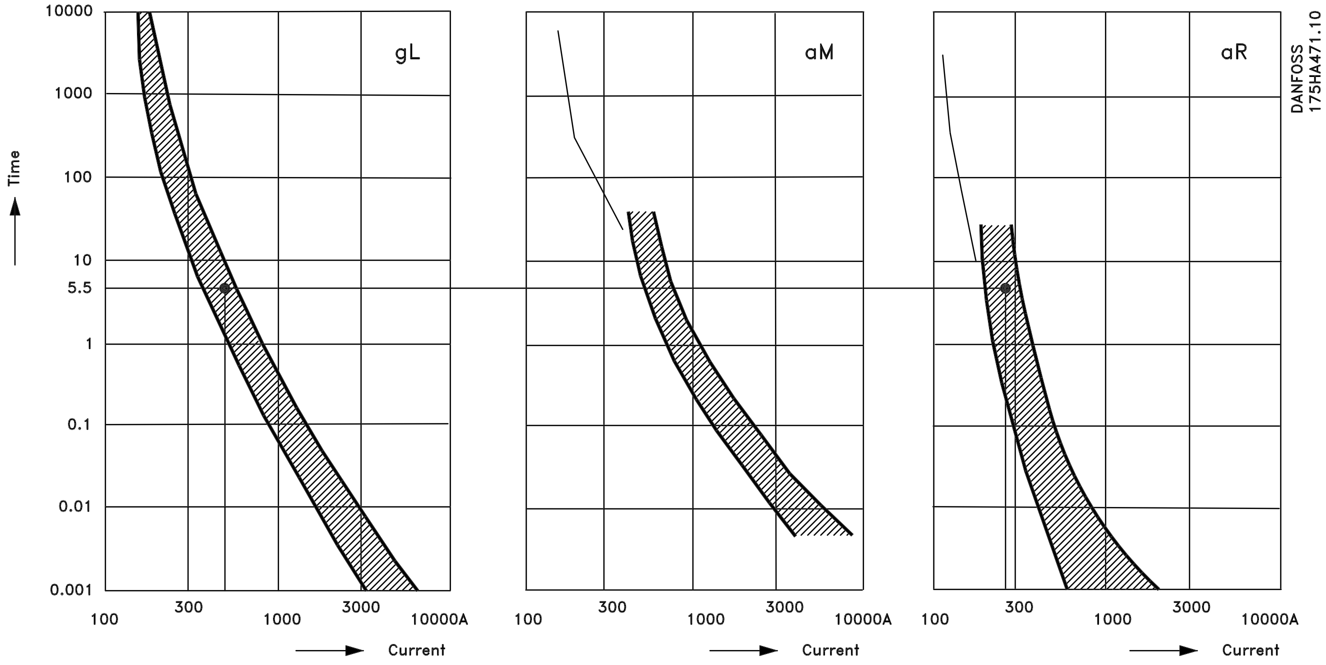
Core number x rated cross-section mm² Main conductor/PEN mm²	R′ [2)] mΩ/m	X′ [3)] mΩ/m	Z′ mΩ/m
1 x 25/16	2,135	0,390	2,170
1 x 25/16	1,904	0,377	1,941
1 x 50/25	1,267	0,373	1,321
1 x 70/35	0,901	0,366	0,973
1 x 95/50	0,660	0,362	0,753
1 x 120/70	0,479	0,359	0,599
1 x 150/70	0,446	0,356	0,571
1 x 185/95	0,333	0,354	0,486
1 x 240/120	0,260	0,349	0,435
1 x 300/150	0,209	0,347	0,405

Table 6
1 Specification for low voltage devices and switchgear assemblies

Current carrying capacity, overload and short-circuit protection of insulated cables in PTTA´s at an ambient temperature of 35 C around the cable(e.g. cablling on open cable tray), permissible operating temperature 70 C.
The values given in the table may be converted in terms of DIN VDE 0100 part 430 for short-time and intermittent.

Column 1	2	3	4	5	6	7	8	9	10	11	12	13
			1)									
Conductor cross-section	Current carrying capacity and setting of overload relay (*a*-release)	Overload protection with fuse, miniature circuit-breaker	Short-circuit protection with fuse, miniature circuit-breaker	Short-circuit protection with circuit-breaker (*n*-release)[2]	Current carrying capacity and setting of overload relay (*a*-release)	Overload protection with fuse, miniature circuit-breaker	Short-circuit protection with fuse, miniature circuit-breaker	Short-circuit protection with circuit-breaker (*n*-release)[2]	Current carrying capacity and setting of overload relay (*a*-release)	Overload protection with fuse, miniature circuit-breaker	Short-circuit protection with fuse, miniature circuit-breaker	Short-circuit protection with circuit-breaker (*n*-release)[2]
mm^2	A	A	A	A	A	A	A	A	A	A	A	A
0.5	6	6	20	90	8	6	20	120	8	6	20	120
0.75	8	6	20	120	8	6	20	120	8	6	20	120
1	8	6	20	120	8	6	20	120	8	6	20	120
1.5	12	10	25	180	12	10	25	180	12	10	25	180
2.5	17	16	32	255	20	20	35	300	20	20	35	300
4	22	20	35	330	25	25	40	375	25	25	40	375
6	28	25	40	420	32	32	50	480	32	32	50	480
10	38	35	63	570	48	40	80	720	50	50	100	750
16	52	50	100	780	64	63	125	960	65	63	125	975
25					85	80	160	1275	85	80	160	1275
35					104	100	200	1560	115	100	200	1725
50					130	125	250	1950	150	125	250	2250
70					161	160	315	2415	175	160	315	2625
95					192	160	315	2880	225	200	400	3375
120					226	200	400	3390	250	250	500	3750
150					275	250	500	4125	275	250	500	4125
185					295	250	500	4425	350	315	630	5250
240					347	315	630	5205	400	400	800	6000
300					400	400	800	6000	460	400	800	6900

[1] In this case, a random laying (or „bounching“) of the conductors is possible. The given values refer to 6 cores, all simultaneously loaded with 100%, within a multi-core bundle.
[2] Instantaneous electromagnetic overcurrent release.



Current time curves from different 100A fuses

Fig. 6

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