13 Conductor Materials and Accessories for Switchgear Installations

13.1 Busbars, stranded-wire conductors and insulators

13.1.1 Properties of conductor materials

Busbars for switchgear installations are made either of copper (E-Cu) or of aluminium (E-Al). Aluminium alloys with good electrical and mechanical properties are also used.

An advantage of aluminium is that a short-circuit arc gives rise only to non-conducting, dust-like residues of aluminium oxide. No metal is deposited on the neighbouring insulators or other components of the installation, thus limiting the extent of the damage. Switchgear installations with aluminium busbars can therefore be reconnected much more quickly after a short-circuit arc.

The values given in Table 13-1 are typical values to be used in calculations concerning the construction of switchgear installations; the most important physical properties of commonly used conductor materials are compared in Table 13-2.

Table 13-1

Typical values for the properties of conductor materials

Symbol	Tensile strength R_m min. N/mm²	Young's modulus E Elasticity modulus N/mm²	Yield strength R_{p02} min. N/mm²	R'_{p02} max. N/mm²	Brinell hardness HB 10 N/mm²	Conductivity κ at 20 °C min. m/Ωmm²
Copper						
E-Cu F 20	200	$11 \cdot 10^4$		120	450… 700	57
E-Cu F 25	250	$11 \cdot 10^4$	200	290	700… 950	56
E-Cu F 30	300	$11 \cdot 10^4$	250	360	800…1050	56
E-Cu F 37	370	$11 \cdot 10^4$	330	400	950…1150	55
Aluminium						
E-Al F 6.5/7	65/70	$6.5 \cdot 10^4$	25	80	200… 300	35.4
E-Al F 8	80	$6.5 \cdot 10^4$	50	100	220… 320	35.2
E-Al F 10	100	$6.5 \cdot 10^4$	70	120	280… 380	34.8
E-Al F 13	130	$6.5 \cdot 10^4$	90	160	320… 420	34.5
Al F 10	100	$\approx 6.5 \cdot 10^4$	70		280… 300	34
Malleable aluminium alloy						
E-Al Mg Si 0.5 F 17	170	$7 \cdot 10^4$	120	180	450… 650	32
E-Al Mg Si 0.5 F 22	220	$7 \cdot 10^4$	160	240	650… 900	30
Copper-clad aluminium						
Cu comprises 15 %	130	$8 \cdot 10^4$	100	130	—	42.3

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Table 13-2

Comparison of the most important properties of common conductor materials

Property		Copper (E-Cu)	Pure aluminium (E-Al)	Pantal (E-AlMg Si 0.5)	Brass (Ms 58)	Steel (galvanized)
Density	kg/dm³	8.9	2.7	2.7	8.5	7.85
El. conductivity at 20 °C	m/Ω · mm²	56	35	30	≈ 18	≈ 7
El. conductivity at 60 °C	m/Ω · mm²	48	30	26	≈ 16	≈ 6
Conductivity.../density...		6.3	13	11	≈ 2	≈ 1
Spec. resistance at 20 °C	Ω · mm²/m	0.0178	0.0286	0.0333	≈ 0.0555	≈ 0.143
Temperature coeff. of el. resistance between 1 °C and 100 °C	K^{-1}	0.0038	0.0040	0.0036	0.0024	0.005
Melting point	° C	1083	658	630	≈ 912	1400
Heat of fusion	Ws/g	181.28	386.86	376.81	167.47	293.07
	Ws/cm³	1612	1047	1017	1444	2302
Mean spec. heat between 1 °C and 100 °C	Ws/g · K	0.393	0.92	0.92	0.397	0.485
	Ws/cm³ · K	3.475	2.386	2.386	3.391	3.558
Thermal conductivity between 1 °C and 100 °C	Ws/cm · s · K	3.85	2.2	1.9	1.1	0.46
Mean coeff. of expansion between 1 °C and 100 °C	mm/m · K	0.017	0.024	0.023	0.018	0.012
Young's modulus	N/mm²	110000	65000	70000	≈ 90000	210000
Thermal limit current density[1)]	A/mm²	154	102	89	91	
Melting current density[1)]	A/mm²	3060	1910	1690	1900	

[1)] Thermal limit current density is the current density at which the conductor temperature rises from 35 °C to 200 °C when loaded for 1 s. Conductive heat removal disregarded.

Melting current density is the current density at which the conductor temperature rises to the melting temperature when loaded for 1/100 s. Values according to Müller-Hillebrand.

13.1.2 Busbars for switchgear installations

Maximum continuous temperatures to DIN 43 670 and DIN 43 671

for bar conductor screw connections to DIN 43 673,
non-oxidized and greased approx. 120 °C,
silvered, or equivalent treatment, approx. 160 °C,
for post insulators and bushings to DIN VDE 0674 Part 1 approx. 85 °C,
for equipment terminals DIN EN 60694 bare approx 90 °C,
(VDE 0670 Part 1000) tinned, silvered approx. 105 °C.

A convenient method of monitoring for thermal overload temperatures is to use temperature-sensitive paints. These change their original colour when certain temperatures are exceeded. The change persists after the painted item has cooled. The original colour is regained only gradually, under the influence of moisture in the air. The colour can be restored immediately by wetting. Temperature-sensitive paints can be applied to any surface. Oil or grease should first be removed with petrol or white spirit.

Influence of bar temperature on strength of conductor material

The strength of the conductor material decreases with rising temperature, and much more rapidly with aluminium than with copper. The values in Table 13-3 are valid for aluminium. For temperatures above 160 °C, they also depend on the duration of heating.

Table 13-3

Influence of temperature on the strength of aluminium

Temperature	20	100	160	250	°C
Tensile strength σ_B	90…130	90…120	80…110	70…30	N/mm^2
Yield point $R_{p0.2}$	80…120	80…110	70…100	60…30	N/mm^2
Elongation at fracture	10…5	10…5	11…7	to 60	%

Under short-circuit conditions, therefore, conductor temperatures of 200 °C for aluminium and for copper must not be exceeded, see VDE 0103.

If items of equipment are influenced only very slightly, or not at all, by the thermal behaviour of the busbars, the maximum permissible conductor temperature is governed only by the long-term thermal strength of the conductors and their insulation.

This is the case, for example, with busbars which owing to sufficiently long connections are not thermally coupled to their associated equipment.

Profile selection and arrangement for alternating current

The cross-sectional shape of busbar conductors has a considerable influence not only on their bending strength, but also on their electrical load capacity.

With direct current, there is no skin effect, so in this case the shape of the conductor is important only with regard to the heat-emitting surface area. For direct current, therefore, it is preferable to use flat bars or continuously cast conductors of large cross section.

With alternating current, on the other hand, skin effect and other factors cause an increase in the conductor resistance, and this must be kept small by selecting an appropriate section profile. The effect the shape and arrangement of component conductors of the same total cross-section area can have on the current-carrying capacity of busbars for AC is illustrated in Fig. 13-1.

If the current permits, one or two flat conductors per phase are provided, thus simplifying installation. Two conductors is the most favorable number from the standpoint of losses, and is therefore to be preferred.

For higher currents, four flat conductors have proved to be an effective arrangement. The distance between the second and third conductor has to be increased in order to achieve a better current distribution. Increasing the distance from 10 to 30 mm produces no significant improvement. It has been shown that with a distance of 70 mm, the relative currents in the individual conductors differ by only ± 7%.

The loading on the four conductors is then:

Conductor	1	2	3	4
Current carried as % of total current	26.7	23.3	23.3	26.7

If four flat conductors per phase are not sufficient, then channel sections are considered. These have favorable skin effect properties. If even more flat conductors were to be used, the result would be a comparatively large cross-section which, in addition, is very uneconomical. For example, an arrangement with seven conductors would give the following current distribution among the conductors:

Conductor	1	2	3	4	5	6	7
Relative current %	25.6	14.2	7.5	5.4	7.5	14.2	25.6

For high currents in low-voltage installations, when using flat conductors, the simplest solution is to split up large composite conductors by dividing the three phases among smaller cross sections, Fig. 13-2. These then have a significantly lower eddy-current factor and also a smaller inductive voltage drop.

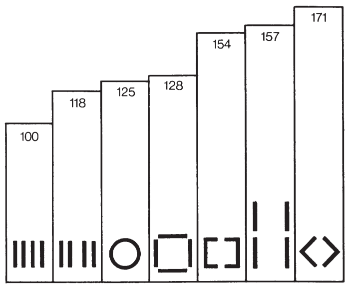

Fig. 13-1

Current-carrying capacity per cent of some busbar conductor arrangements of the same total cross-section area

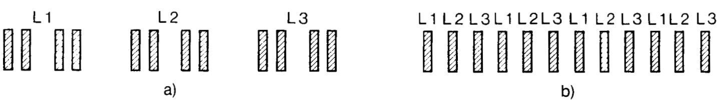

Fig. 13-2

Arrangement of a three-phase bus with four parallel conductors per phase:
a) Usual arrangement with the three phases L_1, L_2, L_3 next to each other
b) Conductors in split phase arrangement L_1, L_2, L_3, L_1, L_2, L_3 …

Continuous current-carrying capacity

The Tables 13-4 to 13-12 below give values for the continuous current-carrying capacity of different cross-sections of *copper* (see DIN 43671) and *aluminium* (see DIN 43670).

For *indoor installations*[1], the tables are based on the following assumptions:

1. ambient air still,
2. bare conductors partly oxidized, giving a radiation coefficient of 0.40 (Cu) and 0.35 (Al), or
3. conductors painted (only the outside surfaces in the case of composite busbars), giving a radiation coefficient of approx. 0.90.

For *outdoor installations,* the tables are based on the following assumptions:

1. slight air movement, e.g. due to ground thermals, of 0.6 m/s,
2. bare conductors normally oxidized, giving a radiation coefficient of 0.60 (Cu) and 0.50 (Al), possible solar irradiation 0.45 (Cu) and 0.35 (Al) kW/m^2, or
3. conductors painted, giving a radiation coefficient of approx. 0.90 and solar irradiation of 0.7 kW/m^2.
   The values for outdoor installations thus correspond to central European conditions.

[1] For open-type indoor installations, the values stated in the tables can be multiplied by between 1.05 and 1.1 since it is found that slight air movements independent of the busbars occur in such cases.

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Continuous current-carrying capacity of copper conductors (DIN 43 671)

Table 13-4

Copper conductors of rectangular cross-section in indoor installations. Ambient temperature 35 °C. Conductor temperature 65 °C. Conductor width vertical: clearance between conductors equal to conductor thickness; with alternating current, clearance between phases > 0.8 × phase centre-line distance.

Width × thickness	Cross-section	Weight[1)]	Material[3)]	Continuous current in A AC up to 60 Hz painted no. of conductors				bare no. of conductors				Continuous current in A DC and AC 16⅔ Hz painted no. of conductors				bare no. of conductors			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
							50[2)]				50[2)]								
mm	mm^2	kg/m																	
12 × 5	59.5	0.529	E-Cu F 37	203	345	411		177	312	398		203	345	411		177	312	398	
12 × 10	119.5	1.063	E-Cu F 37	326	605	879		285	553	811		326	605	879		285	553	811	
20 × 5	99.1	0.882	E Cu F 37	319	560	728		274	500	690		320	562	729		274	502	687	
20 × 10	199	1.77	E-Cu F 30	497	924	1 320		427	825	1 180		499	932	1 300		428	832	1 210	
30 × 5	149	1.33	E-Cu F 37	447	760	944		379	672	896		448	766	950		380	676	897	
30 × 10	299	2.66	E-Cu F 30	676	1 200	1 670		573	1 060	1 480		683	1 230	1 630		579	1 080	1 520	
40 × 5	199	1.77	E-Cu F 37	573	952	1 140		482	836	1 090		576	966	1 160		484	848	1 100	
40 × 10	399	3 55	E-Cu F 30	850	1 470	2 000	2 580	715	1 290	1 770	2 280	865	1 530	2 000		728	1 350	1 880	

1) Calculated for a density of 8.9 kg/dm^3.

2) Minimum clearance given in mm.

3) Material: E-Cu or other material to DIN 40500 Part 3, preferred semi-finished material. Flat bars with rounded edges to DIN 46433 Selection Part 3.

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Table 13-4 (continued)

Copper conductors of rectangular cross-section in indoor installations. Ambient temperature 35 °C. Conductor temperature 65 °C. Conductor width vertical: clearance between conductors equal to conductor thickness; with alternating current, clearance between phases > 0.8 × phase centre-line distance.

Width × thickness	Cross-section	Weight[1)]	Material[3)]	Continuous current in A AC up to 60 Hz painted no. of conductors 1	2	3	4 (50[2)])	bare no. of conductors 1	2	3	4 (50[2)])	Continuous current in A DC and AC 16⅔ Hz painted no. of conductors 1	2	3	4	bare no. of conductors 1	2	3	4
mm	mm²	kg/m																	
50 × 5	249	2.22	E-Cu F 37	679	1 140	1 330	2 010	583	994	1 240	1 920	703	1 170	1370		588	1 020	1 300	
50 × 10	499	4.44	E-Cu F 30	1 020	1 720	2 320	2 950	852	1510	2 040	2 600	1 050	1 830	2 360		875	1 610	2 220	
60 × 5	299	2.66	E-Cu F 30	826	1 330	1 510	2 310	688	1 150	1 440	2 210	836	1 370	1 580	2 060	696	1 190	1 500	1 970
60 × 10	599	5.33	E-Cu F 30	1 180	1 960	2 610	3 290	985	1 720	2 300	2 900	1 230	2 130	2 720	3 580	1 020	1 870	2 570	3 390
80 × 5	399	3.55	E-Cu F 30	1 070	1 680	1 830	2 830	885	1 450	1 750	2 720	1 090	1 770	1 990	2 570	902	1 530	1 890	2 460
80 × 10	799	7.11	E-Cu F 30	1 500	2 410	3 170	3 930	1 240	2 110	2 790	3 450	1 590	2 730	3 420	4 490	1 310	2 380	3 240	4 280
100 × 5	499	4.44	E-Cu F 30	1 300	2 010	2 150	3 300	1 080	1 730	2 050	3 190	1 340	2 160	2 380	3 080	1 110	1 810	2 270	2 960
100 × 10	988	8.89	E-Cu F 30	1 810	2 850	3 720	4 530	1 490	2 480	3 260	3 980	1 940	3 310	4100	5 310	1 600	2 890	3 900	5 150
120 × 10	1 200	10.7	E-Cu F 30	2 110	3 280	4 270	5 130	1 740	2 860	3 740	4 500	2 300	3 900	4 780	6 260	1 890	3 390	4 560	6 010
160 × 10	1 600	14.2	E-Cu F 30	2 700	4 130	5 360	6 320	2 220	3 590	4 680	5 530	3 010	5 060	6 130	8 010	2 470	4 400	5 860	7 710
200 × 10	2 000	17.8	E-Cu F 30	3 290	4 970	6 430	7 490	2 690	4 310	5 610	6 540	3 720	6 220	7 460	9 730	3 040	5 390	7 150	9 390

1) Calculated for a density of 8.9 kg/dm³.

2) Minimum clearance given in mm.

3) Material: E-Cu or other material to DIN 40500 Part 3 preferred semi-finished material. Flat bars with rounded edges to DIN 46433 Selection Part 3.

Table 13-5

Copper conductors of annular cross-section, ambient temperature 35 °C, conductor temperature 65 °C, with alternating current, phase centre-line distance ≧ 2.5 × outside diameter

Outside diameter D mm	Wall-thickness a mm	Cross-section mm²	Weight[1] kg/m	Material[2]	Continuous in A DC and AC up to 60 Hz indoor painted	bare	outdoor painted	bare
20	2	113	1.01	E-Cu F 37	384	329	460	449
	3	160	1.43	E-Cu F 37	457	392	548	535
	4	201	1.79	E-Cu F 30	512	438	613	599
	5	236	2.10	E-Cu F 30	554	475	664	648
	6	264	2.35	E-Cu F 25	591	506	708	691
32	2	188	1.68	E-Cu F 37	602	508	679	660
	3	273	2.44	E-Cu F 37	725	611	818	794
	4	352	3.14	E-Cu F 30	821	693	927	900
	5	424	3.78	E-Cu F 30	900	760	1 020	987
	6	490	4.37	E-Cu F 25	973	821	1 100	1 070
40	2	239	2.13	E-Cu F 37	744	624	816	790
	3	349	3.11	E-CU F 37	899	753	986	955
	4	452	4.04	E-Cu F 30	1 020	857	1 120	1 090
	5	550	4.90	E-Cu F 30	1 130	944	1 240	1 200
	6	641	5.72	E-Cu F 25	1 220	1 020	1 340	1 300
50	3	443	3.95	E-Cu F 37	1 120	928	1 190	1 150
	4	578	5.16	E-Cu F 30	1 270	1 060	1 360	1 310
	5	707	6.31	E-Cu F 30	1 410	1 170	1 500	1 450
	6	829	7.40	E-Cu F 25	1 530	1 270	1 630	1 570
	8	1 060	9.42	E-Cu F 25	1 700	1 420	1 820	1 750
63	3	565	5.04	E-Cu F 30	1 390	1 150	1 440	1 390
	4	741	6.61	E-Cu F 30	1 590	1 320	1 650	1 590
	5	911	8.13	E-Cu F 30	1 760	1 460	1 820	1 750
	6	1 070	9.58	E-Cu F 25	1 920	1 590	1 990	1 910
	8	1 380	12.3	E-Cu F 25	2 150	1 780	2 230	2 140
80	3	726	6.47	E-Cu F 30	1 750	1 440	1 760	1 690
	4	955	8.52	E-Cu F 30	2 010	1 650	2 020	1 930
	5	1 180	10.5	E-Cu F 30	2 230	1 820	2 230	2 140
	6	1 400	12.4	E-Cu F 25	2 430	1 990	2 440	2 340
	8	1 810	16.1	E-Cu F 25	2 730	2 240	2 740	2 630
100	3	914	8.15	E-Cu F 30	2 170	1 770	2 120	2 020
	4	1 210	10.8	E-Cu F 30	2 490	2 030	2 430	2 320
	5	1 490	13.3	E-Cu F 30	2 760	2 250	2 700	2 580
	6	1 770	15.8	E-Cu F 25	3 020	2 460	2 950	2 820
	8	2 310	20.6	E-Cu F 25	3 410	2 780	3 330	3 180

[1] Calculated for a density of 8.9 kg/dm³. Preferred outside diameters in heavy type.

[2] Material: E-Cu or other material to DIN 40500 Part 2; preferably semi-finished material to be used: tube to DIN 1754.

Table 13-6

Copper conductors of round cross-section (round copper bar), ambient temperature 35 °C, conductor temperature 65 °C; with alternating current, phase centre-line distance ≧ 2 × diameter.

Diameter D mm	Cross-section a mm^2	Weight[1)] kg/m	Material[2)]	Continuous current in A DC and AC up to 60 Hz painted	 bare
5	19.6	0.175	E-Cu F 37	95	85
8	50.3	0.447	E-Cu F 37	179	159
10	78.5	0.699	E-Cu F 37	243	213
16	210	1.79	E-Cu F 30	464	401
20	314	2.80	E-Cu F 30	629	539
32	804	7.16	E-Cu F 30	1 160	976
50	1960	17.50	E-Cu F 30	1 930	1 610

[1)] Calculated for a density of 8.9 kg/dm^3.
[2)] Material: E-Cu or other material to DIN 40500 Part 3, preferably semi-finished product to be used: round bars to DIN 1756.

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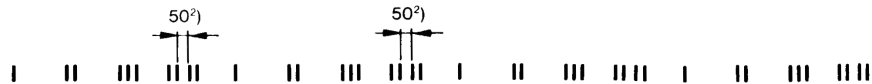
Continuous current-carrying capacity of aluminium conductors (DIN 43670)

Table 13-7

Aluminium conductors of rectangular cross-section in indoor installations. Ambient temperature 35 °C. Conductor temperature 65 °C. Conductor width vertical: clearance between conductors equal to conductor thickness; with alternating current, clearance between phases > 0.8 × phase centre-line distance.



Width × thickness	Cross-section	Weight[1]	Material[3]	Continuous current in A AC up to 60 Hz painted no. of conductors 1	2	3	4	bare no. of conductors 1	2	3	4	Continuous current in A DC and AC 16⅔ Hz painted no. of conductors 1	2	3	4	bare no. of conductors 1	2	3	4
mm	mm²	kg/m																	
12 × 5	59.5	0.160	E-Al F 10	160	292	398		139	263	375		160	292	398		139	263	375	
12 × 10	119.5	0.322	E-Al F 10	257	490	720		224	440	652		257	490	720		224	440	652	
20 × 5	99.1	0.268	E-Al F 10	254	446	570		214	392	537		254	446	576		214	392	539	
20 × 10	199	0.538	E-Al F 10	393	730	1 060		331	643	942		393	733	1 020		331	646	943	
30 × 5	149	0.403	E-Al F 10	356	606	739		295	526	699		356	608	749		296	528	703	
30 × 10	299	0.808	E-Al F 10	536	956	1340		445	832	1 200		538	964	1 280		447	839	1 180	
40 × 5	199	0.538	E-Al F 10	456	762	898		376	658	851		457	766	915		376	662	862	
40 × 10	399	1.08	E-Al F 10	677	1 180	1 650	2 190	557	1 030	1 460	1 900	682	1200	1 570		561	1 040	1 460	
50 × 5	249	0.673	E-Al F 10	556	916	1 050	1 580	455	786	995	1 520	558	924	1 080		456	794	1 020	
50 × 10	499	1.35	E-Al F 10	815	1 400	1 940	2 540	667	1 210	1 710	2 210	824	1 140	1 850		674	1 250	1 730	
60 × 5	299	0.808	E-Al F 10	655	1 070	1 190	1 820	533	910	1 130	1 750	658	1 080	1 240	1 610	536	924	1 170	1 530
60 × 10	599	1.62	E-Al F 10	951	1 610	2 200	2 870	774	1 390	1 940	2 480	966	1 680	2 130	2 810	787	1 450	2 000	2 650

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Table 13-7 (continued)

Width × thickness	Cross-section	Weight[1]	Material[3]	Continuous current in A, AC up to 60 Hz, painted, no. of conductors 1	2	3	4	bare, no. of conductors 1	2	3	4	Continuous current in A, DC and AC 16⅔ Hz, painted, no. of conductors 1	2	3	4	bare, no. of conductors 1	2	3	4
mm	mm²	kg/m		I	II	III	II II (50[2])	I	II	III	II II (50[2])	I	II	III	II II	I	II	III	II II
80 × 5	399	1.08	E-Al F 10	851	1 360	1 460	2 250	688	1 150	1 400	2 180	858	1 390	1 550	2 010	694	1 180	1 470	1 920
80 × 10	799	2.16	E-Al F 10	1 220	2 000	2 660	3 460	983	1 720	2 380	2 990	1 250	2 150	2 670	3 520	1 010	1 840	2 520	3 340
100 × 5	499	1.35	E-Al F 6.5	1 050	1 650	1 730	2 660	846	1 390	1 660	2 580	1 060	1 710	1 870	2 420	858	1 450	1 780	2 320
100 × 10	999	2.70	E-Al F 6.5	1 480	2 390	3 110	4 020	1 190	2 050	2 790	3 470	1 540	2 630	3 230	4 250	1 240	2 250	3 060	4 050
100 × 15	1 500	4.04	E-Al F 6.5	1 800	2 910	3 730	4 490	1 450	2 500	3 220	3 380	1 930	3 380	4 330	5 710	1 560	2 900	4 070	5 400
120 × 10	1 200	3.24	E-Al F 6.5	1 730	2 750	3 540	4 560	1 390	2 360	3 200	3 930	1 830	3 090	3 770	4 940	1 460	2 650	3 580	4 730
120 × 15	1 800	4.86	E-Al F 6 5	2 090	3 320	4 240	5 040	1 680	2 850	3 650	4 350	2 280	3 950	5 020	6 610	1 830	3 390	4 740	6 280
160 × 10	1 600	4.32	E-Al F 6.5	2 220	3 470	4 390	5 610	1 780	2 960	4 000	4 820	2 380	4 010	4 820	6 300	1 900	3 420	4 590	6 060
160 × 15	2 400	6.47	E-Al F 6.5	2 670	4 140	5 230	6 120	2 130	3 540	4 510	5 270	2 960	5 090	6 370	8 380	2 370	4 360	6 040	8 000
200 × 10	2 000	5.40	E-Al F 6.5	2 710	4 180	5 230	6 660	2 160	3 560	4 790	5 710	2 960	4 940	5 880	7 680	2 350	4 210	5 620	7 400
200 × 15	3 000	8.09	E-Al F 6.5	3 230	4 950	6 240	7 190	2 580	4 230	5 370	6 190	3 660	6 250	7 740	10 160	2 920	5 350	7 370	9 750

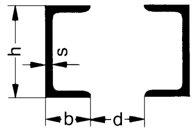
[1] Calculated for a density of 2.7 kg/dm³.

[2] Minimum clearance given in mm.

[3] Material: E-Al or other material to DIN 40501 Part 3, preferred semi-finished material. Flat bars with rounded edges to DIN 46 433 Selection Part 3.

Table 13-8

Aluminium conductors of U-section in indoor installations, ambient temperature 35 °C, conductor temperature 65 °C.



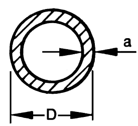
When facing [ ], gap vertical; with alternating current, phase centre-line distance ≧ 2*h*

Material: E-Al or other material to DIN 40501 Part 3; semi-finished product to be used; channel sections to DIN 46424.

Dimensions				Cross-section		Weight[1)]		Material	Continuous current in A DC and AC up to 60 Hz painted		bare	
h mm	*b* mm	*s* mm	*d* mm	[mm²	[] mm²	[kg/m	[] kg/m		[	[]	[	[]
60	30	4	25	448	896	1.22	2.44	E-Al F 6.5	880	1 800	685	1 370
80	37.5	6	25	858	1 720	2.32	4.64	E-Al F 8	1 460	2 540	1 140	2 000
100	37.5	8	25	1 270	2 540	3.47	6.94	E-Al F 8	2 000	3 450	1 550	2 700
120	45	10	30	1 900	3 800	5.17	10.3	E-Al F 8	2 720	4 700	2 100	3 750
140	52.5	11	35	2 450	4 900	6.66	13.3	E-Al F 8	3 350	5 800	2 600	4 600
160	60	12	40	3 070	6 140	8.34	16.7	E-Al F 8	4 000	7 000	3 100	5 400
180	67.5	13	45	3 760	7 520	10.2	20.4	E-Al F 8	4 750	8 200	3 800	6 400
200	75	14	50	4 510	9 020	12.2	24.4	E-Al F 8	5 500	9 500	4 300	7 400

1) Calculated for a density of 2.7 kg/dm³.

Table 13-9



Aluminium conductors of annular cross-section, ambient temperature 35 °C, conductor temperature 65 °C; with alternating current, phase centre-line distance ≧ 2.0 × outside diameter.

Outside diameter D mm	Wall-thickness a mm	Cross-section mm²	Weight[1)] kg/m	Material[2)]	Continuous current in A DC and AC up to 60 Hz indoor painted	bare	Continuous current in A outdoor painted	bare
20	2	113	0.305	E-Al F 10	305	257	365	354
	3	160	0.433	E-Al F 10	363	305	435	421
	4	201	0.544	E-Al F 10	407	342	487	472
	5	236	0.636	E-Al F 10	440	370	527	511
	6	264	0.713	E-Al F 10	465	392	558	540

1) Calculated for a density of 2.7 kg/dm³. Preferred outside diameters in heavy type.
2) Material: E-Al or other material to DIN 40501 Part 2; preferably semi-finished product to be used. Tube to DIN 1795, DIN 9107.

Continued on next page

Table 13-9 (continued)

Outside diameter D mm	Wall-thickness a mm	Cross-section mm²	Weight[1)] kg/m	Material[2)]	Continuous current in A DC and AC up to 60 Hz indoor painted	bare	Continuous current in A outdoor painted	bare
32	2	188	0.509	E-Al F 10	478	395	539	519
	3	273	0.739	E-Al F 10	575	476	649	624
	4	352	0.950	E-Al F 10	653	539	737	708
	5	424	1.15	E-Al F 10	716	592	808	777
	6	490	1.32	E-Al F 10	769	636	868	835
40	2	239	0.645	E-Al F 10	591	485	648	621
	3	349	0.942	E-Al F 10	714	595	783	750
	4	452	1.22	E-Al F 10	813	667	892	854
	5	550	1.48	E-Al F 10	896	734	982	941
	6	641	1.73	E-Al F 10	966	792	1 060	1020
50	4	578	1.56	E-Al F 10	1 010	822	1 080	1030
	5	707	1.91	E-Al F 10	1 120	909	1 190	1 140
	6	829	2.24	E-Al F 10	1 210	983	1 290	1 230
	8	1 060	2.85	E-Al F 7	1 370	1 110	1 460	1390
	10	1 260	3.39	E-Al F 7	1 490	1 210	1 580	1 510
63	4	741	2.00	E-Al F 10	1 270	1 020	1 310	1 240
	5	911	2.46	E-Al F 10	1 400	1 130	1 450	1 380
	6	1 070	2.89	E-Al F 10	1 520	1 230	1 570	1 490
	8	1 380	3.73	E-Al F 7	1 730	1 390	1 790	1 700
80	4	955	2.58	E-Al F 10	1 600	1 280	1 600	1 510
	5	1 180	3.18	E-Al F 10	1 770	1 420	1 780	1 680
	6	1 400	3.77	E-Al F 10	1 920	1 540	1 930	1 820
	8	1 810	4.89	E-Al F 7	2 200	1 760	2 200	2 080
	10	2 200	5.94	E-Al F 7	2 410	1 920	2 420	2 280
100	4	1 210	3.26	E-Al F 10	1 980	1 570	1 930	1 820
	5	1 490	4.03	E-Al F 10	2 200	1 750	2 150	2 020
	6	1 770	4.78	E-Al F 10	2 390	1 900	2 340	2 200
	8	2 310	6.24	E-Al F 7	2 740	2 170	2 670	2 510
120	4	1 460	3.94	E-Al F 10	2 360	1 860	2 250	2 100
	5	1 810	4.88	E-Al F 10	2 620	2 070	2 500	2 340
	6	2 150	5.80	E-Al F 10	2 860	2 250	2 730	2 550
	8	2 820	7.60	E-Al F 7	3 270	2 580	3 120	2 920
	10	3 460	9.33	E-Al F 7	3 590	2 830	3 420	3 200
160	4	1 960	5.29	E-Al F 10	3 110	2 430	2 910	2 710
	5	2 440	6.57	E-Al F 10	3 460	2 710	3 240	3 010
	6	2 900	7.84	E-Al F 10	3 780	2 950	3 530	3 290
	8	3 820	10.3	E-Al F 7	4 340	3 390	4 060	3 780
	10	4 710	12.7	E-Al F 7	4 760	3 720	4 460	4 140

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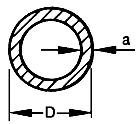
Table 13-9 (continued)

Outside diameter D mm	Wall-thickness a mm	Cross-section mm²	Weight[1)] kg/m	Material[2)]	Continuous current in A DC and AC up to 60 Hz indoor painted	bare	Continuous current in A outdoor painted	bare
200	5	3 060	8.27	E-Al F 10	4 290	3 330	3 960	3 670
	6	3 660	9.87	E-Al F 10	4 690	3 640	4 320	4 000
	8	4 830	13.0	E-Al F 7	5 390	4 180	4 970	4 600
	10	5 970	16.1	E-Al F 7	5 920	4 600	5 460	5 060
	12	7 090	19.1	E-Al F 7	6 330	4 910	5 830	5 400
250	5	3 850	10.4	E-Al F 10	5 330	4 100	4 840	4 460
	6	4 600	12.4	E-Al F 10	5 810	4 480	5 280	4 870
	8	6 080	16.4	E-Al F 7	6 690	5 160	6 080	5 610
	10	7 540	20.4	E-Al F 7	7 360	5 680	6 690	6 170
	12	8 970	24.2	E-Al F 7	7 870	6 070	7 150	6 600

Continuous current-carrying capacity of Al Mg Si conductors

Table 13-10



Conductors of E-AlMgSi 0.5 F 22, annular cross-section, κ = 30 m/Ωmm² at ambient temperature 35 °C and conductor temperature 85 °C with AC, phase centre-line distance ≧ 2 × outside diameter

Outside diameter D mm	Wall-thickness a mm	Cross-section mm²	Weight kg/m	Continuous current in A[1)] DC and AC up to 60 Hz indoor painted	bare	outdoor painted	bare
20	2	113	0.305	372	314	446	432
	3	160	0.433	443	372	531	514
	4	201	0.544	497	418	595	576
	5	236	0.636	537	452	643	624
	6	264	0.713	568	479	681	659
32	2	188	0.509	584	482	658	634
	3	273	0.739	702	581	792	762
	4[2)]	352	0.950	797	658	900	864
	5	424	1.15	874	723	987	949
	6	490	1.32	939	777	1 060	1 020
40	2	239	0.645	721	592	791	758
	3	349	0.942	872	714	958	916
	4	452	1.22	993	814	1 089	1 042
	5[2)]	550	1.48	1 094	896	1 199	1 149
	6	641	1.73	1 179	967	1 294	1 245

Continued on next page

Table 13-10 (continued)

Outside diameter D mm	Wall-thickness a mm	Cross-section mm²	Weight kg/m	Continuous current in A[1] DC and AC up to 60 Hz indoor painted	bare	outdoor painted	bare
50	4[2]	578	1.56	1 233	1 004	1 319	1 258
	5	707	1.91	1 368	1 110	1 453	1 392
	6	829	2.24	1 477	1 200	1 575	1 502
	8[2]	1 060	2.85	1 673	1 355	1 783	1 697
	10	1 260	3.39	1 819	1 477	1929	1844
63	4	741	2.00	1 551	1 245	1 600	1 514
	5[2]	911	2.46	1 709	1 380	1 770	1 685
	6	1 070	2.90	1 856	1 502	1 917	1 819
	8[2]	1 380	3.73	2 112	1 697	2 186	2 076
80	4	955	2.58	1 954	1 563	1 954	1 844
	5[2]	1 180	3.18	2 161	1 734	2 173	2 051
	6[2]	1 400	3.77	2 344	1 880	2 357	2 222
	8[2]	1 810	4.89	2 686	2 149	2 686	2 540
	10	2 200	5.94	2 943	2 344	2 955	2 784
100	4	1 210	3.26	2 420	1 915	2 355	2 220
	5	1 490	4.03	2 685	2 135	2 625	2 466
	6	1 770	4.78	2 920	2 320	2 855	2 685
	8	2 310	6.24	3 345	2 650	3 260	3 065
120	4	1 460	3.94	2 880	2 270	2 745	2 565
	5	1 810	4.88	3 200	2 525	3 055	2 855
	6	2 150	5.80	3 490	2 745	3 335	3 115
	8	2 820	7.60	3 995	3 150	3 810	3 565
	10	3 460	9.33	4 385	3 455	4 175	3 905
160	4	1 960	5.29	3 795	2 965	3 555	3 310
	5	2 440	6.57	4 225	3 310	3 955	3 675
	6	2 900	7.84	4 615	3 600	4 310	4 015
	8	3 820	10.3	5 300	4 140	4 955	4 615
	10	4 710	12.7	5 810	4 540	5 445	5 055
200	5	3 060	8.27	5 240	4 065	4 835	4 480
	6	3 660	9.87	5 725	4 445	5 275	4 885
	8	4 830	13.0	6 580	5 105	6 070	5 615
	10	5 970	16.1	7 230	5 615	6 665	6 180
	12	7 090	19.1	7 730	5 995	7 120	6 595
250	5	3 850	10.4	6 510	5 005	5 910	5 445
	6	4 600	12.4	7 095	5 470	6 445	5 945
	8	6 080	16.4	8 170	6 300	7 425	6 850
	10	7 540	20.4	8 985	6 945	8 170	7 535
	12	8 970	24.2	9 610	7 410	8 730	8 060

[1] The currents have been calculated from Table 13-9 with account taken of the correction factors k_1 = 0.925 as in Fig. 13-3 and k_2 = 1.32 as in Fig. 13-4. With an ambient temperature of 50 °C and a conductor temperature of 85 °C, the currents must be multiplied by the correction factor 0.82.

[2] Preferred wall thickness

Continuous current-carrying capacity of copper-clad aluminium conductors (DIN 43 670, Part 2)

Table 13-11

Copper-clad aluminium conductors of rectangular cross-section in indoor installations, ambient temperature 35 °C, conductor temperature 65 °C. Conductor width vertical: clearance between conductors equal to conductor thickness; with alternating current, clearance between phases > 0.8 × phase centre-line distance.

Width × thickness	Cross-section	Weight[1]	Continuous current in A AC up to 60 Hz painted no. of conductors				bare no. of conductors				Continuous current in A DC and AC 16⅔ Hz painted no. of conductors				bare no. of conductors			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
						50[2]				50[2]								
mm	mm²	kg/m	I	II	III	II II	I	II	III	II II	I	II	III	II II	I	II	III	II II
12 × 5	59.8	0.217	177	324	440		154	292	416		177	324	442		154	292	416	
12 × 10	120	0.434	284	542	796		248	488	722		285	544	778		248	488	722	
20 × 5	98.7	0.358	265	464	594		225	415	562		265	464	600		225	415	565	
20 × 10	192	0.698	408	760	1 100		350	680	985		408	763	1 060		350	632	985	
30 × 5	148	0.538	370	630	772		313	555	733		370	632	780		313	556	736	
30 × 10	292	1.06	555	993	1 390		472	870	1 260		558	1 000	1 330		475	876	1 240	
40 × 5	198	0.719	474	794	937		400	700	895		475	798	953		400	702	905	
40 × 10	392	1.42	705	1 230	1 720	2 280	595	1 090	1 540	2 000	710	1 250	1 640		600	1 100	1 540	

Material: E-Al to DIN 40 501 Parts 2 and 3 and E-Cu to DIN 40 500 Parts 2 and 3, copper cladding comprises 15 % of cross-section area.

[1] Calculated for a density of 3.63 kg/dm³

[2] Minimum clearance given in mm.

(continued)

Table 13-11 (continued)

Copper-clad aluminium conductors of rectangular cross-section in indoor installations. Ambient temperature 35 °C. Conductor temperature 65 °C. Conductor width vertical: clearance between conductors equal to conductor thickness; with alternating current, clearance between phases > 0.8 × phase centre-line distance.

Width × thickness	Cross-section	Weight[1)]	Continuous current in A AC up to 60 Hz painted no. of conductors 1	2	3	4	bare no. of conductors 1	2	3	4	Continuous current in A DC and AC 16⅔ Hz painted no. of conductors 1	2	3	4	bare no. of conductors 1	2	3	4
						50[2)]				50[2)]								
mm	mm²	kg/m																
50 × 5	248	0.901	577	953	1 100	1 650	485	830	1 040	1 580	580	962	1 130		485	840	1 070	
50 × 10	492	1.79	850	1 460	2 020	2 650	705	1 280	1 890	2 340	860	1 500	1 930		713	1 320	1 810	
60 × 5	298	1.08	680	1 120	1 250	1 900	566	965	1 190	1 840	685	1 130	1 300	1 690	570	980	1 230	1 620
60 × 10	592	2.15	990	1 680	2 290	2 990	820	1 470	2 030	2 590	1 010	1 750	2 220	2 930	836	1 530	2 100	2 770
80 × 5	398	1.45	890	1 420	1 540	2 340	733	1 230	1 480	2 260	900	1 450	1 630	2 110	740	1 260	1 550	2 020
80 × 10	792	2.88	1 270	2 070	2 780	3 600	1 030	1 820	2 500	3150	1 310	2 240	2 800	3 670	1 070	1 950	2 650	3 500
100 × 10	992	3.60	1 540	2 500	3 230	4 180	1 270	2 170	2 940	3 670	1 600	2 740	3 360	4 420	1 320	2 390	3 200	4 200
120 × 10	1 192	4.32	1 870	2 850	3 640	4 540	1 540	2 480	3 250	3 980	1 980	3 320	4 330	5 620	1 630	2 880	4 130	5 360

Material: E-Al to DIN 40 501 Parts 2 and 3 and E-Cu to DIN 40 500 Parts 2 and 3, copper cladding comprises 15 % of cross-section area.

1) Calculated for a density of 3.63 kg/dm³

2) Minimum clearance given in mm

Table 13-12

Copper-clad aluminium conductors of round cross-section in indoor installations, ambient temperature 35 °C, conductor temperature 65 °C; with alternating current, phase centre-line distance ≥ 1.25 × diameter.

Diameter mm	Cross section mm²	Weight[1)] kg/m	Continuous current in A DC and AC up to 60 Hz painted	bare
5	19.6	0.0713	78	70
8	50.3	0.182	148	132
10	78.5	0.285	201	177
16	201	0.730	386	335
20	314	1.14	525	452
32	804	2.92	1 000	850
50	1960	7.13	1 750	1 500

Material: E-Al to DIN 40501 Parts 2 and 3 and E-Cu to DIN 40500 Parts 2 and 3, copper cladding comprises 15 % of cross-section area.

[1)] Calculated for a density of 3.63 kg/dm³

Correction factors for deviations from the assumptions

If there are differences between the actual conditions and the assumed conditions, the value of the continuous current taken from Tables 13-4 to 13-9, 13-11 and 13-12 must be multiplied by the following correction factors (DIN 43670, DIN 43670 Part 2 and DIN 43671):

k_1 correction factor for load capacity variations relating to conductivity,

k_2 correction factor for other air and/or busbar temperatures,

k_3 correction factor for thermal load capacity variations due to differences in layout,

k_4 correction factor for electrical load capacity variations (with alternating current) due to differences in layout,

k_5 correction factor for influences specific to location.

The current-carrying capacity is then

$$I_{cont} = I_{table} \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5.$$

The load capacity values for three-phase current with a frequency of 16⅔ Hz are the same as for direct current.

For frequencies $f_x > 50$ Hz, the load capacity value are calculated with the formula

$$I_x = I_{50} \sqrt{\frac{50}{f_x}}$$

Correction factor k_1

for load capacity variations relating to conductivity, see Fig. 13-3.

For example, in the case of the aluminium alloy E-AlMgSi 0.5 (κ = 30 m/Ωmm²), the factor k_1 = 0.925.

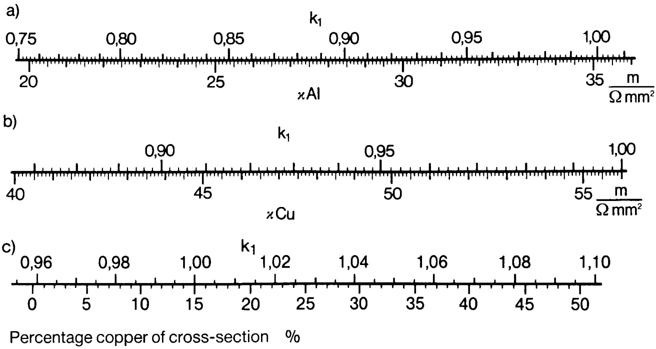


Fig. 13-3

Correction factor k_1 for variation of load capacity when conductivity differs a) from 35.1 m/Ωmm² for aluminium materials and b) from 56 m/Ωmm² for copper materials and c) factor k_1 for load capacity variation with copper-clad aluminium conductors having other than 15 % copper.

Correction factor k_2

for deviations in ambient and/or busbar temperature, see Fig. 13-4.

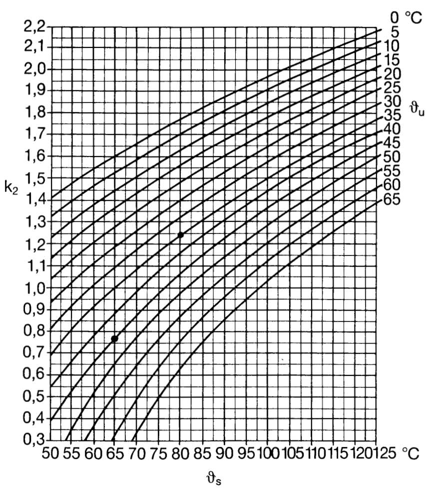


Fig. 13-4

Correction factor k_2 for load capacity variation at ambient temperatures other than 35 °C and/or busbar temperatures other than 65 °C; ϑ_s busbar temperature, ϑ_u mean ambient temperature over 24 hours, short-time maximum value 5 K above mean value.

When selecting the busbar cross-sections, attention must be paid to the maximum permissible operating temperature of the equipment and its connections, and also to heat-sensitive insulating materials. This applies in particular to metal-clad installations.

For example, at an ambient temperature of ϑ_u = 35 °C and an ultimate busbar temperature of ϑ_s = 80 °C (temperature rise 45 K), the factor k_2 = 1.24. With an ambient temperature of ϑ_u = 45 °C and an ultimate busbar temperature of ϑ_s = 65 °C (temperature rise 20 K), factor k_2 = 0.77.

Correction factor k_3

for thermal capacity load variations due to differences in layout, see Table 13-13.

Table 13-13

Correction factor k_3 for load capacity reduction with long side (width) of bus conductors in horizontal position or with busbars vertical for more than 2 m for Al = aluminium conductors DIN 43670, Al/Cu = copper-clad aluminium conductors DIN 43670 Part 2, Cu = copper conductors DIN 43671

Number of conductors	Width of busbar mm	Thickness of conductor and clearance mm	Factor k_3 when conductors painted Al	painted Al/Cu	painted Cu	bare Al	bare Al/Cu	bare Cu
2	50…100 50…200	5…10	— 0.85	0.85 —	— 0.85	— 0.8	0.8 —	— 0.8
3	50…80 100 100…200	5…10	0.85 — 0.8	0.85 0.8 —	0.85 — 0.8	0.8 — 0.75	0.8 0.75 —	0.8 — 0.75
4	up to 100 160 200		— 0.75 0.7	0.8 — —	— 0.75 0.7	— 0.7 0.65	0.75 — —	— 0.7 0.65
2	up to 200		0.95	—	—	0.9	—	—

Correction factor k_4

for electrical load capacity variations (with alternating current) due to different layout, Fig. 13-5 for copper conductors, Fig. 13-6 for aluminium conductors and 13-7 for copper-clad aluminium conductors. Factor k_4 need be considered only if there is no branching within a distance of at least 2 m.

Correction factor k_5

Influences specific to the location (altitude, exposure to sun, etc.) can be allowed for with factor k_5 as given in Table 13-14.

Table 13-14

Correction factor k_5 for reduction in load capacity at altitudes above 1000 m.

Height above sea-level m	Factor k_5 indoors	Factor k_5 outdoors[1)]
1 000	1.00	0.98
2 000	0.99	0.94
3 000	0.96	0.89
4 000	0.90	0.83

[1)] Reduction smaller at geogr. latitude above 60 ° and/or with heavily dust-laden air.

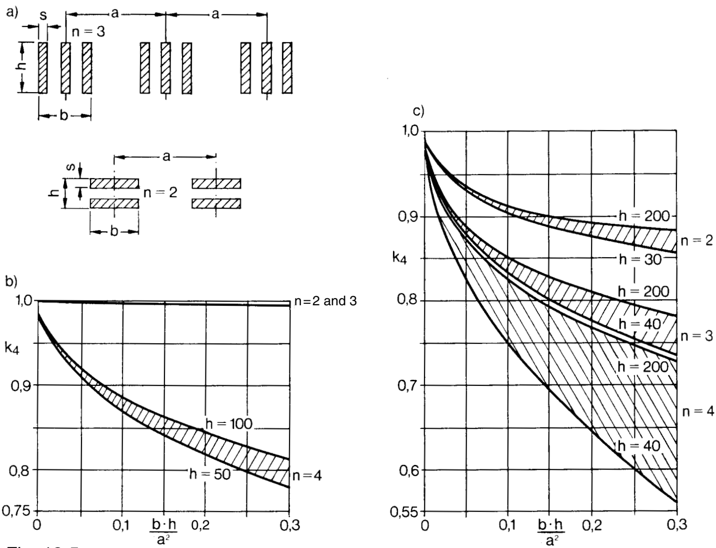
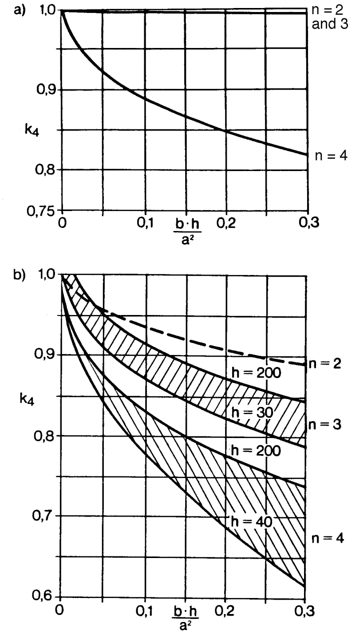


Fig. 13-5

Correction factor k_4 for reduction in load with alternating current up to 60 Hz due to additional skin effect in Cu conductors with small phase centre-line distance a:

a) Examples: Three-phase busbar with n = 3 conductors per phase and conductor thickness s in direction of phase centre-line distance a (above); AC single-phase busbar with n = 2 conductors per phase and conductor thickness s at right angles to phase centre-line distance a (below), b) Factor k_4 for conductors of s = 5 mm, and c) Factor k_4 for conductors of s = 10 mm as a function of $b \cdot h/a^2$; a, b and h in mm; parameter n = number of conductors per phase.

13



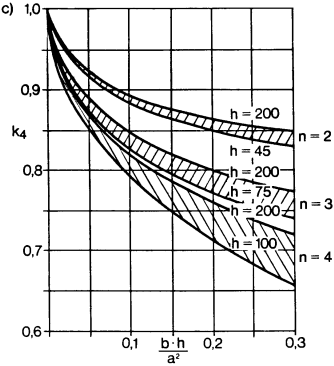
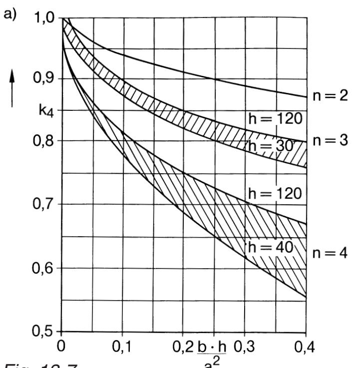


Fig. 13-6

Correction factor k_4 for reduction in load capacity with alternating current up to 60 Hz due to additional skin effect in Al conductors with small phase centre-line distance a; symbols as Fig. 13-5

a) Factor k_4 for conductor thickness s = 5 mm
b) Factor k_4 for conductor thickness s = 10 mm
c) Factor k_4 for conductor thickness s = 15 mm



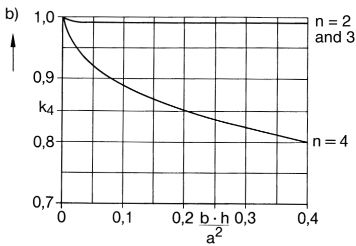


Fig. 13-7

Correction factor k_4 for reduction in load capacity with alternating current up to 60 Hz due to additional skin effect in copper-clad aluminium conductors with small phase centre-line distance a; symbols as Fig. 13-5

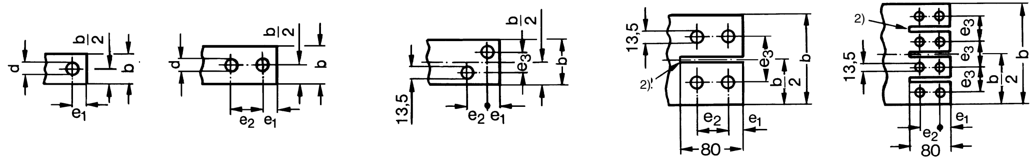
a) Factor k_4 for conductor thickness s = 10 mm
b) Factor k_4 for conductor thickness s = 5 mm

13.1.3 Drilled holes and bolted joints for busbar conductors[3)]

Table 13-15

Drilled holes for busbar conductors of rectangular cross-section (dimensions in mm)

Holes for conductor ends (drilling pattern)



Conductor widths	12 to 50		25 to 60			60			80 to 120			160 to 200		
Shape[1)]	1		2			3			4			6		
Drilling dimensions: Nominal width *b*	*d*	e_1	*d*	e_1	e_2	e_1	e_2	e_3	e_1	e_2	e_3	e_1	e_2	e_3
12	5.5	6	—	—	—	—	—	—	—	—	—	—	—	—
15	6.6	7.5	—	—	—	—	—	—	—	—	—	—	—	—
20	9.0	10	—	—	—	—	—	—	—	—	—	—	—	—
25	11	12.5	11	12.5	30	—	—	—	—	—	—	—	—	—
30	11	15	11	15	30	—	—	—	—	—	—	—	—	—

1) The shape coding 1 to 4 and 6 conforms to DIN 46206 Part 2 Flat connections.
2) With conductor widths of 120 mm and above, slots are to be provided in the end of one conductor or composite conductor. Permitted tolerance for hole-centre distance is ± 0.3 mm.
3) to DIN 43673 Parts 1 and 2

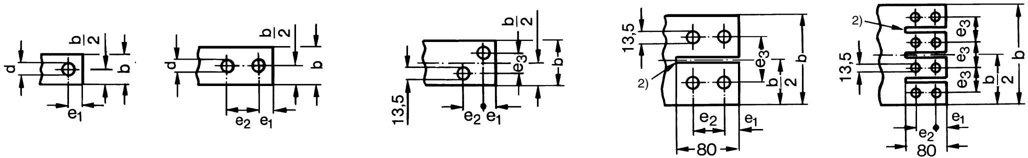
(continued)

Table 13-15 (continued)

Drilled holes for busbar conductors of rectangular cross-section (dimensions in mm)

	Conductor widths 12 to 50		Conductor widths 25 to 60			60			80 to 120			160 to 200		
Shape[1)]	1		2			3			4			6		

Holes for conductor ends (drilling pattern)



Drilling dimensions

Nominal width b	d	e_1	d	e_1	e_2	e_1	e_2	e_3	e_1	e_2	e_3	e_1	e_2	e_3
40	13.5	20	13.5	20	40	—	—	—	—	—	—	—	—	—
50	13.5	25	13.5	20	40	—	—	—	—	—	—	—	—	—
60	—	—	13.5	20	40	17	26	26	—	—	—	—	—	—
80	—	—	—	—	—	—	—	—	20	40	40	—	—	—
100	—	—	—	—	—	—	—	—	20	40	50	—	—	—
120	—	—	—	—	—	—	—	—	20	40	60	—	—	—
160	—	—	—	—	—	—	—	—	—	—	—	20	40	40
200	—	—	—	—	—	—	—	—	—	—	—	20	40	50

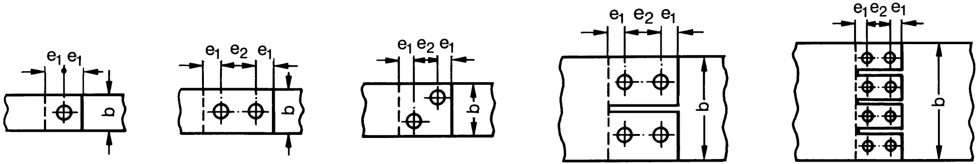
1) The shape coding 1 to 4 and 6 conforms to DIN 46 206 Part 2 Flat connections.

2) With conductor widths of 120 mm and above, slots are to be provided in the end of one conductor or composite conductor. Permitted tolerance for hole-centre distance is ± 0.3 mm.

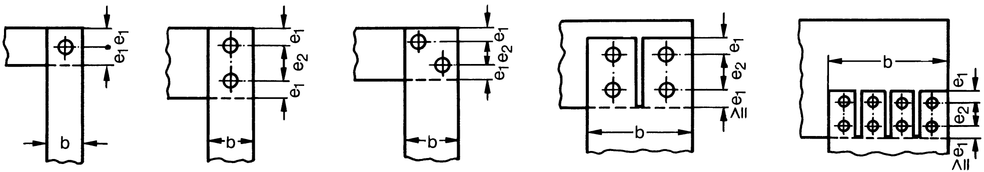
Table 13-16

Examples of bolted joints for busbar conductors of rectangular section

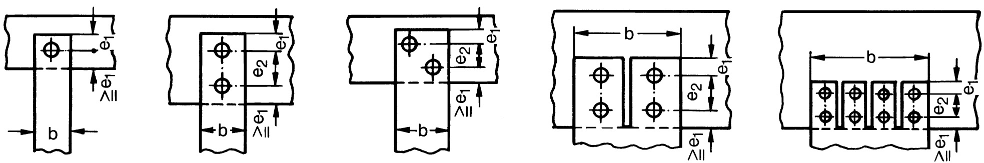
Straight joints



Angle joints



T-joints



Numerical values for *b, d,* e_1 and e_2 as Table 13-15.

Elongated holes are permissible in the end of one conductor or composite conductor.

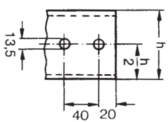
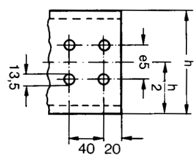
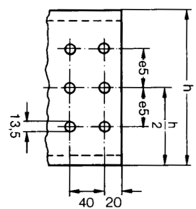
With joints having only one bolt, the conductors must be suitably supported to ensure that the joints cannot come loose.

With T-joints, the width of the horizontal conductors (generally busbar) is shown as greater than or equal to that of the tee-off. In the case of infeeds, however, if the horizontal conductor is symmetrically loaded, it is conceivable that it has only half the cross-section area. In this case, the T-joint is made with only the two upper holes.

Table 13-17

Drilled holes in U-section busbar conductors (dimensions in mm)

Holes in conductor ends

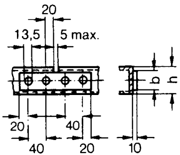
Conductor widths 60 and 80 mm	Conductor widths 100 to 160 mm	Conductor widths 180 to 200 mm
		

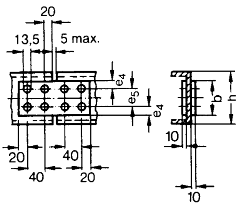
Numerical values for e_5 as Table 13-18. *h* = Height of U-section to DIN 46424. Permitted tol. for hole-centre distances: ± 0.3 mm.

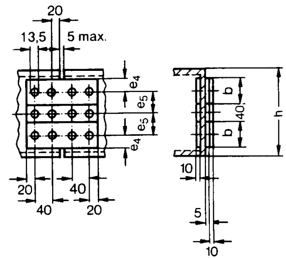
Table 13-18

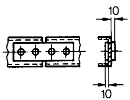
Examples of straight-bolted joints in U-section busbar conductors

Conductor widths 60 and 80 mm	Conductor widths 100 to 160 mm	Conductor widths 180 and 200 mm

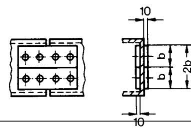








Other dimensions as above

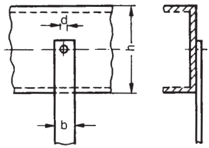


Other dimensions as above

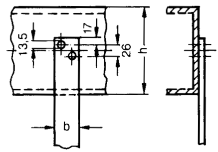
h	60	80	100	120	140	160	180	200
b	50	50	80	80	100	60	50	60
e_4	—	—	20	20	25	30	25	30
e_5	—	—	40	40	50	60	45	50

Table 13-19

Examples of bolted T-joints in U-section busbar conductors

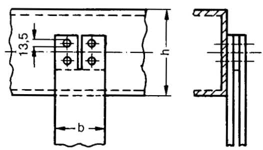


for b = 12 to 50 mm
suitable for all U-sections



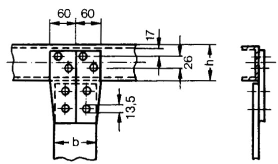
for b = 60 mm
for U-sections from U80 upwards

b	12	15	20	25	30	40	50	60
d	5.5	6.6	9	11	11	13.5	13.5	13.5



Shown for
b = 120 mm

for b = 80 to 120 mm
for U-sections from U100 upwards



b = 80 or 100 mm
for U-sections U80[1)] only

[1)] Required in this case is a fishplate comprising 2 rectangular-section bars 60 mm wide or a rectangular-section slotted bar 120 mm wide. The holes for fixing the 120 mm rectangular bar to the U80 section are then as for 2 rectangular-section bars 60 mm wide.

Designs for busbar bolts

The lubricants, referred to in Table 13-20, are commercially available. With stainless bolts and MoS_2-based lubricants attention must be paid to the specified total friction range. The various torques indicate that torque wrenches are advisable particularly with stainless bolts. The minimum contact pressure of 5 N/mm² is then maintained between – 5 °C and 90 °C and the bolts are not overstressed by short circuits. If there is any doubt regarding the friction factors of a bolt, it may be necessary to measure the torque and tension force on a sample with an appropriate number of bolts and to proceed in accordance with VDI 2230, Page 1, July 1986.

The figures in the Table are valid for DC and AC up to 60 Hz. Bolts A2-70 or A4-70 to DIN ISO 3506 are recommended for AC above 6300 A.

Table 13-20

Design of bolted joints in busbar conductors

		Indoor	Indoor and outdoor	
Bolt Strength class		8.8 or higher to DIN 267 Part 1	8.8 or higher to DIN 267 Part 1	A2-70 or A4-70 to DIN ISO 3506
Corrosion protection		A2G, A4G (gal Zn) B2G, B4G (gal Cd) to DIN ISO 4042	tZn (hot galva- nized) to DIN 267 Part 10	—
Nut Strength class		8 or higher to DIN ISO 898 Part 2	8.8 or higher to DIN ISO 898 Part 1	A2-70, A4-70, A2-80 or A4-80 to DIN ISO 3506
Corrosion protection		A2G, A4G (gal Zn) B2G, B4G (gal Cd) to DIN ISO 4042	tZn (hot galva- nized) to DIN 267 Part 10	—
Spring element Spring washer[1)]		to DIN 6796 corrosion-protected	to DIN 6796	
Lubricant on thread and head contact face		oil or grease	on MoS_2 base	
Recommended	M 4	1.5	2	
nominal	M 5	2.5	3	
torque	M 6	4.5	5.5	
N · m	M 8	10	15	
on thread	M 10	20	30	
	M 12	40	60	
	M 16	80	120	

1) Other spring elements capable of maintaining the required contact pressure may be used. Flat washers may also be needed.

The nominal torques are selected so that softer materials experience a contact pressure of roughly 7 to 20 N/mm², except for some torque values with bolts M 10 and

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M 12. The nominal torques are determined according to circumstances listed in Table 13-21.

Table 13-21

Conditions for calculating nominal torques

		Indoor	Indoor and outdoor	
Bolt, nut, surface		gal Zn, gal Cd	tZn	A2-70, A4-70
Lubricant		Oil or grease	on MoS_2 base	
Total friction coefficient μ_{tot} from		0.05	0.105	0.13
to		0.12	0.15	0.21
Tread	Engaged length (mm)	Minimum contact force obtained with nominal torque kN as Table 13-20 kN	kN	
M 4	4 to 8	1.55	1.40	
M 5	4 to 12	2.15	1.55	
M 6	4 to 18	3.20	2.60	
M8	4 to 60	4.15	3.95	
M 10	6 to 60	6.15	5.30	
M 12	10 to 120	12.6	15.1	
M 16	10 to 120	20.1	19.3	

The spring washers keep the clamping force on the bolt within acceptable limits and so secure the bolts sufficiently; if the force is inadequate, the bolt can work loose. These optimum values must be aimed for particularly on joints that are hard to access later.

It is important to note that, if necessary, agreement should be reached on test torques, taking into account the tolerances of the joints and tools.

Spring washers under bolt head and nut are recommended to increase the area of force transfer to the conductors. Footnote[1)] in Table 13-20 refers to equivalent solutions if the recommended spring washers are not used. Plain washers of equal area are also necessary if spring washers can be dispensed with, e.g. if aluminium joints are made with light-alloy bolts of sufficient strength so that differential thermal expansion does not occur.

It must be remembered that good contact between joined aluminium surfaces can be achieved only if the nonconducting oxide film is removed with a wire brush, file or similar immediately before joining, and renewed oxidation is prevented by applying a thin protective film of grease (neutral vaseline).

13.1.4 Technical values for stranded-wire conductors

Table 13-22

Copper wire conductors to DIN 48201 Part 1 (also refer to DIN VDE 0210)

	Number of strands 7	19	37	61
Max. permissible tensile stress in N/mm^2	175	175	175	175
Practical Young's modulus E in kN/mm^2	113	105	105	100
Linear expansion coefficient $\varepsilon_t \left(\frac{10^{-6}}{K}\right)$	17	17	17	17
Cross-section weight force/length $QLK \left(\frac{N}{m \times mm^2}\right)$	0.0906	0.0906	0.0906	0.0906

Table 13-23

Aluminium wire conductors to DIN 48201 Part 5 (also refer to DIN VDE 0210)

	Number of strands 7	19	37	61	91
Max. permissible tensile stress in N/mm^2	70	70	70	70	70
Practical Young's modulus E in kN/mm^2	60	57	57	55	55
Linear expansion coefficient $\varepsilon_t \left(\frac{10^{-6}}{K}\right)$	23	23	23	23	23
Cross-sectional weight force/length $QLK \left(\frac{N}{m \times mm^2}\right)$	0.0275	0.0275	0.0275	0.0275	0.0275

Table 13-24

Copper wire conductors to DIN 48201 Part 1

Nominal cross section mm^2	Rated cross section mm^2	Conductor configuration No. of strands × diameter mm	Diameter of cond. d mm	Calculated breaking force kN	Weight of cond. kg/m	Weight force/length N/m	Standard additional load[1)] N/m	Ohmic resistance at 20 °C Ω/km
10	10.02	7 × 1.35	4.1	4.02	0.090	0.882	5.41	1.8055
16	15.89	7 × 1.70	5.1	6.37	0.143	1.402	5.51	1.1385
25	24.25	7 × 2.10	6.3	9.72	0.218	2.138	5.63	0.7461
35	34.36	7 × 2.50	7.5	13.77	0.310	3.041	5.75	0.5265
50	49.48	7 × 3.00	9.0	19.38	0.446	4.375	5.90	0.3656
50	48.35	19 × 1.80	9.0	19.38	0.437	4.286	5.90	0.3760
70	65.81	19 × 2.10	10.5	26.38	0.596	5.846	6.05	0.2762
95	93.27	19 × 2.50	12.5	37.89	0.845	8.289	6.25	0.1950

(continued)

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Table 13-24 (continued)

Copper wire conductors to DIN 48201 Part 1

Nominal cross-section mm²	Rated cross-section mm²	Conductor configuration No. of strands × diameter mm	Diameter of cond. d mm	Calculated breaking force kN	Weight of cond. kg/m	Weight force/length N/m	Standard additional load[1)] N/m	Ohmic resistance at 20 °C Ω/km
120	116.99	19 × 2.80	14.0	46.90	1.060	10.398	6.40	0.1554
150	147.11	37 × 2.25	15.8	58.98	1.337	13.115	6.58	0.1238
185	181.62	37 × 2.50	17.5	72.81	1.649	16.176	6.75	0.1003
240	242.54	61 × 2.25	20.2	97.23	2.209	21.670	7.02	0.0753
300	299.43	61 × 2.50	22.5	120.04	2.725	26.732	7.25	0.0610
400	400.14	61 × 2.89	26.0	160.42	3.640	35.708	7.60	0.0457
500	499.83	61 × 3.23	29.1	200.38	4.545	44.586	7.91	0.0365

1) Normal added load due to ice to DIN VDE 0210 (5 + 0.1 d) in N/m.
The increased added load can be much greater than the normal added load and depends on location and climate.

Table 13-25

Aluminium wire conductors to DIN 48201 Part 5

Nominal cross-section mm²	Rated cross-section mm²	Conductor configuration No. of strands × diameter mm	Diameter of cond. d mm	Calculated breaking force kN	Weight of cond. kg/m	Weight force/length N/m	Standard additional load[1)] N/m	Ohmic resistance at 20 °C Ω/km
16	15.89	7 × 1.70	5.1	2.84	0.043	0.421	5.51	1.8020
25	24.25	7 × 2.10	6.3	4.17	0.066	0.647	5.63	1.1808
35	34.36	7 × 2.50	7.5	5.78	0.094	0.922	5.75	0.8332
50	49.48	7 × 3.00	9.0	7.94	0.135	1.324	5.90	0.5786
50	48.35	19 × 1.80	9.0	8.45	0.133	1.304	5.90	0.5970
70	65.81	19 × 2.10	10.5	11.32	0.181	1.775	6.05	0.4386
95	93.27	19 × 2.50	12.5	15.68	0.256	2.511	6.25	0.3095
120	116.99	19 × 2.80	14.0	18.78	0.322	3.158	6.40	0.2467
150	147.11	37 × 2.25	15.8	25.30	0.406	3.982	6.58	0.1960
185	181.62	37 × 2.50	17.5	30.54	0.500	4.905	6.75	0.1587
240	242.54	61 × 2.25	20.3	39.51	0.670	6.572	7.03	0.1191
300	299.43	61 × 2.50	22.5	47.70	0.827	8.112	7.25	0.0965
400	400.14	61 × 2.89	26.0	60.86	1.104	10.830	7.60	0.0722
500	499.83	61 × 3.23	29.1	74.67	1.379	13.527	7.91	0.0578
625	626.20	91 × 2.96	32.6	95.25	1.732	16.990	8.26	0.0462
800	802.09	91 × 3.35	36.9	118.39	2.218	21.758	8.69	0.0361
1000	999.71	91 × 3.74	41.1	145.76	2.767	27.144	9.11	0.0290

1) Normal added load due to ice to DIN VDE 0210 (5 + 0.1 d) in N/m.
The increased added load can be much greater than the normal added load and depends on location and climate.

Table 13-26

Aluminium/steel wire conductors to DIN 48204 (also refer to VDE 0210)

	Number of strands 14/7	14/19	12/7	30/7	6/1	26/7	24/7	54/7	54/19	48/7	45/7	72/7
Cross-section ratio	1.4	1.4	1.7	4.3	6	6	7.7	7.7	7.7	11.3	14.5	23.1
Max. permissible tensile stress in N/mm^2	240	240	220	140	120	120	110	110	110	95	90	80
Practical Young's modulus E in kN/mm^2	110	110	107	82	81	77	74	70	68	62	61	60
Linear expansion coefficient $\varepsilon_t \left(\frac{10^{-6}}{K}\right)$	15.0	15.0	15.3	17.8	19.2	18.9	19.6	19.3	19.4	20.5	20.9	21.7
Cross-sectional weight force/length *QLK* $\left(\frac{N}{m \times mm^2}\right)$	0.0491	0.0491	0.0466	0.0375	0.0350	0.0350	0.0336	0.0336	0.0336	0.0320	0.0309	0.0298
Rel. weight of aluminium in %	37.7	32.7	37.4	59.8	67.4	67.9	72.7	72.7	72.7	79.5	83.2	89.0

Table 13-27

Aluminium/steel wire conductors to DIN 48204

Nominal cross section mm²	Cross-section mm² Al	St	Cond. cross-section mm²	Cond. configuration No. of strands × diameter Al	St	Cross-section ratio	Diameter of cond. d mm	Calculated breaking load kN	Weight of cond. kg/m	Weight force/ length N/m	Added load[1)] N/m	Ohmic resistance at 20 °C Ω/km
16/2.5	15.27	2.54	17.8	6 × 1.8	1 × 1.8	6	5.4	5.81	0.062	0.608	5.54	1.8793
25/4	23.86	3.98	27.8	6 × 2.25	1 × 2.25	6	6.8	9.02	0.097	0.951	5.68	1.2028
35/6	34.35	5.73	40.1	6 × 2.7	1 × 2.7	6	8.1	12.70	0.140	1.373	5.81	0.8353
44/32	43.98	31.67	75.7	14 × 2.0	7 × 2.4	1.4	11.2	45.46	0.373	3.659	6.12	0.6573
50/8	48.25	8.04	56.3	6 × 3.2	1 × 3.2	6	9.6	17.18	0.196	1.922	5.96	0.5946
50/30	51.17	29.85	81.0	12 × 2.33	7 × 2.33	1.7	11.7	44.28	0.378	3.708	6.17	0.5644
70/12	69.89	11.40	81.3	26 × 1.85	7 × 1.44	6	11.7	26.31	0.284	2.786	6.17	0.4130
95/12	94.39	15.33	109.7	26 × 2.15	7 × 1.67	6	13.6	35.17	0.383	3.757	6.36	0.3058
95/55	96.51	56.30	152.8	12 × 3.2	7 × 3.2	1.7	16.0	80.20	0.714	7.004	6.60	0.2992
105/75	105.67	75.55	181.2	14 × 3.1	19 × 2.25	1.4	17.5	106.69	0.899	8.730	6.75	0.2736
120/20	121.57	19.85	141.4	26 × 2.44	7 × 1.9	6	15.5	44.94	0.494	4.846	6.55	0.2374
120/70	122.15	71.25	193.4	12 × 3.6	7 × 3.6	1.7	18.0	98.16	0.904	8.868	6.80	0.2364
125/30	127.92	29.85	157.8	30 × 2.33	7 × 2.33	4.3	16.3	57.86	0.590	5.787	6.63	0.2259
150/25	148.86	24.25	173.1	26 × 2.7	7 × 2.1	6	17.1	54.37	0.604	5.925	6.71	0.1939
170/40	171.77	40.08	211.9	30 × 2.7	7 × 2.7	4.3	18.9	77.01	0.794	7.789	6.89	0.1682
185/30	183.78	29.85	213.6	26 × 3.0	7 × 2.33	6	19.0	66.28	0.744	7.298	6.90	0.1571
210/35	209.1	34.09	243.2	26 × 3.2	7 × 2.49	6	20.3	74.94	0.848	8.318	7.03	0.1380
210/50	212.06	49.48	261.5	30 × 3.0	7 × 3.0	4.3	21.0	92.25	0.979	9.603	7.10	0.1363

[1)] Normal added load due to ice to DIN VDE 0210 (5 + 0.1 d) In N/m.
The increased added load can be much greater than the normal added load and depends on location and climate.

Continued on next page

Table 13-27 (continued)

Aluminium/steel wire conductors to DIN 48204 (see VDE 0210)

Nominal cross section mm²	Cross-section mm² Al	St	Cond. cross-section mm²	Cond. configuration No. of strands × diameter Al	St	Cross-section ratio	Diameter of cond. d mm	Calculated breaking load kN	Weight of cond. kg/m	Weight force/length N/m	Added load[1] N/m	Ohmic resistance at 20 °C Ω/km
230/30	230.91	29.85	260.8	24 × 3.5	7 × 2.33	7.7	21.0	73.09	0.874	8.573	7.10	0.1249
240/40	243.05	39.49	282.5	26 × 3.45	7 × 2.68	6	21.8	86.46	0.985	9.662	7.18	0.1188
265/35	263.66	34.09	297.8	24 × 3.74	7 × 2.49	7.7	22.4	82.94	0.998	9.790	7.24	0.1094
300/50	304.26	49.48	353.7	26 × 3.86	7 × 3.0	6	24.5	105.09	1.233	12.895	7.45	0.0949
305/40	304.62	39.49	344.1	54 × 2.68	7 × 2.68	7.7	24.1	99.30	1.155	11.330	7.41	0.0949
340/30	339.29	29.85	369.1	48 × 3.0	7 × 2.33	11.3	25.0	92.56	1.174	11.516	7.50	0.0851
380/50	381.7	49.48	431.2	54 × 3.0	7 × 3.0	7.7	27.0	120.91	1.448	14.204	7.70	0.0757
385/35	386.04	34.09	420.1	48 × 3.2	7 × 2.49	11.3	26.7	104.31	1.336	13.106	7.67	0.0748
435/55	434.29	56.30	490.6	54 × 3.2	7 × 3.2	7.7	28.8	136.27	1.647	16.157	7.88	0.0666
450/40	448.71	39.49	488.2	48 × 3.45	7 × 2.68	11.3	28.7	120.19	1.553	15.234	7.87	0.0644
490/65	490.28	63.55	553.8	54 × 3.4	7 × 3.4	7.7	30.6	152.85	1.860	18.246	8.06	0.0590
495/35	494.36	34.09	528.4	45 × 3.74	7 × 2.49	14.5	29.9	120.31	1.636	16.049	7.99	0.0584
510/45	510.54	45.28	555.8	48 × 3.68	7 × 2.87	11.3	30.7	134.33	1.770	17.363	8.07	0.0566
550/70	549.65	71.25	620.9	54 × 3.6	7 × 3.6	7.7	32.4	167.42	2.085	20.453	8.24	0.0526
560/50	561.7	49.48	611.2	48 × 3.86	7 × 3.0	11.3	32.2	146.28	1.943	19.060	8.22	0.0514
570/40	571.16	39.49	610.7	45 × 4.02	7 × 2.68	14.5	32.2	137.98	1.889	18.531	8.22	0.0506
650/45	653.49	45.28	698.8	45 × 4.3	7 × 2.87	14.5	34.4	155.52	2.163	21.219	8.44	0.0442
680/85	678.58	85.95	764.5	54 × 4.0	19 × 2.4	7.7	36.0	209.99	2.564	25.152	8.60	0.0426
1 045/45	1 045.58	45.28	1 090.9	72 × 4.3	7 × 2.87	23.1	43.0	217.87	3.249	31.872	9.30	0.0277

[1] Normal added load due to ice to DIN VDE 0210 (5 + 0.1 d) In N/m.
The increased added load can be much greater than the normal added load and depends on location and climate.

Table 13-28

Wire conductors of E-AlMgSi (aldrey) to DIN 48201, Part 6
(also refer to DIN VDE 0210)

	Number of strands 7	19	37	61	91
Max. permissible tensile stress in N/mm²	140	140	140	140	140
Practical Young's modulus E in kN/mm²	60	57	57	55	55
Linear expansion coefficient $\varepsilon_t \left(\frac{10^{-6}}{K}\right)$	23	23	23	23	23
Cross-sectional weight force/length $QLK \left(\frac{N}{m \times mm^2}\right)$	0.0275	0.0275	0.0275	0.0275	0.0275

Table 13-29

Wire conductors of E-AlMgSi (aldrey) to DIN 48201 Part 6

Nominal cross-section mm²	Rated cross-section mm²	Conductor configuration No. of strands × diameter mm	Diameter of cond. d mm	Calculated breaking force kN	Weight of cond. kg/m	Weight force/length N/m	Standard additional load[1)] N/m	Ohmic resistance at 20 °C Ω/km
16	15.89	7 × 1.70	5.1	4.44	0.043	0.421	5.51	2.0910
25	24.25	7 × 2.10	6.3	6.77	0.066	0.647	5.63	1.3702
35	34.36	7 × 2.50	7.5	9.60	0.094	0.922	5.75	0.9669
50	49.48	7 × 3.00	9.0	13.82	0.135	1.324	5.90	0.6714
50	48.35	19 × 1.80	9.0	13.50	0.133	1.304	5.90	0.6905
70	65.81	19 × 2.10	10.5	18.38	0.181	1.775	6.05	0.5073
95	93.27	19 × 2.50	12.5	26.05	0.256	2.511	6.25	0.3580
120	116.99	19 × 2.80	14.0	32.63	0.322	3.158	6.40	0.2854
150	147.11	37 × 2.25	15.8	41.09	0.406	3.982	6.58	0.2274
185	181.62	37 × 2.50	17.5	50.73	0.500	4.905	6.75	0.1842
240	242.54	61 × 2.25	20.3	67.74	0.670	6.572	7.03	0.1383
300	299.43	61 × 2.50	22.5	83.63	0.827	8.112	7.25	0.1120
400	400.14	61 × 2.89	26.0	111.76	1.104	10.830	7.60	0.0838
500	499.83	61 × 3.23	29.1	139.60	1.379	13.527	7.91	0.0671
625	626.20	91 × 2.96	32.6	174.90	1.732	16.990	8.26	0.0537
800	802.09	91 × 3.36	36.9	224.02	2.218	21.758	8.69	0.0419
1 000	999.71	91 × 3.74	41.1	279.22	2.767	27.144	9.11	0.0336

1) Normal added load due to ice to DIN VDE 0210 (5 + 0.1 d) in N/m.
The increased added load can be much greater than the normal added load and depends on location and climate.

Table 13-30

Wire conductors of aluminium/steel and aluminium not to DIN standards

Cond. cross-section Al mm²	St mm²	Total mm²	Diameter of cond. mm	Breaking load kN	Weight of cond. kg/m	Weight force/length N/m	Stand. add. load[1] N/m	Cont. current-carrying capacity[2] A	Code word[3]
152.0	24.70	176.7	17.28	57.300	0.613	6.013	6.73	460	Ostrich
170.5	39.78	210.3	18.83	77.350	0.782	7.670	6.88	500	Oriole
201.4	32.72	234.2	19.88	73.400	0.812	7.960	6.99	550	Ibis
241.7	39.48	281.1	21.80	88.200	0.975	9.56	7.18	620	Hawk
306.6	39.78	346.4	24.21	102.100	1.158	11.36	7.42	720	Duck
337.8	43.72	381.5	25.38	111.400	1.276	12.51	7.54	750	Gull
402.8	52.15	455.1	27.76	129.500	1.522	14.93	7.78	850	Condor
443.1	57.36	500.6	29.11	142.450	1.674	16.42	7.91	900	Crane
483.4	62.81	546.1	30.38	155.350	1.826	17.91	8.04	940	Cardinal
500.0	50.00	550.0	31.00	—	1.856	18.20	8.10	975	—
509.0	110.00	619.0	33.40	—	2.048	20.09	8.34	1 000	—
537.0	53.00	590.0	32.00	131.300	1.937	19.00	8.21	1 025	—
563.9	71.55	636.5	32.84	182.350	2.120	21.79	8.28	1 050	Finch
604.3	76.89	680.8	33.99	195.500	2.271	22.27	8.40	1 100	Grackle
684.8	86.66	771.5	36.17	215.900	2.574	25.25	8.62	1 200	Martin
725.1	91.78	817.0	37.21	228.600	2.725	26.73	8.72	1 250	Plover
765.4	97.03	862.4	38.25	241.750	2.877	28.22	8.83	1 300	Parrot
805.7	102.43	907.8	39.24	254.450	3.028	29.70	8.92	1 350	Falcon

[1] Normal added load due to ice to DIN VDE 0210 (5 + 0.1 d) in N/m.
The increased added load can be much greater than the normal added load and depends on location and climate.

[2] Typical values

[3] Canadian Standard sizes

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Table 13-31

Nominal cross-sections Copper, aldrey and aluminium conductors mm²	Aluminium/ steel conductors mm²	Continuous current[1)] Copper A	Aluminium A	Aldrey A	Aluminium/ steel A
10		90			
16	16/2.5	125	110	105	105
25	25/4	160	145	135	140
35	35/6	200	180	170	170
50	50/8	250	225	210	210
70	70/12	310	270	255	290
95	95/15	380	340	320	350
120	120/20	440	390	365	410
	125/30				425
150	150/25	510	455	425	470
	170/4o				520
185	185/30	585	520	490	535
	210/35				590
	210/50				610
	230/30				630
240	240/40	700	625	585	645
	265/35				680
300	300/50	800	710	670	740
	305/40				740
	340/30				790
	380/50				840
	385/35				850
400		960	855	810	
	435/55				900
	450/40				920
	490/65				960
	495/35				985
500		1 110	960	930	
	510/45				995
	550/70				1 020
	560/50				1 040
	570/40				1 050
625			1 140	1 075	
	650/45				1 120
	680/85				1 150
800			1 340	1 255	
1 000	1 045/45		1 540	1 450	1 580

1) The figures given are typical values for a wind speed of 0.6 m/s and sunshine for an ambient temperature of 35 °C and the following ultimate conductor temperatures:
Copper conductors 70 °C:
Aluminium, aldrey (E-AlMgSi) and aluminium/steel conductors 80 °C.
In special situations with no wind, values must be reduced by an average of 30 %.

Table 13-32

Stranded wires of aluminium/zirconium alloy (T Al, "hot wires")

Nominal cross-section	Rated cross-section	Cond. design Wire number × diameter	Cond. diameter d	Calculated breaking force	Standard additional[1)] load	Ohmic resistance at 20°C	at 150°C	Current-carrying capacity [2)]
mm²	mm²	mm	mm	kN	N/m	Ω/km	Ω/km	A
95	93.27	19 × 2.50	12.5	15.68	6.25	0.314	0.477	514
120	116.99	19 × 2.80	14.0	18.78	6.40	0.250	0.380	596
150	147.11	37 × 2.25	15.8	25.30	6.58	0.200	0.303	692
185	181.62	37 × 2.50	17.5	30.54	6.75	0.161	0.245	793
240	242.54	61 × 2.25	20.3	39.51	7.03	0.121	0.184	958
300	299.43	61 × 2.50	22.5	47.70	7.25	0.097	0.149	1 100
400	400.14	61 × 2.89	26.0	60.89	7.60	0.073	0.112	1 330
500	499.83	61 × 3.23	29.1	74.67	7.91	0.059	0.089	1 540
625	626.20	91 × 2.96	32.6	95.25	8.26	0.047	0.071	1 780
800	802.09	91 × 3.36	36.9	118.39	8.69	0.036	0.056	2 100
1 000	999.71	91 × 3.74	41.1	145.76	9.11	0.029	0.045	2 430

1) Normal added load due to ice as per DIN VDE 0210 (5 + 0.1 d) in N/m,
The increased supplementary load may be several times the normal added load and depends on the topographical and meteorological conditions of the site of an installation or overhead line.

2) The continuous current values are typical values, applicable for a wind speed of 0.6 m/s and the effects of the sun at an ambient temperature of 35 °C and a temperature of 150 °C at the ends of the conductors.

T Al stranded wires for overhead cables can also be used in switchgear installations at increased operating temperatures without losing mechanical strength.

The advantages of T Al stranded wires

– continuous current-carrying capacity nearly 50 % higher than Al stranded wires of the same design and cross-section
– corrosion resistance as with E-Al
– reliable continuous operating temperature to 150 °C
– short-time operating temperature (30 min) to 180 °C
– permissible temperature under short circuit currents to 250 °C
– no special fittings

T Al wires are particularly suited for later increases in the performance data of existing installations. The low weight is also an advantage in new installations. However, the cross-section of conductors connecting to devices must be selected to ensure that the permissible temperature of the connection terminals is not exceeded. For increased mechanical stress, stranded wires reinforced with steel wires are also available (T Al/stalum).

Table 13-33

Stranded wires of T Al/steel (stalum)

Nominal cross-section mm²	Cond. cross section T Al mm²	steel mm²	Cond. config. Number of strands x diameter T Al mm	steel mm	Cond. diameter d mm	Calculated breaking force kN	Standard additional load[1)] N/m	Ohmic resistance at 20 °C Ω/km	at 150 °C Ω/km	Current-carrying capacity[2)] A
25/4	23.86	3.98	6 x 2.25	1 x 2.25	6.75	9.20	5.68	1.1450	1.7404	220
35/6	34.35	5.73	6 x 2.70	1 x 2.70	8.10	12.98	5.81	0.7951	1.2085	280
44/32	43.98	31.67	14 x 2.00	7 x 2.40	11.20	47.07	6.12	0.5299	0.8054	380
50/8	48.25	8.04	6 x 3.20	1 x 3.20	9.60	17.86	5.96	0.5661	0.8491	350
50/30	51.17	29.85	12 x 2.33	7 x 2.33	11.65	45.75	6.17	0.4730	0.7189	405
95/55	96.51	56.30	12 x 3.20	7 x 3.20	16.00	85.25	6.60	0.2507	0.3180	615
105/75	105.67	75.55	14 x 3.10	19 x 225	17.45	110.45	6.75	0.2215	0.3366	675
120/70	122.15	71.25	12 x 3.60	7 x 3.60	18.00	99.57	6.80	0.1981	0.3011	760
125/30	127.92	29.85	30 x 2.33	7 x 2.33	16.31	59.36	6.63	0.2106	0.3201	675
150/25	148.66	24.25	26 x 2.70	7 x 2.10	17.10	55.58	6.71	0.1850	0.2812	735
170/40	171.77	40.08	30 x 2.70	7 x 2.70	18.90	79.01	6.89	0.1569	0.2384	823
185/30	183.78	29.85	26 x 3.00	7 x 2.33	18.99	67.78	6.90	0.1499	0.2278	820
210/50	212.06	49.48	30 x 3.00	7 x 3.00	21.00	96.70	7.10	0.1270	0.1930	945
230/30	230.91	29.85	24 x 3.50	7 x 2.33	20.99	74.58	7.10	0.1207	0.1834	970
240/40	243.05	39.49	26 x 3 45	7 x 2.68	21.84	88.43	7.18	0.1134	0.1724	1015
265/35	263.66	34.09	24 x 3.74	7 x 2.49	22.43	84.64	7.24	0.1056	0.1605	1060
300/50	304.26	29.48	26 x 3 86	7 x 3.00	24.44	109.54	7.45	0.0905	0.1376	1175
305/40	304.62	39.49	54 x 2.68	7 x 2.68	24.12	107.27	7.41	0.0917	0.1393	1160
340/30	339.29	29.85	48 x 3.00	7 x 2.33	24.99	94.06	7.50	0.0834	0.1267	1230
380/50	381.70	49.48	54 x 3.00	7 x 3.00	27.00	125.37	7.70	0.0732	0.1112	1350
385/35	386.04	34.09	48 x 3.20	7 x 2.49	26.67	106.01	7.67	0.0734	0.1115	1340
435/55	434.29	56.30	54 x 3.20	7 x 3.20	28.80	141.34	7.88	0.0643	0.0977	1470
450/40	448.71	39.49	48 x 3.45	7 x 2.68	28.74	122.16	7 87	0.0631	0.0959	1480
490/65	490.28	63.55	54 x 3.40	7 x 3.40	30.60	154.12	8.06	0.0579	0.0880	1590
550/70	549.65	72.25	54 x 3.60	7 x 3.60	32.40	168.84	8.24	0.0508	0.0772	1830
560/50	561.70	49.48	48 x 3.86	7 x 3.00	32.16	150.77	8.22	0.0504	0.0768	1715
570/40	571.16	39.49	45 x 4.02	7 x 2.68	32.16	139.96	8.22	0.0499	0.7580	1725
650/45	653.49	45.28	45 x 4.30	7 x 2.87	34.41	159.60	8.44	0.0436	0.0662	1885
680/85	678.58	85.95	54 x 4.00	19 x 2.40	36.00	214.29	8.60	0.0415	0.0630	2422

1) Normal added load due to ice as per DIN VDE 02 10 (5 + 0.1d) in N/m. The increased added load may be several times the normal added load and depends on the topographical and meteorological conditions of the site of an installation or overhead line.

2) The continuous current values are typical values, applicable for a wind speed of 0.6 m/s and the effects of the sun at an ambient temperature of 35 °C and a temperature of 150 °C at the ends of the conductors.

13.1.5 Post-type insulators and overhead-line insulators

Post-type and string insulators in substations are used to carry bare conductors. They must possess the necessary creepage distance between live parts and earth, and also withstand the electrodynamic stresses during short circuits.

Busbars, overhead line feeders and guys are usually tensioned with double dead-end strings. The insulators can be of the long-rod, cap-and-pin or plastic type (see Tables 13-36, 13-39 and 13-42). Fittings are used to join the insulators into strings. The fittings serve as mechanical attachment, electrical connection and means of protecting the insulators and conductors (DIN EN 61284 (VDE 0212 Part 1).

Fittings

Fixings to the steel structures are made with anchor links, shackles or U-bolts. The insulators are joined to their anchorages by ball-eyes, socket-eyes, double eyes and spacers, etc. Long-rod insulators with clevis end-caps are fastened to the anchors with double eyes and bolts or rivets. Cap-type insulators made up into strings (e.g. LP 75/22/1230) are joined together with twin-ball pins and attached to the other fittings with ball-eyes and socket-eyes. The joints between ball and insulator element are secured with split pins. The fittings are mostly made of hot-galvanized steel or malleable cast iron.

Anchor clamps

The conductors are attached to the insulator strings by terminal clamps which also create an electrical connection between the tensioned wires and the jumper loop .

A distinction is made between detachable terminals (keyed, conical or screw terminals) and permanent (compression) terminals. Which one is chosen depends on the particular application, see also Section 11.3.2.

Anti-arc fittings

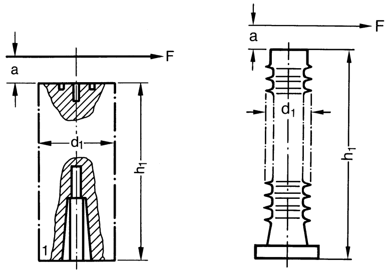
The purpose of anti-arc fittings is to intercept arcs created when an insulator flashes over and divert them away from the insulator and other parts of the string. They also serve as a means of voltage and field control along the string, so restricting corona discharges.

For rated voltages of 220 kV and above, strings of cap-and-pin insulators are provided with so-called corona rings. The effect of these is to control voltage and field, so reducing electrical stresses on the line-side insulators and thereby limiting to an acceptable value any corona discharges and the radio interference they may cause.

DIN VDE 0212 Part 55 states a partial-discharge extinction voltage of $U_m/\sqrt{3} \cdot 1.2$. This value applies to the whole insulator string i.e. including fittings and electrical connections.

Table 13-34

Moulded-resin insulators for indoor installation, principal dimensions to DIN 48136



Shape	Former voltage series	Max. permitted service voltage U_m kV	Rated lightning impulse withstand voltage U_{rB} kV	Nominal bending stress F N	*a* mm	d_1 max. dimension mm	h_1 ± 1 mm
A	10 S	12	60	3 750	30	75	95
	10 N	12	75	or		80	130
	20 S	24	95	5 000		80	175
	20 N	24	125			90	210
	30 S	36	145			90	270
	30 N	36	170			100	300
B	10 S	12	60	7 500	40	90	95
	10 N	12	75	or		100	130
	20 S	24	95	10 000		100	175
	20 N	24	125			110	210
	30 S	36	145			110	270
	30 N	36	170			130	300
C	10 S	12	60	12500	50	110	95
	10 N	12	75	or		110	130
	20 S	24	95	16000		120	175
	20 N	24	125			130	210
	30 S	36	145			130	270
	30 N	36	170			150	300
	60 S	72.5	250	7 000	50	120	570
	110 S	123	450	7 000	75	140	970
	110 N	123	550	6 000	75	140	1 180

Table 13-35

Selection criteria for outdoor post-type Insulators

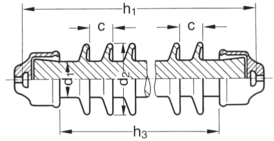
Relevant standard	Max. permitted service voltage U_m kV	Rated lightning impulse withstand voltage U_{rB} kV	Rated switching impulse withstand voltage U_{rS} kV	Insulator height H mm	Ultimate bending stress F kN 4	6	8	10	12.5	Minimum creepage distance in cm to IEC 60815 with pollution degree 1-4 referred to U_m [1)] 1 slight 1.6 cm/kV	2 average 2.0 cm/kV	3 severe 2.5 cm/kV	4 very severe 3.1 cm/kV
DIN 43632	12	75		285	×		×		×	19	24	30	37
	24	125		375	×		×		×	38	48	60	74
	36	170		490	×		×		×	57	72	90	111
IEC 60273	72.5	325	—	770		×				116	145	181	225
	123	550	—	1 220		×	×	×		197	246	307	381
	145	650	—	1 500		×				232	290	362	449
	170	750	—	1 700		×	×	×		272	340	425	527
	245	1 175	—	2 650			×	×		392	490	612	759
	(245)[2)]	1 050	—	2 300			×	×	×	392	490	612	759
DIN 48119	72.5	325	—	770			×			116	145	181	225
DIN 48120	123	550	—	1 215			×			197	246	307	381
DIN 48123	245	1 050	—	2 624			×	×	×	392	490	612	759
IEC 60273	362	1 050	950	2 900		×	×			579	724	905	1 122
	420	1 300	1 050	3 650		×	×	×	×	672	840	1 050	1 432
	525	1 425	1 175	4 000		×	×	×		840	1 050	1 312	1 627

1) Pollution degrees: *1 slight* = regions with little industry at least 10-20 km from the sea, *2 average* = industrial areas with little waste gas pollution, not immediately on coast, *3 severe* = much industry and towns with air-polluting heating systems, coastal areas, *4 very severe* = industrial centres and cities with heavy air pollution and conductive deposits, areas with heavily salt-laden coastal winds or desert areas with winds bearing much sand and salt.

2) Restricted to use in installations with earth fault factor $\delta < 1.4$.

Table 13-36a

Dimensions and nominal data of LP long-rod insulators



Symbol[1] to DIN 48006 Part 1	Symbol to IEC 433	d_1 mm	Tol. mm	No. of sheds	h_1 mm	Tol. mm	c ≈ mm	d_2 mm	Tol. mm	h_3 mm	Tol. mm
LP 60/5/380	—	60	± 3.9	5	380	± 15.5	46	120	± 6.3	260	± 11.9
LP 60/5/390	L 70 BE 245	60	± 3.9	5	390	± 15.8	46	120	± 6.3	240	± 11.1
LP 60/7/490	—	60	± 3.9	7	490	± 18.3	46	120	± 6.3	340	± 14.5
LP 60/14/830	L 100 BE 550	60	± 3.9	14	830	± 26.8	46	120	± 6.3	675	± 22.9
LP 60/19/870	L 100 BE 550	60	± 3.9	19	870	± 27.8	35	120	± 6.3	715	± 23.9
LP 60/22/1170	L 100 BE 1000	60	± 3.9	22	1 170	± 35.3	46	120	± 6.3	1 015	± 31.4
LP 60/30/1240	L 100 BE 1000	60	± 3.9	30	1 240	± 37	35	120	± 6.3	1 085	± 33.1
LP 75/14/860	L 120 BE 550	75	± 4.5	14	860	± 27.5	46	150	± 7.5	690	± 23.3
LP 75/17/860	L 120 BE 550	75	± 4.5	17	860	± 27.5	38	150	± 7.5	690	± 23.3
LP 75/22/1230	L 120 BE 1000	75	± 4.5	22	1 230	± 36.8	46	150	± 7.5	1 065	± 32.6
LP 75/22s/1230	L 120 BE 1000	75	± 4.5	22	1 230	± 36.8	46	175	± 8.5	1 065	± 32.6
LP 75/27/1230	L 120 BE 1000	75	± 4.5	27	1 230	± 36.8	38	150	± 7.5	1 065	± 32.6
LP 75/14/870	L 160 BE 550	75	± 4.5	14	870	± 27.8	46	150	± 7.5	690	± 23.3
LP 75/17/870	L 160 BE 550	75	± 4.5	17	870	± 27.8	38	150	± 7.5	690	± 23.3
LP 75/22/1250	L 160 BE 1000	75	± 4.5	22	1 250	± 37.3	46	150	± 7.5	1 065	± 32.6
LP 75/22s/1250	L 160 BE 1000	75	± 4.5	22	1 250	± 37.3	46	175	± 8.5	1 065	± 32.6
LP 75/27/1250	L 160 BE 1000	75	± 4.5	27	1 250	± 37.3	38	150	± 7.5	1 065	± 32.6
LP 85/14/900	—	85	± 4.9	14	900	± 28.5	46	160	± 7.9	690	± 23.3
LP 85/17/900	—	85	± 4.9	17	900	± 28.5	38	160	± 7.9	690	± 23.3
LP 85/22/1270	L 210 BE 1000	85	± 4.9	22	1 270	± 37.8	46	160	± 7.9	1 065	± 32.6
LP 85/22s/1270	L 210 BE 1000	85	± 4.9	22	1 270	± 37.8	46	185	± 8.9	1 065	± 32.6
LP 85/27/1270	L 210 BE 1000	85	± 4.9	27	1 270	± 37.8	38	160	± 7.9	1 065	± 32.6
LP 95/22/1300	—	95	± 5.3	22	1 300	± 38.5	46	170	± 8.3	1 065	± 32.6
LP 95/22s/1300	—	95	± 5.3	22	1 300	± 38.5	46	195	± 9.3	1 065	± 32.6
LP 95/27/1300	—	95	± 5.3	27	1 300	± 38.5	38	170	± 8.3	1 065	± 32.6
LP 105/22/1330	L 300 BE 1000	105	± 5.7	22	1 330	± 39.3	46	180	± 8.7	1 065	± 32.6
LP 105/22s/1330	L 300 BE 1000	105	± 5.7	22	1 330	± 39.3	46	205	± 9.7	1 065	± 32.6
LP 105/27/1330	L 300 BE 1000	105	± 5.7	27	1 330	± 39.3	38	180	± 8.7	1 065	± 32.6

[1] Suffix “s” denotes increased shed diameter.

(continued)

Table 13-36a (continued)

Dimensions and nominal data of LP long-rod insulators

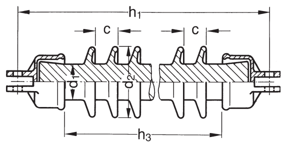
Nom. strength kN	Test strength kN	Nom. creepage distance[2)] cm	Weight[3)] kg ≈	Nom. pin size to DIN 48073	Rated power frequency withstand voltage wet kV Number of units 1	2	3	Rated lightning impulse withstand voltage kV Number of units 1	2	3
40	32	50	8	11	70	145	210	190	400	600
70	56	49	9	16	70	145	210	190	400	600
70	56	70	10	16	90	200	290	200	420	630
100	80	137	15	16	180	400	580	380	780	1170
100	80	168	16	16	195	430	640	390	800	1200
100	80	212	20	16	275	605	880	560	1 160	1730
100	80	260	22	16	300	620	900	590	1 240	1850
120	96	158	23	16	195	430	640	390	800	1200
120	96	177	24	16	195	430	640	390	800	1200
120	96	246	31	16	300	620	900	580	1 220	1820
120	96	295	38	16	300	620	900	580	1 220	1820
120	96	279	33	16	300	620	900	580	1 220	1820
160	128	158	24	20	195	430	640	390	800	1200
160	128	177	25	20	195	430	640	390	800	1200
160	128	246	32	20	300	620	900	580	1 220	1820
160	128	295	39	20	300	620	900	580	1 220	1820
160	128	279	34	20	300	620	900	580	1 220	1820
210	168	158	31	20	195	430	640	390	800	1200
210	168	177	33	20	195	430	640	390	800	1200
210	168	246	40	20	300	620	900	580	1 220	1820
210	168	295	46	20	300	620	900	580	1 220	1820
210	168	279	45	20	300	620	900	580	1 220	1820
250	200	246	54	24	300	620	900	580	1 220	1820
250	200	295	62	24	300	620	900	580	1 220	1820
250	200	279	57	24	300	620	900	580	1 220	1820
300	240	246	67	24	300	620	900	580	1 220	1820
300	240	295	77	24	300	620	900	580	1 220	1820
300	240	279	70	24	300	620	900	580	1 220	1820

2) Tolerances to DIN VDE 0446 Part 1

3) When a bonding agent other than lead is used, e.g. Portland or sulfur cement, the weights stated are about 2 kg lighter for d_1 = 60 mm, about 3 kg for d_1 = 75 mm, about 5 kg for d_1 = 85 mm, about 6 kg for d_1 = 95 mm and about 8 kg for d_1 = 105 mm.

Table 13-36b

Dimensions and nominal data of LG long-rod insulators



Symbol[1)] to DIN 48006	Symbol to IEC 433	d_1 mm	Tol. mm	No. of sheds	h_1 mm	Tol. mm	c ≈ mm	d_2 mm	Tol. mm	h_3 mm	Tol. mm
LG 60/14/880	L 100 CE 550	60	± 3.9	14	860	± 27.5	46	120	± 6.3	675	± 22.9
LG 60/19/900	L 100 CE 550	60	± 3.9	19	900	± 28.5	35	120	± 6.3	715	± 23.9
LG 60/22/1200	L 100 CE 1000	60	± 3.9	22	1 200	± 36	46	120	± 6.3	1 015	± 31.4
LG 60/30/1270	L 100 CE 1000	60	± 3.9	30	1 270	± 37.8	35	120	± 6.3	1 085	± 33.1
LG 75/14/900	L 160 CE 550	75	± 4.5	14	900	± 28.5	46	150	± 7.5	690	± 23.3
LG 75/22/1270	L 160 CE 1000	75	± 4.5	22	1 270	± 37.8	46	150	± 7.5	1 065	± 32.6
LG 75/22s/1270	L 160 CE 1000	75	± 4.5	22	1 270	± 37.8	46	175	± 8.5	1 065	± 32.6
LG 75/27/1270	L 160 CE 1000	75	± 4.5	27	1 270	± 37.8	38	150	± 7.5	1 065	± 32.6
LG 85/14/940	—	85	± 4.9	14	940	± 29.5	46	160	± 7.9	690	± 23.3
LG 85/22/1310	L 210 CE 1000	85	± 4.9	22	1 310	± 38.8	46	160	± 7.9	1 065	± 32.6
LG 85/22s/1310	L 210 CE 1000	85	± 4.9	22	1 310	± 38.8	46	185	± 8.9	1 065	± 32.6
LG 85/27/1310	L 160 CE 1000	85	± 4.9	27	1 310	± 38.8	38	160	± 7.9	1 065	± 32.6
LG 95/22/1340	L 250 CE 1000	95	± 5.3	22	1 340	± 39.5	46	170	± 8.3	1 065	± 32.6
LG 95/22s/1340	L 250 CE 1000	95	± 5.3	22	1 340	± 39.5	46	195	± 9.3	1 065	± 32.6
LG 95/27/1340	L 250 CE 1000	95	± 5.3	27	1 340	± 39.5	38	170	± 8.3	1 065	± 32.6
LG 105/22/1370	L 300 CE 1000	105	± 5.7	22	1 370	± 40.3	46	180	± 8.7	1 065	± 32.6
LG 105/22s/1370	L 300 CE 1000	105	± 5.7	22	1 370	± 40.3	46	205	± 9.7	1 065	± 32.6
LG 105/27/1370	L 300 CE 1000	105	± 5.7	27	1 370	± 40.3	38	180	± 8.7	1 065	± 32.6

1) Suffix "s" denotes increased shed diameter.

(continued)

13-36b (continued)

Mechanical and electrical data of LG long-rod insulators

Nom. strength	Test strength	Nom. creepage distance[2)]	Weight[3)]	To fit bolts N or S to DIN 48073	Rated power frequency withstand voltage wet kV Number of units			Rated lightning impulse withstand voltage kV Number of units		
			kg	ø						
kN	kN	cm	≈	mm	1	2	3	1	2	3
100	80	137	15	19	190	415	620	380	770	1 160
100	80	168	17	19	200	455	650	400	810	1 220
100	80	212	21	19	280	590	865	585	1 170	1 760
100	80	260	23	19	300	620	900	580	1 220	1 820
160	128	158	23	19	195	430	640	390	800	1 200
160	128	246	31	19	300	620	900	580	1 220	1 820
160	128	295	39	19	300	620	900	580	1 220	1 820
160	128	279	34	19	300	620	900	580	1 220	1 820
210	168	158	32	22	195	430	640	390	800	1 200
210	168	246	41	22	300	620	900	580	1 220	1 820
210	168	295	46	22	300	620	900	580	1 220	1 820
210	168	279	45	22	300	620	900	580	1 220	1 820
250	200	246	55	22	300	620	900	580	1 220	1 820
250	200	295	63	22	300	620	900	580	1 220	1 820
250	200	279	58	22	300	620	900	580	1 220	1 820
300	240	246	68	25	300	620	900	580	1 220	1 820
300	240	295	78	25	300	620	900	580	1 220	1 820
300	240	279	71	25	300	620	900	580	1 220	1 820

[2)] Tolerances to DIN VDE 0446 Part 1

[3)] When a bonding agent other than lead is used, e.g. Portland or sulfur cement, the weights stated are about 2 kg lighter for d_1 = 60 mm, about 3 kg for d_1 = 75 mm, about 5 kg to d_1 = 85 mm, about 6 kg for d_1 = 95 mm and about 8 kg for d_1 = 105 mm.
For insulators, the added load to be allowed for ice, frost or snow is 50 N per 1 m string length (DIN VDE 0210).

Long-rod insulators of ceramic insulating material are a further development of solid-core insulators. Since the breakdown distance is roughly the same as the flashover distance and the dielectric strength of the material is greater than that of air, flashover along the surface will always occur before puncture-type breakdown. They can therefore be classified among the puncture-proof insulators.

When correctly designed in terms of geometry and creepage distance, their shape is such that they require virtually no maintenance.

The steady increase in transmission line ratings in recent years has necessitated the use of larger conductor cross-sections, and hence has led to heavier mechanical loadings on the insulator strings. Insulators with shank diameters of 95 mm and 105 mm and nominal strengths of 250 kN and 300 kN have therefore been developed and incorporated into DIN 48006 Part 2. In this way, account is also taken of the desire to avoid as far as possible the mechanical shortcomings of triple strings, and continue to use the established technique of double straining with the higher loadings as well.

The dimensions and technical data of long-rod insulators, and also suggestions as to their selection, are given in Tables 13-36a and b as well as 13-37.

Long-rod insulators LP with socket caps to DIN 48006 Part 1

Insulator material:	ceramic C 120 or C 220 to DIN EN 60672-1 (VDE 0335 Part 1) to manufacturer's choice
Finish:	exposed ceramic surface brown glazed to DIN 40686 Part 1 and Part 6. Centre lines of sockets must not be misaligned by more than 15°
Classification and testing:	DIN EN 60383-1 (VDE 0446 Part 1)
Bonding agent:	sulfur cement[1)], Portland cement[2)] or lead antimony
Designation:	shank diameter d_1 = 75 mm, 22 sheds and height h_1 = 1230 mm (symbol LP 75/22/1230): long-rod insulator DIN VDE 48006 – LP 75/22/1230
Application:	consult VDE 0210

1) Sulfur cement is not recommended in polluted areas as partial arcs can cause burning of the cement.

2) Portland cement should no longer be used owing to the risk of shed breakage.

Long-rod insulators LG with clevis caps to DIN 48006 Part 2

Insulator material:	ceramic C 120 or C 220 to DIN EN 60672-1 (VDE 0335 Part 1) to manufacturer's choice
Finish:	exposed ceramic surfaces brown glazed to DIN 40686. Centre lines of cap bores must not be misaligned by more than 4°.
Classification and testing:	DIN EN 60383-1(VDE 0446 Part 1)
Bonding agent:	Portland cement or lead antimony
Designation:	designation of a long-rod insulator LG with clevis caps, shank diameter d_1 = 75 mm, 22 sheds and height h_1 = 1270 mm (symbol LG 75/22/1270): long-rod insulator LG 75/22/1270 DIN 48006.
Application:	consult DIN VDE 0210.

Table 13-37

Suggestions for selection of LG long-rod insulators for different operating voltages and pollution degrees (no account taken of nominal strength)

Max. operating voltage U_m 1) kV	Rated lightning impulse withstand voltage U_{rB} 1) kV	Rated power-frequency withstand voltage U_{rW} 1) kV	Rated switching impulse withstand voltage U_{rS} 1) kV	Insulator type	No. of units/creepage distance with different degrees of pollution 2): 1 slight 1.6 cm/kV -/cm	2 average 2.0 cm/kV -/cm	3 severe 2.5 cm/kV -/cm	4 very severe 3.1cm/kV -/cm
123	550	230	—	LG 60/14/860	—	2/274	3/411	3/411
				LG 60/19/900	—	2/336	2/336	3/504
				LG 60/22/1200	1/212	2/424	2/424	2/424
				LG 60/30/1270	1/260	1/260	2/520	2/520
				LG 75/14/900	2/316	2/316	2/316	3/474
				LG 75/22/1270	1/246	1/246	2/492	2/492
				LG 75/22s/1270	1/295	1/295	1/295	2/590
				LG 75/27/1270	1/279	1/295	2/558	2/558
				LG 85/14/940	2/316	2/316	2/316	3/474
				LG 85/22/1310	1/246	1/246	2/492	2/492
				LG 85/22s/1310	1/295	1/295	1/295	2/590
				LG 85/27/1310	1/279	1/279	2/558	2/558
				LG 95/22/1340	1/246	1/246	2/492	2/492
				LG 95/22s/1340	1/295	1/295	1/295	2/590
				LG 95/27/1340	1/279	1/279	2/558	2/558
245	1 050	460	—	LG 60/19/900	3/504	3/504	4/672	5/840
				LG 60/22/1200	2/424	3/636	3/636	4/848
				LG 60/30/1270	2/520	2/520	3/780	3/780
				LG 75/14/900	3/474	4/632	4/632	5/790
				LG 75/22/1270	2/492	2/492	3/738	4/984
				LG 75/22s/1270	2/590	2/590	3/885	3/885
				LG 75/27/1270	2/558	2/558	3/837	3/837
				LG 85/14/940	3/474	4/632	4/632	5/790
				LG 85/22/1310	2/492	2/492	3/738	4/984
				LG 85/22s/1310	2/590	2/590	3/885	3/885
				LG 85/27/1310	2/558	2/558	3/837	3/837
				LG 95/22/1340	2/492	2/492	3/738	4/984
				LG 95/22s/1340	2/590	2/590	3/885	3/885
				LG 95/27/1340	2/553	2/558	3/837	3/837
				LG 105/22/1370	2/492	2/492	3/738	4/984
				LG 105/22s/1370	2/590	2/590	3/885	3/885
				LG 105/27/1370	2/558	2/558	3/837	3/837
420	1425	—	1050	LG 75/22/1270	3/738	4/984	5/1230	6/1476
				LG 75/22s/1270	3/885	3/885	4/1180	5/1475
				LG 75/27/1270	3/837	3/837	4/1116	5/1395
				LG 85/22/1310	3/738	4/984	5/1230	6/1476
				LG 85/22s/1310	3/885	3/885	4/1180	5/1475
				LG 85/27/1310	3/837	4/1116	4/1116	5/1395
				LG 95/22/1340	3/738	4/984	4/1230	5/1476
				LG 95/22s/1340	3/885	3/885	4/1180	5/1475
				LG 95/27/1340	3/837	4/1116	4/1116	5/1395

Continued on next page

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Table 13-37 (continued)

Max. operating voltage U_m[1) kV	Rated lightning impulse withstand voltage U_{rB}[1) kV	Rated power-frequency withstand voltage U_{rW}[1) kV	Rated switching impulse withstand voltage U_{rS}[1) kV	Insulator type	No. of units/creepage distance with different degrees of pollution[2) 1 slight 1.6 cm/kV -/cm	2 average 2.0 cm/kV -/cm	3 severe 2.5 cm/kV -/cm	4 very severe 3.1cm/kV -/cm
420	1 425	—	1 050	LG 105/22/1370	3/738	4/984	4/1230	5/1476
				LG 105/22s/1370	3/885	3/885	4/1180	5/1475
				LG 105/27/1370	3/837	4/1116	4/1116	5/1395
525	1 550	—	1 175	LG 75/22/1270	4/984	5/1230	6/1476	7/1722
				LG 75/22s/1270	3/885	4/1180	5/1475	6/1770
				LG 85/22/1310	4/984	5/1230	6/1476	7/1722
				LG 85/22s/1310	3/885	4/1180	5/1475	6/1770
				LG 95/22/1340	4/984	5/1230	6/1476	7/1722
				LG 95/22s/1340	3/885	4/1180	5/1475	6/1770
				LG 105/22/1370	4/984	5/1230	6/1476	7/1722
				LG 105/22si1370	3/885	4/1180	5/1475	6/1770

1) Values to DIN EN 60071-1 (VDE 0111 Part 1)

2) Minimum creepage distances per degree of pollution to IEC 815/85; referred to maximum operating voltage U_m. See Table 13-35 for definition of pollution degrees.

Cap-and-pin insulators K and NK of glass with skirts to DIN 48013 [1)]/IEC 60305

Material: insulator body: toughened glass

caps: malleable iron to DIN 1692 or cast zinc alloy to DIN 1743 (subject to agreement)

balls: heat-treatable steel to DIN 17200 or mechanically equivalent steels (to manufacturer's choice)

Finish: exposed surface green, caps of malleable iron and balls, see DIN VDE 0210
caps of cast zinc alloy: bare

Classification and testing: to DIN EN 60383-1 (VDE 0446 Part 1)

Designation: designation of a cap-and-pin insulator with symbol K 12 and height *h* = 130 mm: pin-and-cap insulator K 12 x 130 DIN 48013

Application: consult DIN VDE 0210

The symbol K denotes a cap-and-pin insulator, and NK a fog-type pin insulator. The two types differ in having different shed shapes and creepage distances.

For dimensions, technical data and notes on selection, see Tables 13-38 to 13-41.

1) DIN 48013 has been withdrawn, subject is covered by IEC 60305

Cap-and-pin insulators have the advantage that almost any creepage distance can be obtained by arranging the required number of units one after the other. Because of their construction, however, they must be classified among the non-puncture-proof insulators. Assemblies of cap-and-pin insulators made from toughened glass are almost disintegration-proof. If flashover occurs between ball and cap, only the shed of the insulator breaks off. The ball is held by the unstressed glass between metal cap and ball. The insulator thus retains its mechanical strength. However, the insulator which has undergone electrical breakdown must be replaced, because there is a risk that a subsequent arc may originate at the electrically weakened point, and melt the ball. Also, the insulators in the string have to assume a greater proportion of the voltage. The fact that the shed breaks off with glass caps allows the state of the insulation to be checked easily by eye from the ground.

Cap-and-pin insulators made of ceramic are also used in many countries, as well as glass insulators. Ceramic cap-and-pin insulators are also non-puncture-proof because the flashover distance is very much greater than the puncture path through the insulator body. In contrast to glass cap-and-pin insulators, puncturing does not cause the shed to break off.

Cap-and-pin insulators are not manufactured in Germany. VDE 0446 Part 6 is based on IEC 60305. The number in the IEC symbol denotes the electromechanical strength of the insulator in kN. A cap-and-pin insulator DIN-coded K 12, for example, has the IEC symbol U120 BS. The letter B stands for ball & socket connection, the letters S or L for short and long and the letter P for pollution.

Table 13-38

Dimensions and nominal data of typical cap-and-pin insulators to DIN EN 60305 (VDE 0446 Part 6)

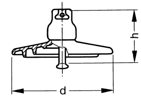
Symbol	Electromechanical or mechanical strength kN	Max. shed diameter D mm	Height H mm	Nominal creepage distance mm	To fit nominal ball size d_1
U 40 B	40	175	110	190	11
U 40 BP	40	210	110	295	11
U 70 BS	70	255	127	295	16
U 70 BL	70	255	146	295	16
U 70 BLP	70	280	146	440	16
U 100 BS	100	255	127	295	16
U 100 BL	100	255	146	295	16
U 100 BLP	100	280	146	440	16
U 120 B	120	255	146	295	16
U 120 BP	120	280	146	440	16
U 160 BS	160	280	146	315	20
U 160 BSP	160	330	146	440	20
U 160 BL	160	280	170	340	20
U 160 BLP	160	330	170	525	20
U 210 B	210	300	170	370	20
U 210 BP	210	330	170	525	20
U 300 B	300	330	195	390	24
U 300 BP	300	400	195	590	24
U 400 B	400	380	205	525	28
U 530 B	530	380	240	600	32

See Tables 13-39 and 13-40 for electrical data

Table 13-39

Electrical data[1] in kV and length in mm of cap-and-pin insulator strings without protective fittings

Standard type



Standard insulator

Insulator type (DIN EN 60305)	U 70 BS U 100 BS				U 70 BL U 100 BL U 120 B U 160 BS				U 160 BL U 210 B				U 300 B			
D x P	255 mm x 127 mm				255 mm x 146 mm 280 mm x 146 mm				280 mm x 170 mm 300 mm x 170 mm				330 mm x 195 mm			
No. of units	Short-dur. power-fr. withstand voltage		Lightning impulse withstand voltage	Design length	Short-dur. power-fr. withstand voltage		Lightning impulse withstand voltage	Design length	Short-dur. power-fr. withstand voltage		Lightning impulse withstand voltage	Design length	Short-dur. power-fr. withstand voltage		Lightning impulse withstand voltage	Design length
	dry	wet			dry	wet			dry	wet			dry	wet		
	kV	kV	kV	mm	kV	kV	kV	mm	kV	kV	kV	mm	kV	kV	kV	mm
1	70	40	100	127	70	40	100	146	75	45	110	170	85	50	130	195
2	120	72	190	254	130	75	190	292	135	75	205	340	150	85	225	390
3	165	105	260	381	180	110	270	438	190	110	285	510	215	120	315	585
4	205	135	320	508	225	140	340	584	240	145	360	680	375	160	405	780
5	245	165	380	635	270	175	410	730	290	185	440	850	330	200	495	975
6	285	195	435	762	315	210	480	876	335	220	520	1 020	385	235	580	1 170
7	325	225	490	889	360	245	550	1 022	380	255	600	1 190	440	270	665	1 365
8	365	260	550	1 016	405	280	620	1 168	430	290	675	1 360	490	310	745	1 560
9	400	290	615	1 143	450	310	690	1 314	475	325	755	1 530	540	350	830	1 755
10	440	320	675	1 270	490	345	760	1 460	520	360	835	1 700	590	385	910	1 950
11	475	345	735	1 397	530	375	830	1 606	565	390	915	1 870	645	420	990	2 145
12	510	370	795	1 524	570	405	900	1 752	610	420	990	2 040	695	455	1 070	2 340
13	545	395	860	1 651	610	435	970	1 898	655	450	1 065	2 210	740	490	1 150	2 535
14	580	425	925	1 778	650	465	1 035	2 044	695	485	1 140	2 380	785	525	1 230	2 730
15	615	450	985	1 905	690	495	1 100	2 190	740	515	1 215	2 550	830	560	1 315	2 925

[1] The withstand voltage values given are guidance values. If required, obtain precise values from the manufacturer.

(continued)

Table 13-39 (continued)

Electrical data[1] in kV and length in mm of cap-and-pin insulator strings without protective fittings

Standard insulator

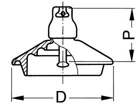
Insulator type (DIN EN 60305)	U 70 BS U 100 BS				U 70 BL U 100 BL U 120 B U 160 BS				U 160 BL U 210 B				U 300 B			
D x P	255 mm x 127 mm				255 mm x 146 mm 280 mm x 146 mm				280 mm x 170 mm 300 mm x 170 mm				330 mm x 195 mm			
No. of units	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impulse withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impulse withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impulse withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impulse withstand voltage kV	Design length mm
16	650	475	1 045	2 032	725	525	1 165	2 336	785	550	1 290	2 720	875	590	1 395	3 120
17	685	500	1 105	2 159	765	555	1 230	2 482	830	580	1 360	2 890	925	625	1 475	3 315
18	715	525	1 165	2 286	800	585	1 295	2 628	875	610	1 435	3 060	970	655	1 555	3 510
19	750	550	1 225	2 413	840	610	1 360	2 774	920	640	1 510	3 230	1 015	690	1 640	3 705
20	780	575	1 280	2 540	875	640	1 425	2 920	965	670	1 580	3 400	1 060	720	1 720	3 900
21	815	600	1 340	2 667	915	670	1 490	3 066	1 005	700	1 650	3 570	1 110	755	1 795	4 095
22	850	625	1 400	2 794	950	700	1 565	3 212	1 050	730	1 725	3 740	1 155	785	1 875	4 290
23	880	650	1 455	2 921	985	725	1 620	3 358	1 095	760	1 795	3 910	1 200	820	1 950	4 485
24	915	675	1 510	3 048	1 025	755	1 680	3 504	1 140	790	1 870	4 080	1 245	850	2 025	4 680
25	945	700	1 570	3 175	1 060	785	1 745	3 650	1 180	820	1 940	4 250	1 290	880	2 100	4 875
26	975	725	1 625	3 302	1 100	815	1 805	3 796	1 225	845	2 010	4 420	1 330	910	2 175	5 070
27	1 010	750	1 680	3 429	1 135	840	1 870	3 942	1 270	875	2 080	4 590	1 375	940	2 250	5 265
28	1 040	775	1 730	3 556	1 170	865	1 935	4 088	1 310	900	2 150	4 760	1 420	970	2 320	5 460
29	1 070	800	1 780	3 683	1 205	895	2 000	4 234	1 355	930	2 220	4 930	1 460	1 000	2 400	5 655
30	1 100	825	1 835	3 810	1 240	920	2 060	4 380	1 395	955	2 290	5 100	1 505	1 030	2 475	5 850

[1] The withstand voltage values given are guidance values. If required, obtain precise values from the manufacturer.

Table 13-40

Electrical data[1)] in kV and length in mm of cap-and-pin insulator strings without protective fittings

Pollution insulator



Pollution type

Insulator type (DIN EN 60305)	U 70 BLP U 100 BLP U 160 BSP				U 160 BLP U 210 BP				U 300 BP			
D x P	280 mm x 146 mm 330 mm x 146 mm				330 mm x 170 mm				400 mm x 195 mm			
No. of units	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impuls withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impuls withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impuls withstand voltage kV	Design length mm
1	70/85	40/50	110/125	146	90	55	140	170	100	60	155	195
2	130	75	235	292	135	85	270	340	150	100	280	390
3	180	100	320	438	190	110	370	510	215	130	390	585
4	225	130	390	584	240	145	450	680	275	170	495	780
5	270	155	465	730	290	175	540	850	330	200	600	975
6	315	185	545	876	335	205	625	1 020	305	240	700	1 170
7	360	215	620	1 022	380	240	710	1 190	440	270	810	1 365
8	405	245	695	1 168	430	275	800	1 360	490	310	910	1 560
9	450	270	775	1 314	475	305	890	1 530	540	340	1 015	1 755
10	490	290	855	1 460	520	335	980	1 700	590	380	1 120	1 950
11	530	320	935	1 606	565	360	1 070	1 870	645	410	1 230	2 145
12	570	340	1 015	1 752	610	385	1 170	2 040	695	450	1 340	2 340
13	610	365	1 100	1 898	655	410	1 260	2 210	740	480	1 450	2 535
14	650	390	1 180	2 044	695	440	1 355	2 380	785	520	1 555	2 730
15	690	410	1 260	2 190	740	465	1 450	2 550	830	550	1 660	2 925

[1)] The withstand voltage values given are guidance values. If required, obtain precise values from the manufacturer.

Continued on next page

Table 13-40

Electrical data[1] in kV and length in mm of cap-and-pin insulator strings without protective fittings

Pollution insulator

Insulator type (DIN EN 60305)	U 70 BLP U 100 BLP U 160 BSP				U 160 BLP U 210 BP				U 300 BP			
D x P	280 mm x 146 mm 330 mm x 146 mm				330 mm x 170 mm				400 mm x 195 mm			
No. of units	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impuls withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impuls withstand voltage kV	Design length mm	Short-dur. power-fr. withstand voltage dry kV	wet kV	Lightning impuls withstand voltage kV	Design length mm
16	725	430	1 340	2 336	785	490	1 540	2 720	875	590	1 765	3 120
17	765	450	1 425	2 482	830	515	1 640	2 890	925	620	1 865	3 315
18	800	480	1 500	2 628	875	540	1 730	3 060	970	655	1 965	3 510
19	840	500	1 580	2 774	920	565	1 810	3 230	1 015	690	2 070	3 705
20	875	520	1 655	2 920	965	590	1 900	3 400	1 060	725	2 170	3 900
21	915	540	1 730	3 066	1 005	610	1 990	3 570	1 110	755	2 255	4 095
22	950	565	1 810	3 212	1 050	640	2 080	3 740	1 155	790	2 370	4 290
23	985	585	1 885	3 358	1 095	660	2 160	3 910	1 200	825	2 475	4 485
24	1 025	610	1 950	3 504	1 140	690	2 245	4 080	1 245	860	2 575	4 680
25	1 060	630	2 025	3 650	1 180	710	2 325	4 250	1 290	895	2 680	4 875
26	1 100	650	2 095	3 796	1 225	740	2 410	4 420	1 330	930	2 785	5 070
27	1 135	670	2 170	3 942	1 270	760	2 490	4 590	1 375	965	2 890	5 265
28	1 170	695	2 240	4 088	1 310	780	2 575	4 760	1 420	1 000	2 990	5 460
29	1 205	710	2 305	4 234	1 355	805	2 650	4 930	1 460	1 030	3 090	5 655
30	1 240	730	2 365	4 380	1 395	830	2 720	5 100	1 505	1 060	3 185	5 850

[1] The withstand voltage values given are guidance values. If required ,obtain precise values from the manufacturer.

Table 13-41
Selection of cap-and-pin insulators for different operatlng voltages and degrees of pollution (no account taken of electromechanical strength)

Max. operating voltage U_m [1) kV	Rated lightning impulse with-stand voltage U_{rB} [1) kV	Rated power frequency withstand voltage U_{rW} [1) kV	Rated switching impulse withstand voltage Phase-to-earth U_{rS} [1) kV	Insulator type DIN EN 60305	Overall height P mm	No. of units/creepage distance with different degrees of pollution[2) 1 slight 1.6 cm/kV –/cm	2 average 2.0 cm/kV –/cm	3 severe 2.5 cm/kV –/cm	4 very severe 3.1 cm/kV –/cm
36	170	70	—	U 70 BL	146	3/88.5	3/88.5	4/118	4/118
52	250	95	—	U 70 BL	146	4/118	4/118	5/147.5	6/177
				U 70 BLP[3)	146	–	–	4/176	4/176
72.5	325	140	—	U 70 BL	146	5/147.5	5/147.5	7/206.5	8/236
				U 70 BLP	146	–	–	5/220	6/264
123	550	230	—	U 120 B	146	8/236	9/266.5	11/324.5	13/383.5
				U 120 BP	146	–	–	8/352	9/396
145	650	275	—	U 120 B	146	9/266.5	10/290.5	13/383.5	16/472
				U 120 BP	146	–	–	9/396	11/484
170	750	325	—	U 120 B	146	11/324.5	12/354	15/442.5	18/531
				U 120 BP	146	–	–	11/484	12/528
245	1050	460	—	U 120 B	146	15/442.5	17/501.5	21/619.5	26/767
				U 120 BP	146	–	–	15/660	18/792
362	1175	—	950	U 120 B	146	20/590	25/735	31/914.5	39/1150.5
				U 120 BP	146	–	20/880	21/924	26/1144
420	1425	—	1050	U 120 B	146	24/708	29/855	37/1091.5	45/1327.5
				U 120 BP	146	–	–	24/1056	30/1320
525	1550	—	1175	U 120 B	146	29/855	36/1062	45/1327.5	56/1652
				U 120 BP	146	–	29/1076	30/1320	37/1628

1) Values to DIN EN 60071 (VDE 0111 Part 1)
2) Minimum creepage distances per degree of pollution to IEC 815/85; referred to maximum operating voltage U_m.
See Table 13-35 for definition of pollution degrees

Insulator material	glass-fibre-reinforced epoxy resin rod (GFR rod) with shed of silicone rubber (insulating materials to DIN VDE 0441-1)
Caps	hot-galvanized wrought steel press-fitted to rod end. Hot-galvanized malleable iron, cap forms: ball, socket, strap and clevis
Testing	DIN 57441-2 (VDE 0441 Part 2), IEC 61109
Designation	e.g. symbol 30/15(134) – 1300:

shank diameter	d_1	=	30 mm
number of sheds	n	=	15
shed diameter	d_2	=	134 mm
height	h_1	=	1300 mm

Application	consult DIN VDE 0210

Synthetic-composite long-rod insulators with sheds of silicone rubber have been developed from constructions using ceramic materials. With all the advantages of conventional long-rod insulators, they have the added merits of being unbreakable, light in weight and able to be made in one piece up to 6 m long. The intermediate fittings necessary with multi-element insulator strings are therefore not required, resulting in shorter strings at high operating voltages. However, with higher operating voltages e.g. 220 kV, so-called field distribution rings are needed in order to control the electrical field.

Owing to the water-repellent properties of the silicone rubber sheds, these insulators respond better to contamination than ceramic insulators.

Composite long-rod insulators are used mainly where their advantages over conventional types can be of benefit. Their particular features also make them very suitable as phase separators. In this case, the insulators are strung between the phases in an appropriate arrangement. Retrofitting is also possible. This prevents the phases from touching or coming too close together if the wires swing or “gallop”, so reducing outages and damage to the wires.

Synthetic-composite insulators have been performing well for more than 20 years at all voltage levels including DC applications.

The technical data and dimensions of some typical versions of these insulators can be seen in Table 13-42.

Synthetic-composite insulators with clevis caps

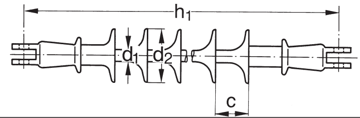


Table 13-42

Dimensions and nominal data of synthetic-composite insulators

Symbol	d_1 ± 3 % mm	Number of sheds	h_1 ± 1% mm	c ± 5 % mm	d_2 ± 2 % mm	Weight ≈ kg	To fit bolts to DIN 43073 N or S ∅ mm	Bolt length mm	Nominal strenght kN	Creepage distance ≈ cm	Appli-cation[1)] Degree of pollution	Max. operating voltage U_m kV	Power-frequency withstand voltage, wet kV[2)]	Lightning impulse withstand voltage, positive kV[2)]	Switching impulse withstand voltage, wet kV[2)]
30/15(134)-1 200	30	15	1 200	60	134	7	19	48	100	223	slight	123	300	585	—
30/22(134)-1 200	30	22	1 200	42	134	9	19	48	100	283	medium			590	
30/15(134)-1 300	30	15	1 300	60	134	9	19	53	160	223	slight			585	
30/22(134)-1 300	30	22	1 300	42	134	10	19	53	160	283	medium			590	
30/22(134)-2 300	30	22	2 300	86	134	11	22	53	160	383	slight	245	595	1 185	—
30/38(134)-2 300	30	38	2 300	50	134	15	22	53	160	519	medium		600	1 190	
30/46(134)-3 000	30	46	3 000	57	134	19	22	53	160	657	slight	420	—	1 600	950
30/65(134)-3 000	30	65	3 000	40	134	21	22	53	160	818	medium			1 600	
43/46(147)-3 000	43	46	3 000	57	147	24	22	57	220	659	slight			1 605	
43/65(147)-3 000	43	65	3 000	40	147	29	22	57	220	820	medium			1 605	
43/46(147)-3 250	43	46	3 250	60	147	29	32	70	320	669	slight			1 655	
43/64(147)-3 250	43	64	3 250	42	147	33	32	70	320	822	medium			1 655	
30/62(134)-3 500	30	62	3 500	50	134	21	22	53	160	843	slight	525	—	1 865	1 175
30/75(148)-3500	30	75	3 500	41	148	26	22	53	160	1 066	medium			1 865	

1) Minimum creepage distances per degree of pollution to IEC 60815; referred to maximum operating voltage U_m. Definition, see Table 13-37. Because of the shed's water-repellent properties, in borderline cases, the insulator can be assigned to the next-higher pollution category. Special models are obtainable for very severe pollution.

2) Rated values

13.2 Cables, wires and flexible cords

13.2.1 Specifications, general

During the course of implementing the unified internal European market, there have been changes in the standardization of low and medium-voltage cables. The sections relevant after implementation of the corresponding European harmonization document (HD) for Germany have been collected in a new VDE regulation DIN VDE 0276:

Product group	Former standards DIN VDE ...	Voltage series (kV)	New VDE regulation DIN VDE ...
PVC cable	0271	1	0276 Part 603 (number of cores ≤ 4)
			0276 Part 627 (number of cores > 4)
XLPE cable	0272	1	0276 Part 603
XLPE cable	0273	10, 20, 30	0276 Part 620
XLPE cable	0255	10, 20, 30	0276 Part 621

Cables, wires and flexible cords often have to satisfy very different requirements throughout the cable route. Before deciding the type and cross-section, therefore, one must examine their particular electrical function and also climatic and operational factors influencing system reliability and the expected life time of the equipment. Critical stresses at places along the route can endanger the entire link. Particularly important are the specified conditions for heat dissipation.

In the VDE specifications, the codes for the construction, properties and current-carrying capacity of power cables and wires are contained in Group 2 “Power guides”, and for cables and wires in telecommunications and information processing systems in Group 8 “Information technology”.

The identification codes for cables are obtained by adding the symbols in Table 13-43 to the initial letter “N” (types according to DIN VDE) in the sequence of their composition, starting from the conductor. Copper conductors are not identified in the type designation. With paper-insulated cables, the form of insulation is also not mentioned in the code.

Recommendations for the use, supply, transportation and installation and for the current-carrying capacity of cables can be found in the relevant sections of the VDE regulation DIN VDE 0276 and the VDE regulations for installation. Application information for flexible cords is given in DIN VDE 0298-3. The guidelines for up to 1000 V also contain notes on the selection of overload and short-circuit protection facilities.

Table 13-43

Code symbols for cables

Codes for plastic-insulated cables	
A	Aluminium conductor
I	House wiring cable
Y	Insulation of thermoplastic polyvinyl chloride (PVC)
2Y	Insulation of thermoplastic polyethylene (PE)
2X	Insulation of cross-linked polyethylene (XLPE)
HX	Insulation of cross-linked halogen-free polymer
C	Concentric copper conductor
CW	Concentric copper conductor, meander-shaped applied
S	Copper screen
SE	Copper screen, applied over each core of three-core cables
(F)	Screen area longitudinally watertight
Y	Protective PVC inner sheath
F	Armouring of galvanized flat steel wire
R	Armouring of galvanized round steel wire
G	Counter tape or binder of galvanized steel strip
Y	PVC outer sheath
2Y	PE outer sheath
H	Outer sheath of thermoplastic halogen-free polymer
HX	Outer sheath of cross-linked halogen-free polymer
–FE	Insulation maintained in case of fire
Codes for paper-insulated cables	
A	Aluminium conductor
H	Screening for Höchstädter cable
E	Metal sheath over each core (three-sheath cable)
K	Lead sheath
E	Protective cover with embedded layer of elastomer tape or plastic foil
Y	Protective PVC inner sheath
B	Armouring of steel strip
F	Armouring of galvanized flat steel wire
FO	Armouring of galvanized flat steel wire, open
G	Counter tape or binder of steel strip
A	Protective cover of fibrous material
Y	PVC outer sheath
YV	Reinforced PVC outer sheath
For cables U_0/U 0.6/1 kV without concentric conductor	
–J	Cable with core coded green/yellow
–O	Cable without core coded green/yellow
Codes for conductor shape and type	
RE	Solid round conductor
RM	Stranded round conductor
SE	Solid sector-shaped conductor
SM	Stranded sector-shaped conductor
RF	Flexible stranded round conductor

13.2.2 Current-carrying capacity

Specifications for the “rated currents” and the conversion factors in the case of deviations in operating conditions are to be found in the following VDE regulations:

DIN VDE 0276-603:	for PVC cables (number of cores ≤ 4) and XLPE cables 1 kV
DIN VDE 0276-604:	for cables with improved behaviour in case of fire for 1 kV
DIN VDE 0276-620:	for XLPE cables 10, 20 and 30 kV and for PVC cables 10 kV
DIN VDE 0276-621:	for paper-insulated cables 10, 20 and 30 kV
DIN VDE 0276-622:	for cables with improved behaviour in case of fire for power plants 10, 20 and 30 kV
DIN VDE 0276-627:	for PVC cables (number of cores > 4) 1 kV
DIN VDE 0271:	for PVC cables 1 kV (special designs) and PVC cables to 6 kV
DIN VDE 0276-1000:	conversion factors (current-carrying capacity)
DIN VDE 0298-4:	for lines

The values for the current capacity of cables laid underground can be found in Tables 13-44, and 13-46 to 13-49. They are applicable for a load factor of m = 0.7 (electrical utility load), for a specific ground thermal resistance of 1 K · m/W, for a ground temperature of 20 °C and for laying at a depth of 0.7 m to 1.2 m. The electrical utility load (load factor m = 0.7) is based on a load curve that is usual in power supply company networks; see Fig. 13-8. The load factor is calculated from the 24-hour load cycle and is a quotient of the “area under the load curve” to “total area of the rectangle (maximum load × 24 h)”.

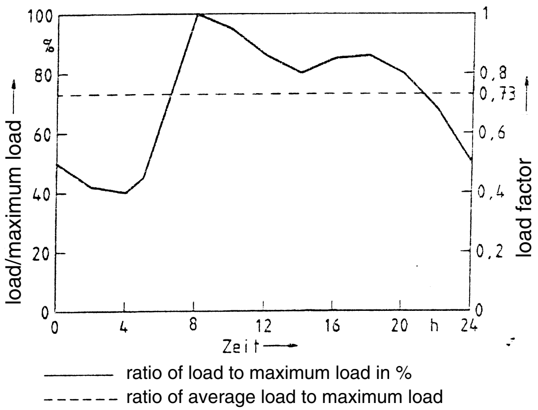


Fig. 13-8

24-hour load cycle and calculating of the load factor (example for a load factor of 0.73)

The values for the current capacity of cables laid in air can be found in Tables 13-45 to 13-49. They are applicable for three-phase continuous operation at an ambient temperature of 30 °C.

Different conditions must be taken into account by application of conversion factors to the above current rating values.

For multiconductor cables the conversion factors given in Table 13-50 apply.
The following apply for cables laid in air

– for different ambient temperatures, the conversion factors given in Table 13-51 and
– for the influence of laying and grouping the conversion factors from Tables 13-52 and 13-53.

The following applies for underground cables:

– for different ground temperatures, the conversion factor f_1 given in Tables 13-54 and 13-55 and
– for cables laying and grouping, the conversion factor f_2 given in Tables 13-56 to 13-59

Both factors also include the ground conditions and the configuration of the cables in the ground. Therefore, both conversion factors, f_1 and f_2, must be always used.

Additional conversion factors for laying cables underground may be:

– 0.85 when laying cables in conduits
– 0.9 when laying cables under covers with air space.

Examples for calculating the permissible current-carrying capacity:

Example 1

Current-carrying capacity of XLPE cable N2XSY 1 × 240 RM/25 6/10 kV:

Operating conditions: cables laid in trefoil formation in ground, covers containing air, load factor m = 0.7, specific soil thermal resistance 1.5 K · m/W, soil temperature 25 °C, 4 systems next to each other, spacing 7 cm.

1.	Current rating from Table 13-47, column 10	526 A
2.	Conversion factor f_1 for 25 °C ground temperature and a max. operating temperature of 90 °C, soil thermal resistance 1.5 K · m/W, load factor m = 0.7, from Table 13-54, column 5	0.87
3.	Conversion factor for grouping f_2 for 4 parallel systems as in Table 13-56, column 5 (1.5/0.7)	0.70
4.	Reduction factor for protective shells	0.90
5.	Max. permitted capacity: 526 A × 0.87 × 0.70 × 0.9 =	288 A

Example 2

Current rating for PVC cable NYY-J 3 × 120 SM/70 SM 0.6/1kV

Operating conditions: cables laid in air, ambient temperature 40 °C, 3 cables on a cable rack with unimpeded air circulation, spacing = cable outside diameter, two cable racks

1.	Current rating from Table 13-45, column 3	285 A
2.	Conversion factor for 40 °C from Table 13-51, column 10	0.87
3.	Conversion factor for laying and grouping from Table 13-53, column 5	0.98
4.	Reduced current rating: 285 A × 0.87 × 0.98 =	243 A

Table 13-44

Rated current (three-phase operation) as per DIN VDE 0276-603 cables with U_0/U = 0.6/1 kV laid underground

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Insulation material	PVC					VPE		
Permissible operating temperature	70 °C					90 °C		
Type designation	N(A)YY			N(A)YCWY[3]		N(A)2XY; N(A)2X2Y		
Configuration	[1]					[1]		
Number of loaded conductors	1	3	3	3	3	1	3	3
Cross-section in mm²	Copper conductor: rated current in A							
1.5	41	27	30	27	31	48	31	33
2.5	55	36	39	36	40	63	40	42
4	71	47	50	47	51	82	52	54
6	90	59	62	59	63	102	64	57
10	124	79	83	79	84	136	86	89
16	160	102	107	102	108	176	112	115
25	208	133	138	133	139	229	145	148
35	250	159	164	160	166	275	174	177
50	296	188	195	190	196	326	206	209
70	365	232	238	234	238	400	254	256
95	438	280	286	280	281	480	305	307
120	501	318	325	319	315	548	348	349
150	563	359	365	357	347	616	392	393
185	639	406	413	402	385	698	444	445
240	746	473	479	463	432	815	517	517
300	848	535	541	518	473	927	585	583
400	975	613	614	579	521	1064	671	663
500	1125	687	693	624	574	1227	758	749
Cross-section in mm²	Aluminium conductor: rated current in A							
25	160	102	106	103	108	177	112	114
35	193	123	127	123	129	212	135	136
50	230	144	151	145	153	252	158	162
70	283	179	185	180	187	310	196	199
95	340	215	222	216	223	372	234	238
120	389	245	253	246	252	425	268	272
150	436	275	284	276	280	476	300	305
185	496	313	322	313	314	541	342	347
240	578	364	375	362	358	631	398	404
300	656	419	425	415	397	716	457	457
400	756	484	487	474	441	825	529	525
500	873	553	558	528	489	952	609	601
Conversion factors								
f_1 [2] from tables	13-54	13-54	13-54	13-54	13-54	13-54	13-54	13-54
f_2 [3] from tables	13-59	13-59	13-56 13-57	13-59	13-56 13-57	13-59	13-59	13-56 13-57

[1] Rated current in DC systems with remote return conductors
[2] for ground temperature
[3] for grouping

Table 13-45

Rated current (three-phase operation) as per DIN VDE 0276-603
cables with $U_0/U = 0.6/1$ kV
laid in air

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Insulation material	PVC					VPE		
Permissible operating temperature	70°C					90°C		
Type designation	N(A)YY			N(A)YCWY[3]		N(A)2XY; N(A)2X2Y		
Configuration	[1] 					[1] 		
Number of loaded conductors	1	3	3	3	3	1	3	3
Cross-section in mm²	Copper conductor: rated current in A							
1.5	27	19.5	21	19.5	22	33	24	26
2.5	35	25	28	26	29	43	32	34
4	47	34	37	34	39	57	42	44
6	59	43	47	44	49	72	53	56
10	81	59	64	60	67	99	74	77
16	107	79	84	80	89	131	98	102
25	144	106	114	108	119	177	133	138
35	176	129	139	132	146	217	162	170
50	214	157	169	160	177	265	197	207
70	270	199	213	202	221	336	250	263
95	334	246	264	249	270	415	308	325
120	389	285	307	289	310	485	359	380
150	446	326	352	329	350	557	412	437
185	516	374	406	377	399	646	475	507
240	618	445	483	443	462	774	564	604
300	717	511	557	504	519	901	649	697
400	843	597	646	577	583	1060	761	811
500	994	669	747	626	657	1252	866	940
Cross-section in mm²	Aluminium conductor: rated current in A							
25	110	82	87	83	91	136	102	106
35	135	100	107	101	112	166	126	130
50	166	119	131	121	137	205	149	161
70	210	152	166	155	173	260	191	204
95	259	186	205	189	212	321	234	252
120	302	216	239	220	247	376	273	295
150	345	246	273	249	280	431	311	339
185	401	285	317	287	321	501	360	395
240	479	338	378	339	374	600	427	472
300	555	400	437	401	426	696	507	547
400	653	472	513	468	488	821	600	643
500	772	539	600	524	556	971	695	754
Conversion factors								
f [2] from tables	13-51	13-51	13-51	13-51	13-51	13-51	13-51	13-51
f [3] from tables	13-53	13-53	13-52	13-53	13-52	13-53	13-53	13-52

[1] Rated current in DC systems with remote return conductors
[2] for air temperature
[3] for grouping

Table 13-46

Rated current (three-phase operation) as per DIN VDE 0271
cables with U_0/U = 3.6/6 kV
laid underground and in air

1	*2*	*3*
Insulation material	PVC	
Metal sheath	—	
Type designation Permissible operating temperature	NYFY[3]; NYSY 70 °C	
Configuration		
Laying	*in ground*	*in air*
Nominal cross-section of copper conductor mm²	rated current in A	
25	129	105
35	155	128
50	184	155
70	227	196
95	272	242
120	309	280
150	346	319
185	390	366
240	449	430
300	502	489
400	562	560
Conversion factors		
f_1/f [1] from tables	13-54	13-51
f_2/f [2] from tables	13-59	13-53

1) for ground temperature/for air temperature
2) for grouping in ground/in air
3) three-core

Table 13-47

Rated current (three-phase operation) as per DIN VDE 0276-620 (PVC and XLPE cable) and DIN VDE 0276-621 (paper cable)
cable with U_0 / U = 6/10 kV
laid underground and in air

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	
Insulation mat.	Impreg. paper		PVC				XL PE					
Metal sheath	Lead		—						—			
Type designation	N(A)KBA		N(A)YSEY[3] N(A)YSY[4]				N(A)2XSEY, N(A)2XSE2Y[3] N(A)2XSY, N(A)2XS2Y[4]					
Permissible operating temp.	65 °C		70 °C				90 °C					
Configuration												
Installation	*Ground*	*Air*	*Ground*	*Air*	*Ground*	*Air*	*Ground*	*Air*	*Ground*	*Air*	*Ground*	*Air*
Nominal cross-section					Rated current in A							
Copper mm²												
25	122	100	134	114	137	119	151	147	157	163	179	194
35	150	123	160	138	163	143	181	178	187	197	212	235
50	179	148	189	165	192	172	213	213	220	236	249	282
70	222	187	231	205	234	214	261	265	268	294	302	350
95	269	228	276	249	279	261	312	322	320	358	359	426
120	308	263	313	286	316	301	355	370	363	413	405	491
150	347	301	351	324	352	341	399	420	405	468	442	549
185	392	345	396	371	397	391	451	481	456	535	493	625
240	454	408	458	434	457	460	523	566	526	631	563	731
300	511	467	—	—	512	526	590	648	591	722	626	831
400	577	536	—	—	571	602	—	—	662	827	675	920
500	—	—	—	—	639	691	—	—	744	949	748	1043
Aluminium mm²												
25	95	78	—	—	—	—	—	—	—	—	—	—
35	117	96	—	—	—	—	140	138	145	153	165	182
50	139	115	147	128	149	133	165	165	171	183	194	210
70	173	145	179	159	182	166	203	206	208	228	236	273
95	209	177	214	193	217	203	242	249	248	278	281	333
120	240	205	244	222	246	234	276	288	283	321	318	384
150	270	234	273	252	276	266	309	326	315	364	350	432
185	307	270	309	289	311	306	351	375	357	418	394	496
240	357	320	358	340	359	361	408	442	413	494	452	583
300	403	368	404	389	405	415	463	507	466	568	506	666
400	461	428	—	—	457	481	—	—	529	660	558	755
500	—	—	—	—	520	560	—	—	602	767	627	868
Conversion factors from tables												
f_1/f[1]	13-54	13-51	13-55	13-51	13-54	13-51	13-54	13-51	13-54	13-51	13-54	13-51
f_2/f[2]	13-59	13-53	13-59 13-57	13-53	13-56	13-52	13-59 13-57	13-53	13-56	13-52	13-58	13-52

[1] for ground temperature/for air temperature
[2] for grouping in ground/in air
[3] three-core
[4] single-core

Table 13-48

Rated current (three-phase operation) as per DIN VDE 0276-620 (XLPE cables) and DIN VDE 0276-621 (paper cable)
cable with U_0/U = 12/20 kV
laid underground and in air

1	*2*	*3*	*4*	*5*	*6*	*7*
Insulation material	Impregnated paper		XLPE			
Metal sheath	Lead					
Type designation	N(A)EKBA		N(A)2XSY, N(A)2XS2Y N(A)2X(F)2Y			
Permissible operating temperature	65 °C		90 °C			
Configuration	⊛	⊛	⊙ ⊙⊙	⊙ ⊙⊙	⊙⊙⊙	⊙⊙⊙
Installation	*Ground*	*Air*	*Ground*	*Air*	*Ground*	*Air*
Nominal cross-section Copper conductor mm²	Rated current in A					
25	129	111	—	—	—	—
35	155	134	189	200	213	235
50	185	161	222	239	250	282
70	229	200	271	297	303	351
95	274	243	323	361	360	426
120	314	279	367	416	407	491
150	354	317	409	470	445	549
185	402	363	461	538	498	625
240	468	426	532	634	568	731
300	530	488	599	724	633	830
400	600	560	671	829	685	923
500	674	641	754	953	760	1045
Aluminium conductor mm²						
25	100	86	—	—	—	—
35	121	104	—	—	—	—
50	144	125	172	185	195	219
70	178	156	210	231	237	273
95	213	189	251	280	282	332
120	244	218	285	323	319	384
150	275	247	319	366	352	432
185	314	284	361	420	396	494
240	367	334	417	496	455	581
300	417	384	471	569	510	663
400	478	445	535	660	564	753
500	545	516	609	766	634	866
Conversion factors						
f_1/f [1)] from tables	13-54	13-51	13-54	13-51	13-54	13-51
f_2/f [2)] from tables	13-59	13-53	13-56 13-57	13-52	13-58	13-52

[1)] for ground temperature/for air temperature
[2)] for grouping in ground/in air

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Table 13-49

Rated current (three-phase operation) as per DIN VDE 0276-620 (XLPE cables) and DIN VDE 0276-621 (paper cable)
cable with U_0 /U = 18/30 kV
laid underground and in air

1	*2*	*3*	*4*	*5*	*6*	*7*
Insulation material	Impregnated paper		XLPE			
Metal sheath	Lead					
Type designation	N(A)EKEBA		N(A)2XSY, N(A)2XS2Y N(A)2XS(F)2Y			
Permissible operating temperature	60 °C		90 °C			
Configuration	⊛	⊛	⁂	⁂	⊙⊙⊙	⊙⊙⊙
Installation	*Ground*	*Air*	*Ground*	*Air*	*Ground*	*Air*
Nominal cross-section Copper conductor mm²	Rated current in A					
35	146	126	—	—	—	—
50	174	150	225	241	251	282
70	215	187	274	299	304	350
95	259	227	327	363	362	425
120	297	261	371	418	409	488
150	334	295	414	472	449	548
185	379	338	466	539	502	624
240	442	397	539	635	574	728
300	501	453	606	725	640	828
400	569	519	680	831	695	922
500	644	594	765	953	773	1045
Aluminium conductor mm²						
35	113	98	—	—	—	—
50	135	117	174	187	195	219
70	167	145	213	232	238	273
95	201	176	254	282	283	331
120	231	203	289	325	321	382
150	260	230	322	367	354	429
185	297	264	364	421	399	492
240	347	311	422	496	458	578
300	394	356	476	568	514	659
400	454	414	541	650	570	750
500	520	478	616	764	642	861
Conversion factors						
f_1/f [1] from tables	13-54	13-51	13-54	13-51	13-54	13-51
f_2/f [2] from tables	13-59	13-53	13-56 13-57	13-52	13-58	13-52

[1] for ground temperature/for air temperature
[2] for grouping in ground/in air

Table 13-50

Conversion factors[1),],
for multicore cables with conductor cross-sections of 1.5 to 10 mm^2
laid underground or in air (as per DIN VDE 0276-1000)

1	*2*	*3*
Number of loaded cores	Laid underground	in air
5	0.70	0.75
7	0.60	0.65
10	0.50	0.55
14	0.45	0.50
19	0.40	0.45
24	0.35	0.40
40	0.30	0.35
61	0.25	0.30

1) The conversion factors must be used when
laid underground to the values in Table 13-44, column 3
laid in air to the values in Table 13-45, column 3

Table 13-51

Conversion factors for different air temperatures (as per DIN VDE 0276-1000)

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Type	Permissible operating temperature	Permissible temperature rise	Conversion factors for the air temperature in °C								
			10	15	20	25	30	35	40	45	50
—	°C	K	—	—	—	—	—	—	—	—	—
XLPE cables	90	—	1.15	1.12	1.08	1.04	1.0	0.96	0.91	0.87	0.82
PVC cables	70	—	1.22	1.17	1.12	1.06	1.0	0.94	0.87	0.79	0.71
Mass-impreg. cables: Belted cables 6/10 kV	65	35	1.0	1.0	1.0	1.0	1.0	0.93	0.85	0.76	0.65
Single-core, three-core single lead sheathed and H-type cables 12/20 kV	65	35	1.0	1.0	1.0	1.0	1.0	0.93	0.85	0.76	0.65
18/30 kV	60	30	1.0	1.0	1.0	1.0	1.0	0.91	0.82	0.71	0.58

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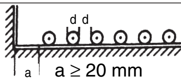
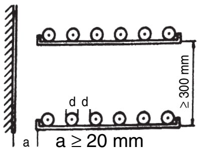
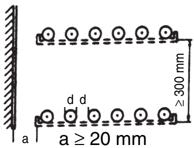
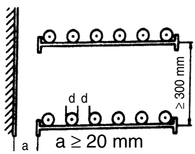
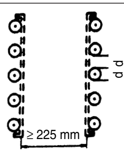
Table 13-52

Conversion factors for grouping in air[1], single-core cables in three-phase systems (as per DIN VDE 0276-1000)

1	*2*	*3*	*4*	*5*
Installation in flat formation Spacing = cable diameter *d*	Number of troughs/ racks vertical	Number of systems[2] horizontal 1	 2	 3
Laid on the floor 	1	0.92	0.89	0.88
Unperforated cable troughs[3] 	1	0.92	0.89	0.88
	2	0.87	0.84	0.83
	3	0.84	0.82	0.81
	6	0.82	0.80	0.79
Perforated cable troughs[3] 	1	1.00	0.93	0.90
	2	0.97	0.89	0.85
	3	0.96	0.88	0.82
	6	0.94	0.85	0.80
Cable racks[4] 	1	1.00	0.97	0.96
	2	0.97	0.94	0.93
	3	0.96	0.93	0.92
	6	0.94	0.91	0.90
On racks or on the wall or on perforated cable troughs in vertical configuration 	Number of troughs horizontal	Number of systems vertical 1	 2	 3
	1	0.94	0.91	0.89
	2	0.94	0.90	0.86

[1] If the air temperature is increased by the heat loss of the cables in small buildings or because of high grouping, the conversion factors for different air temperatures in Table 13-51 must also be used.

[2] Factors as per DIN VDE 0255 (VDE 0255)

[3] A cable trough is a continuous surface with raised edges but no cover. A cable trough is considered perforated if it is perforated over at least 30 % of the entire surface area.

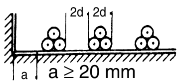
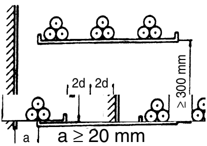
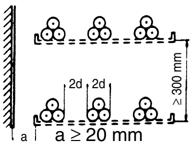
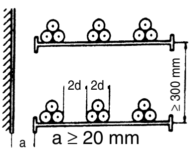
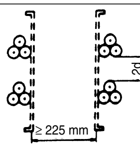
[4] A cable rack is a support structure in which the supporting area is no more than 10% of the total area of the structure.

When cables with metal sheathing or shielding are laid flat, the increased sheathing or shielding losses act against the reduced mutual heating when the spacing is increased. For this reason no information on reduction-free configurations can be given.

(continued)

Table 13-52 (continued)

Conversion factors for grouping in air[1], single-core cables in three-phase systems (as per DIN VDE 0276-1000)

6		*7*	*8*	*9*	*10*
Installation in trefoil formation Spacing = 2 · cable diameter *d*		Number of troughs/ racks vertical	Number of systems[2] horizontal 1	2	3
Laid on the floor		1	0.98	0.96	0.94
Unperforated cable troughs[3]		1	0.98	0.96	0.94
		2	0.95	0.91	0.87
		3	0.94	0.90	0.85
		6	0.93	0.88	0.82
Perforated cable troughs[3]		1	1.00	0.98	0.96
		2	0.97	0.93	0.89
		3	0.96	0.92	0.85
		6	0.95	0.90	0.83
Cable racks[4] (cable gratings)		1	1.00	0.97	0.96
		2	0.97	0.95	0.93
		3	0.96	0.94	0.90
		6	0.95	0.93	0.87
On racks or on the wall or on perforated cable troughs in vertical configuration		Number of troughs horizontal	Number of systems vertical 1	2	3
		1	1.00	0.91	0.89
		2	1.00	0.90	0.86

1) If the air temperature is increased by the heat loss of the cables in small buildings or because of high grouping, the conversion factors for different air temperatures in Table 13-51 must also be used.

2) Factors as in CENELEC Report R064.001 re HD 384,5.523:1991.

3) A cable trough is a continuous surface with raised edges but no cover. A cable trough is considered perforated if the perforations cover at least 30 % of the entire surface area.

4) A cable rack is a support structure in which the supporting area is no more than 10 % of the total area of the structure.

Load reduction is not required when laying in bundles where the spacing of adjacent systems is at least four times the cable diameter, as long as the ambient temperature is not increased by the heat loss (see footnote 1).

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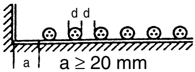
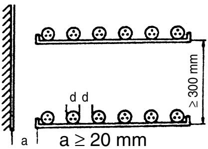
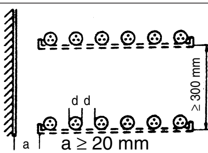
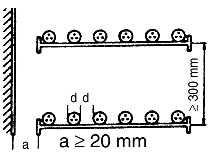
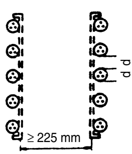
Table 13-53

Conversion factors for grouping in air[1)], multicore cables and single-core DC cables (as per DIN VDE 0276-1000)

1		*2*	*3*	*4*	*5*	*6*	*7*
Installation Spacing = cable diameter *d*		Number of troughs/ racks vertical	Number of cables horizontal[4)] 1	2	3	4	6
Laid on the floor		1	0.97	0.96	0.94	0.93	0.90
Unperforated cable troughs[2)]		1	0.97	0.96	0.94	0.93	0.90
		2	0.97	0.95	0.92	0.90	0.86
		3	0.97	0.94	0.91	0.89	0.84
		6	0.97	0.93	0.90	0.88	0.83
Perforated cable troughs[2)]		1	1.00	1.00	0.98	0.95	0.91
		2	1.00	0.99	0.96	0.92	0.87
		3	1.00	0.98	0.95	0.91	0.85
		6	1.00	0.97	0.94	0.90	0.84
Cable racks[3)] (cable gratings)		1	1.00	1.00	1.00	1.00	1.00
		2	1.00	0.99	0.98	0.97	0.96
		3	1.00	0.98	0.97	0.96	0.93
		6	1.00	0.97	0.96	0.94	0.91
On racks or on the wall or on perforated cable troughs in vertical configuration		Number of troughs horizontal	Number of systems vertical 1	2	3	4	6
		1	1.00	0.91	0.89	0.88	0.87
		2	1.00	0.91	0.88	0.87	0.85

1) If the air temperature is increased by the heat loss of the cables in small buildings or because of high grouping, the conversion factors for different air temperatures in Table 13-51 must also be used.

2) A cable trough is a continuous surface with raised edges but no cover. A cable trough is considered perforated if it is perforated over at least 30 % of the entire surface area.

3) A cable rack is a support structure in which the supporting area is no more than 10 % of the total area of the structure.

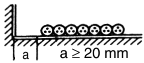
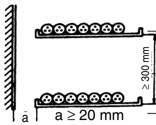
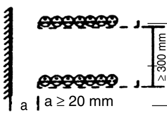
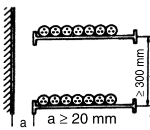
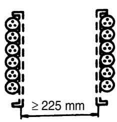
4) Factors as in CENELEC Report R064.001 re HD 384.5.523:1991.

Load reduction is not required where the horizontal or vertical spacing of adjacent cables is at least twice the cable diameter, as long as the ambient temperature is not increased by the heat loss (see footnote 1).

(continued)

Table 13-53 (continued)

Conversion factors for grouping in air[1], multicore cables and single-core d.c. systems (as per DIN VDE 0276-1000)

8		*9*	*10*	*11*	*12*	*13*	*14*	*15*
Installation		Number of troughs/racks	Number of cables horizontal[4]					
Mutual contact		vertical	1	2	3	4	6	9
Laid on the floor		1	0.97	0.85	0.78	0.75	0.71	0.68
Unperforated cable troughs[2]		1	0.97	0.85	0.78	0.75	0.71	0.68
		2	0.97	0.84	0.76	0.73	0.68	0.63
		3	0.97	0.83	0.75	0.72	0.66	0.63
		6	0.97	0.81	0.73	0.69	0.63	0.58
Perforated cable troughs[2]		1	1.00	0.88	0.82	0.79	0.76	0.73
		2	1.00	0.87	0.80	0.77	0.73	0.68
		3	1.00	0.86	0.79	0.76	0.71	0.66
		6	1.00	0.84	0.77	0.73	0.68	0.64
Cable racks[3] (cable gratings)		1	1.00	0.87	0.82	0.80	0.79	0.78
		2	1.00	0.86	0.80	0.78	0.76	0.73
		3	1.00	0.85	0.79	0.76	0.73	0.70
		6	1.00	0.83	0.76	0.73	0.69	0.66
Perforated cable troughs vertical configuration		Number of troughs horizontal	Number of cables vertical 1	2	3	4	6	9
		1	1.00	0.88	0.82	0.78	0.73	0.72
		2	1.00	0.88	0.81	0.76	0.71	0.70
On racks or on the wall in vertical configuration			Number of cables vertical 1	2	3	4	6	9
			0.95	0.78	0.73	0.72	0.68	0.66

1) If the air temperature is increased by the heat loss of the cables in small buildings or because of high grouping, the conversion factors for different air temperatures in Table 13-51 must also be used.

2) A cable trough is a continuous surface with raised edges but no cover. A cable trough is considered perforated if it is perforated over at least 30 % of the entire surface area.

3) A cable rack is a support structure in which the supporting area is no more than 10 % of the total area of the structure.

4) Factors as in CENELEC Report R064.001 re HD 384,5.523:1991.

Load reduction is not required where the horizontal or vertical spacing of adjacent systems is at least twice the cable diameter, so long as the ambient temperatures are not increased by the heat loss (see footnote 1).

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Table 13-54

*C*onversion factors f_1, cables laid in ground
All cables (except PVC cables for 6/10 kV) (as per DIN VDE 0276-1000)

1	*2*	*3*					*4*					*5*					*6*
Permissible operating temperature °C	Soil temperature °C	Specific thermal resistance of soil K · m/W 0.7					1.0					1.5					2.5
		Load factor					Load factor					Load factor					Load factor
		0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.5 to 1.00
90	5	1.24	1.21	1.18	1.13	1.07	1.11	1.09	1.07	1.03	1.00	0.99	0.98	0.97	0.96	0.94	0.89
	10	1.23	1.19	1.16	1.11	1.05	1.09	1.07	1.05	1.01	0.98	0.97	0.96	0.95	0.93	0.91	0.86
	15	1.21	1.17	1.14	1.08	1.03	1.07	1.05	1.02	0.99	0.95	0.95	0.93	0.92	0.91	0.89	0.84
	20	1.19	1.15	1.12	1.06	1.00	1.05	1.02	1.00	0.96	0.93	0.92	0.91	0.90	0.88	0.86	0.81
	25						1.02	1.00	0.98	0.94	0.90	0.90	0.88	0.87	0.85	0.84	0.78
	30								0.95	0.91	0.88	0.87	0.86	0.84	0.83	0.81	0.75
	35													0.82	0.80	0.78	0.72
	40																0.68
80	5	1.27	1.23	1.20	1.14	1.08	1.12	1.10	1.07	1.04	1.00	0.99	0.98	0.97	0.95	0.93	0.88
	10	1.25	1.21	1.17	1.12	1.06	1.10	1.07	1.05	1.01	0.97	0.97	0.95	0.94	0.92	0.91	0.85
	15	1.23	1.19	1.15	1.09	1.03	1.07	1.05	1.03	0.99	0.95	0.94	0.93	0.92	0.90	0.88	0.82
	20	1.20	1.17	1.13	1.07	1.01	1.05	1.03	1.00	0.96	0.92	0.91	0.90	0.89	0.87	0.85	0.78
	25						1.03	1.00	0.97	0.93	0.89	0.88	0.87	0.86	0.84	0.82	0.75
	30								0.95	0.91	0.86	0.85	0.84	0.83	0.81	0.78	0.72
	35													0.80	0.77	0.75	0.68
	40																0.64
70	5	1.29	1.26	1.22	1.15	1.09	1.13	1.11	1.08	1.04	1.00	0.99	0.98	0.97	0.95	0.93	0.86
	10	1.27	1.23	1.19	1.13	1.06	1.11	1.08	1.06	1.01	0.97	0.96	0.95	0.94	0.92	0.89	0.83
	15	1.25	1.21	1.17	1.10	1.03	1.08	1.06	1.03	0.99	0.94	0.93	0.92	0.91	0.88	0.86	0.79
	20	1.23	1.18	1.14	1.08	1.01	1.06	1.03	1.00	0.96	0.91	0.90	0.89	0.87	0.85	0.83	0.76
	25						1.03	1.00	0.97	0.93	0.88	0.87	0.85	0.84	0.82	0.79	0.72
	30								0.94	0.89	0.85	0.84	0.82	0.80	0.78	0.76	0.68
	35													0.77	0.74	0.72	0.63
	40																0.59

The conversion factor f_1 must always be used with the conversion factor f_2.
(continued)

Table 13-54 (continued)

1	*2*	*3*					*4*					*5*					*6*
Permissible operating temperature °C	Soil temperature °C	Specific thermal resistance of soil K · m/W 0.7					1.0					1.5					2.5
		Load factor					Load factor					Load factor					Load factor
		0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.5 to 1.00
65	5	1.31	1.27	1.23	1.16	1.09	1.14	1.11	1.09	1.04	1.00	0.99	0.98	0.96	0.94	0.92	0 85
	10	1.29	1.24	1.20	1.14	1.06	1.11	1.09	1.06	1.02	0.97	0.96	0.95	0.93	0.91	0.89	0.82
	15	1.26	1.22	1.18	1.11	1.04	1.09	1.06	1.03	0.98	0.94	0.93	0.91	0.90	0.88	0.85	0.78
	20	1.24	1.20	1.15	1.08	1.01	1.06	1.03	1.00	0.95	0.90	0.90	0.88	0.86	0.84	0.82	0.74
	25						1.03	1.00	0.97	0.92	0.87	0.86	0.84	0.83	0.80	0.78	0.70
	30								0.94	0.89	0.83	0.82	0.81	0.79	0.77	0.74	0.65
	35													0.75	0.72	0.70	0.60
	40																0.55
60	5	1.33	1.28	1.24	1.17	1.10	1.15	1.12	1.09	1.05	1.00	0.99	0.98	0.96	0.94	0.92	0.84
	10	1.30	1.26	1.21	1.14	1.07	1.12	1.09	1.06	1.02	0.97	0.96	0.94	0.93	0.90	0.88	0.80
	15	1.28	1.23	1.19	1.12	1.04	1.09	1.06	1.03	0.98	0.93	0.92	0.91	0.89	0.87	0.84	0.76
	20	1.25	1.21	1.16	1.09	1.01	1.06	1.03	1.00	0.95	0.90	0.89	0.87	0.86	0.83	0.80	0.72
	25						1.03	1.00	0.97	0.92	0.86	0.85	0.83	0.82	0.79	0.76	0.67
	30								0.93	0.88	0.82	0.81	0.79	0.78	0.75	0.72	0.62
	35													0.73	0.70	0.67	0.57
	40																0.51

With mass-impregnated cables, increasing the current rating at temperatures below 20 °C is subject to conditions. The conversion factor f_1 must be applied only together with conversion factor f_2.

Table 13-55

Conversion factors f_1, cables laid in ground, PVC cables for 6/10 kV (as per DIN VDE 0276-1000)

1	*2*	*3*	*4*	*5*					*6*					*7*					*8*
Number of three-phase systems		Number of three-phase cables	Soil temperature °C	Specific thermal resistance of soil K · m/W 0.7					1.0					1.5					2.5
				Load factor 0.50	0.60	0.70	0.85	1.00	Load factor 0.50	0.60	0.70	0.85	1.00	Load factor 0.50	0.60	0.70	0.85	1.00	Load factor 0.5 to 1.0
1	1	1	5	1.31	1.27	1.23	1.16	1.09	1.14	1.12	1.09	1.05	1.00	0.99	0.98	0.96	0.94	0.92	0.85
			10	1.29	1.25	1.21	1.14	1.07	1.12	1.09	1.06	1.02	0.97	0.96	0.95	0.93	0.91	0.89	0.81
			15	1.27	1.22	1.18	1.11	1.04	1.09	1.06	1.03	0.98	0.94	0.93	0.91	0.90	0.87	0.85	0.77
			20	1.24	1.20	1.15	1.08	1.01	1.06	1.03	1.00	0.95	0.90	0.89	0.88	0.86	0.84	0.81	0.73
			25						1.03	1.00	0.97	0.92	0.87	0.86	0.84	0.83	0.80	0.77	0.69
			30								0.94	0.89	0.83	0.82	0.80	0.79	0.76	0.73	0.64
			35													0.75	0.72	0.70	0.59
			40																0.54
4	3	3	5	1.29	1.24	1.20	1.13	1.06	1.11	1.08	1.05	1.01	0.96	0.95	0.94	0.93	0.90	0.88	0.81
			10	1.26	1.22	1.17	1.11	1.03	1.08	1.05	1.03	0.98	0.93	0.92	0.91	0.89	0.87	0.84	0.77
			15	1.24	1.19	1.15	1.08	1.00	1.05	1.03	0.99	0.95	0.90	0.89	0.87	0.86	0.83	0.81	0.73
			20	1.21	1.17	1.12	1.05	0.97	1.03	0.99	0.96	0.91	0.86	0.85	0.84	0.82	0.79	0.77	0.68
			25						0.99	0.96	0.93	0.88	0.83	0.82	0.80	0.78	0.76	0.73	0.64
			30								0.90	0.84	0.79	0.78	0.76	0.74	0.71	0.68	0.59
			35													0.70	0.67	0.64	0.53
			40																0.47
10	5	6	5	1.26	1.21	1.17	1.10	1.03	1.08	1.05	1.02	0.97	0.93	0.92	0.90	0.89	0.86	0.84	0.76
			10	1.23	1.19	1.14	1.07	1.00	1.05	1.02	0.99	0.94	0.89	0.88	0.87	0.85	0.83	0.80	0.72
			15	1.21	1.16	1.12	1.04	0.96	1.02	0.99	0.96	0.91	0.86	0.85	0.83	0.81	0.79	0.76	0.68
			20	1.18	1.14	1.09	1.01	0.93	0.99	0.96	0.93	0.87	0.82	0.81	0.79	0.77	0.75	0.72	0.63
			25						0.96	0.93	0.89	0.84	0.78	0.77	0.75	0.73	0.70	0.68	0.58
			30								0.86	0.80	0.74	0.73	0.71	0.69	0.66	0.63	0.52
			35													0.64	0.61	0.58	0.46
			40																0.38

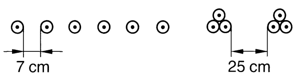
Conversion factor f_1 must be applied only together with conversion factor f_2.

(continued)

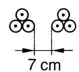
Table 13-55 (continued)

1	2	3	4	5					6					7					8
Number of three-phase systems		Number of three-phase cables	Soil temperature °C	Specific thermal resistance of soil K · m/W 0.7					1.0					1.5					2.5
				Load factor					Load factor					Load factor					Load factor
				0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.5 to 1.0
—	8	10	5	1.23	1.19	1.14	1.07 .	0.99	1.05	1.02	0.99	0.94	0.89	0.88	0.86	0.85	0.82	0.80	0.72
			10	1.21	1.16	1.11	1.04	0.96	1.02	0.99	0.96	0.91	0.85	0.84	0.83	0.81	0.78	0.76	0 67
			15	1.18	1.13	1.09	1.01	0.93	0.99	0.96	0.92	0.87	0.82	0.81	0.79	0.77	0.74	0.72	0.63
			20	1.15	1.11	1.06	0.98	0.90	0.96	0.92	0.89	0.84	0.78	0.77	0.75	0.73	0.70	0.67	0.57
			25						0.92	0.89	0.85	0.80	0.74	0.73	0.71	0.69	0.66	0.63	0.52
			30								0.82	0.76	0.70	0.68	0.66	0.64	0 61	0.57	0.45
			35													0.60	0.56	0.52	0.38
			40																0.29
—	10	—	5	1.22	1.17	1.13	1.05	0.98	1.03	1.00	0.97	0.92	0.87	0.86	0.84	0.83	0.80	0.78	0.69
			10	1.19	1.15	1.10	1.02	0.94	1.00	0.97	0.94	0.89	0.83	0.82	0.81	0.79	0.76	0.73	0.65
			15	1.17	1.12	1.07	0.99	0.91	0.97	0.94	0.90	0.85	0.79	0.78	0.77	0.75	0.72	0.69	0.60
			20	1.14	1.09	1.04	0.96	0.88	0.94	0.90	0.87	0.81	0.76	0.74	0.73	0.71	0.68	0.65	0.54
			25						0.90	0.87	0.83	0.78	0.71	0.70	0.68	0.66	0.63	0.60	0.48
			30								0.79	0.73	0.67	0.66	0.63	0.61	0.58	0.54	0.41
			35													0.56	0.52	0.48	0.33
			40																0.22

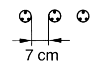
Arrangement of three-phase systems in column 1



Arrangement of three-phase systems in column 2

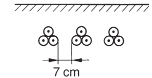


Arrangement of three-phase cables in column 3



Conversion factor f_1 must be applied only together with conversion factor f_2.

Table 13-56



Conversion factor f_2, cables laid in ground
Single-core cables in three phase systems, trefoil formation (as per DIN VDE 0276-1000)

1	*2*	*3*					*4*					*5*					*6*				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
XLPE cables		load factor					load factor					load factor					load factor				
0.6/1 kV		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
6/10 kV	1	1.09	1.04	0.99	0.93	0.87	1.11	1.05	1.00	0.93	0.87	1.13	1.07	1.01	0.94	0.87	1.17	1.09	1.03	0.94	0.87
12/20 kV	2	0.97	0.90	0.84	0.77	0.71	0.98	0.91	0.85	0.77	0.71	1.00	0.92	0.86	0.77	0.71	1.02	0.94	0.87	0.78	0.71
18/30 kV	3	0.88	0.80	0.74	0.67	0.61	0.89	0.82	0.75	0.67	0.61	0.90	0.82	0.76	0.68	0.61	0.92	0.83	0.76	0.68	0.61
	4	0.83	0.75	0.69	0.62	0.56	0.84	0.76	0.70	0.62	0.56	0.85	0.77	0.70	0.62	0.56	0.86	0.78	0.71	0.63	0.56
	5	0.79	0.71	0.65	0.58	0.52	0.80	0.72	0.66	0.58	0.52	0.80	0.73	0.66	0.58	0.52	0.82	0.73	0.67	0.59	0.52
	6	0.76	0.68	0.62	0.55	0.50	0.77	0.69	0.63	0.55	0.50	0.77	0.70	0.63	0.56	0.50	0.78	0.70	0.64	0.56	0.50
	8	0.72	0.64	0.58	0.51	0.46	0.72	0.65	0.59	0.52	0.46	0.73	0.65	0.59	0.52	0.46	0.74	0.66	0.59	0.52	0.46
	10	0.69	0.61	0.56	0.49	0.44	0.69	0.62	0.56	0.49	0.44	0.70	0.62	0.56	0.49	0.44	0.70	0.63	0.57	0.49	0.44
PVC cables		load factor					load factor					load factor					load factor				
0.6/1 kV		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
3.6/6 kV	1	1.01	1.02	0.99	0.93	0.87	1.04	1.05	1.00	0.93	0.87	1.07	1.06	1.01	0.94	0.87	1.11	1.08	1.01	0.94	0.87
6/10 kV	2	0.94	0.89	0.84	0.77	0.71	0.97	0.91	0.85	0.77	0.71	0.99	0.92	0.86	0.77	0.71	1.01	0.93	0.87	0.78	0.71
	3	0.86	0.79	0.74	0.67	0.61	0.89	0.81	0.75	0.67	0.61	0.90	0.83	0.76	0.68	0.61	0.91	0.83	0.77	0.68	0.61
	4	0.82	0.75	0.69	0.62	0.56	0.84	0.76	0.70	0.62	0.56	0.85	0.77	0.71	0.62	0.56	0.86	0.78	0.71	0.63	0.56
	5	0.78	0.71	0.65	0.58	0.52	0.80	0.72	0.66	0.58	0.52	0.80	0.73	0.66	0.58	0.52	0.81	0.73	0.67	0.59	0.52
	6	0.75	0.68	0.62	0.55	0.50	0.77	0.69	0.63	0.55	0.50	0.77	0.70	0.64	0.56	0.50	0.78	0.70	0.64	0.56	0.50
	8	0.71	0.64	0.58	0.51	0.46	0.72	0.65	0.59	0.52	0.46	0.73	0.65	0.59	0.52	0.46	0.73	0.66	0.60	0.52	0.46
	10	0.68	0.61	0.55	0.49	0.44	0.69	0.62	0.56	0.49	0.44	0.69	0.62	0.56	0.49	0.44	0.70	0.63	0.57	0.49	0.44

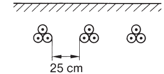
The conversion factor f_2 must be applied only together with conversion factor f_1.

Table 13-56 (continued)

1	*2*	*3*					*4*					*5*					*6*				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
Mass-impregnated cables 0.6/1 kV 3.6/6 kV 6/10 kV 12/20 kV 18/30 kV	1	0.94	0.95	0.97	0.93	0.87	0.99	0.99	1.00	0.93	0.87	1.06	1.04	1.01	0.94	0.87	1.15	1.08	1.02	0.94	0.87
	2	0.88	0.88	0.84	0.77	0.71	0.93	0.91	0.85	0.77	0.71	0.97	0.92	0.86	0.77	0.71	1.01	0.93	0.87	0.78	0.71
	3	0.84	0.79	0.74	0.67	0.61	0.87	0.81	0.75	0.67	0.61	0.90	0.82	0.76	0.68	0.61	0.91	0.83	0.76	0.68	0.61
	4	0.82	0.74	0.69	0.62	0.56	0.84	0.76	0.70	0.62	0.56	0.85	0.77	0.71	0.62	0.56	0.86	0.78	0.71	0.63	0.56
	5	0.78	0.70	0.65	0.58	0.52	0.79	0.72	0.65	0.58	0.52	0.80	0.73	0.66	0.58	0.52	0.81	0.73	0.67	0.59	0.52
	6	0.75	0.68	0.62	0.55	0.50	0.76	0.69	0.63	0.55	0.50	0.77	0.70	0.63	0.56	0.50	0.78	0.70	0.64	0.56	0.50
	8	0.71	0.64	0.58	0.51	0.46	0.72	0.64	0.58	0.52	0.46	0.72	0.65	0.59	0.52	0.46	0.73	0.66	0.59	0.52	0.46
	10	0.68	0.61	0.55	0.49	0.44	0.69	0.61	0.56	0.49	0.44	0.69	0.62	0.56	0.49	0.44	0.70	0.62	0.56	0.49	0.44

The conversion factor f_2 must be applied only together with conversion factor f_1.

Table 13-57



Conversion factor f_2, cables laid in ground
Single-core cables in three phase systems, trefoil formation (as per DIN VDE 0276-1000)

1	2	3					4					5					6				
Type	Number of systems	Specific thermal resistance of soil in K · m/W																			
		0.7					1.0					1.5					2.5				
XLPE cables		load factor					load factor					load factor					load factor				
0.6/1 kV		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
6/10 kV	1	1.09	1.04	0.99	0.93	0.87	1.11	1.05	1.00	0.93	0.87	1.13	1.07	1.01	0.94	0.87	1.17	1.09	1.03	0.94	0.87
12/20 kV	2	1.01	0.94	0.89	0.82	0.75	1.02	0.95	0.89	0.82	0.75	1.04	0.97	0.90	0.82	0.75	1.06	0.98	0.91	0.83	0.75
18/30 kV	3	0.94	0.87	0.81	0.74	0.67	0.95	0.88	0.82	0.74	0.67	0.97	0.89	0.82	0.74	0.67	0.99	0.90	0.83	0.74	0.67
	4	0.91	0.84	0.78	0.70	0.64	0.92	0.84	0.78	0.70	0.64	0.93	0.85	0.79	0.70	0.64	0.95	0.86	0.79	0.71	0.64
	5	0.88	0.80	0.74	0.67	0.60	0.89	0.81	0.75	0.67	0.60	0.90	0.82	0.75	0.67	0.60	0.91	0.83	0.76	0.67	0.60
	6	0.86	0.79	0.72	0.65	0.59	0.87	0.79	0.73	0.65	0.59	0.88	0.80	0.73	0.65	0.59	0.89	0.81	0.74	0.65	0.59
	8	0.83	0.76	0.70	0.62	0.56	0.84	0.76	0.70	0.62	0.56	0.85	0.77	0.70	0.62	0.56	0.86	0.78	0.71	0.62	0.56
	10	0.81	0.74	0.68	0.60	0.54	0.82	0.74	0.68	0.60	0.54	0.83	0.75	0.68	0.61	0.54	0.84	0.76	0.69	0.61	0.54
PVC cables		load factor					load factor					load factor					load factor				
0.6/1 kV		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
3.6/6 kV	1	1.01	1.02	0.99	0.93	0.87	1.04	1.05	1.00	0.93	0.87	1.07	1.06	1.01	0.94	0.87	1.11	1.08	1.01	0.94	0.87
6/10 kV	2	0.97	0.95	0.89	0.82	0.75	1.00	0.96	0.90	0.82	0.75	1.03	0.97	0.91	0.82	0.75	1.06	0.98	0.92	0.83	0.75
	3	0.94	0.88	0.82	0.74	0.67	0.97	0.88	0.82	0.74	0.67	0.97	0.89	0.83	0.74	0.67	0.98	0.90	0.84	0.74	0.67
	4	0.91	0.84	0.78	0.70	0.64	0.92	0.85	0.79	0.70	0.64	0.93	0.86	0.79	0.70	0.64	0.95	0.87	0.80	0.71	0.64
	5	0.88	0.81	0.75	0.67	0.60	0.89	0.82	0.76	0.67	0.60	0.90	0.82	0.76	0.67	0.60	0.91	0.83	0.77	0.67	0.60
	6	0.86	0.79	0.73	0.65	0.59	0.87	0.80	0.74	0.65	0.59	0.88	0.81	0.74	0.65	0.59	0.89	0.81	0.75	0.65	0.59
	8	0.83	0.76	0.70	0.62	0.56	0.84	0.77	0.71	0.62	0.56	0.85	0.78	0.71	0.62	0.56	0.86	0.78	0.72	0.62	0.56
	10	0.82	0.75	0.69	0.60	0.54	0.82	0.75	0.69	0.60	0.54	0.83	0.76	0.69	0.61	0.54	0.84	0.76	0.70	0.61	0.54

The conversion factor f_2 must be applied only together with conversion factor f_1.

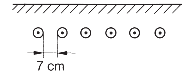
(continued)

Table 13-57 (continued)

1	*2*	*3*					*4*					*5*					*6*				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
Mass-impregnated cables 0.6/1 kV 3.6/6 kV 6/10 kV 12/10 kV 18/30 kV	1	0.94	0.95	0.97	0.93	0.87	0.99	0.99	1.00	0.93	0.87	1.06	1.04	1.01	0.94	0.87	1.15	1.08	1.02	0.94	0.87
	2	0.90	0.91	0.88	0.82	0.75	0.95	0.94	0.89	0.82	0.75	1.00	0.96	0.89	0.82	0.75	1.05	0.97	0.90	0.83	0.75
	3	0.87	0.86	0.80	0.74	0.67	0.91	0.87	0.81	0.74	0.67	0.95	0.88	0.81	0.74	0.67	0.97	0.89	0.82	0.74	0.67
	4	0.86	0.82	0.76	0.70	0.64	0.89	0.83	0.77	0.70	0.64	0.91	0.83	0.77	0.70	0.64	0.92	0.84	0.78	0.71	0.64
	5	0.84	0.79	0.73	0.67	0.60	0.86	0.79	0.73	0.67	0.60	0.87	0.80	0.73	0.67	0.60	0.89	0.81	0.74	0.67	0.60
	6	0.83	0.77	0.71	0.65	0.59	0.84	0.77	0.71	0.65	0.59	0.85	0.78	0.71	0.65	0.59	0.86	0.78	0.72	0.65	0.59
	8	0.80	0.73	0.67	0.62	0.56	0.81	0.74	0.68	0.62	0.56	0.82	0.74	0.68	0.62	0.56	0.83	0.75	0.68	0.62	0.56
	10	0.78	0.71	0.65	0.60	0.54	0.79	0.71	0.65	0.60	0.54	0.80	0.72	0.66	0.61	0.54	0.81	0.73	0.66	0.61	0.54

The conversion factor f_2 must be applied only together with conversion factor f_1.

Table 13-58



Conversion factor f_2, cables laid in ground
Single-core cables in three phase systems, flat formation (as per DIN VDE 0276-1000)

1	*2*	*3*					*4*					*5*					*6*				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
XLPE cables 0.6/1 kV 6/10 kV 12/20 kV 18/30 kV		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
	1	1.08	1.05	0.99	0.91	0.85	1.13	1.07	1.00	0.92	0.85	1.18	1.09	1.01	0.92	0.85	1.19	1.11	1.03	0.93	0.85
	2	1.01	0.93	0.86	0.77	0.71	1.03	0.94	0.87	0.78	0.71	1.05	0.95	0.88	0.78	0.71	1.06	0.96	0.88	0.79	0.71
	3	0.92	0.84	0.77	0.69	0.62	0.93	0.85	0.77	0.69	0.62	0.95	0.86	0.78	0.69	0.62	0.96	0.86	0.79	0.69	0.62
	4	0.88	0.80	0.73	0.65	0.58	0.89	0.80	0.73	0.65	0.58	0.90	0.81	0.74	0.65	0.58	0.91	0.82	0.74	0.65	0.58
	5	0.84	0.76	0.69	0.61	0.55	0.85	0.77	0.70	0.61	0.55	0.87	0.78	0.70	0.62	0.55	0.87	0.78	0.71	0.62	0.55
	6	0.82	0.74	0.67	0.59	0.53	0.83	0.75	0.68	0.60	0.53	0.84	0.75	0.68	0.60	0.53	0.85	0.76	0.69	0.60	0.53
	8	0.79	0.71	0.64	0.57	0.51	0.80	0.71	0.65	0.57	0.51	0.81	0.72	0.65	0.57	0.51	0.81	0.72	0.65	0.57	0.51
	10	0.77	0.69	0.62	0.55	0.49	0.78	0.69	0.63	0.55	0.49	0.78	0.70	0.63	0.55	0.49	0.79	0.70	0.63	0.55	0.49
PVC cables 0.6/1 kV 3.6/6 kV 6/10 kV		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
	1	0.96	0.97	0.98	0.91	0.85	1.01	1.01	1.00	0.92	0.85	1.07	1.05	1.01	0.92	0.85	1.16	1.10	1.02	0.93	0.85
	2	0 92	0.89	0.86	0.77	0.71	0.96	0.94	0.87	0.78	0.71	1.00	0.95	0.88	0.78	0.71	1.05	0.97	0.89	0.79	0.71
	3	0.88	0.84	0.77	0.69	0.62	0.91	0.85	0.78	0.69	0.62	0.95	0.86	0.79	0.69	0.62	0.96	0.87	0.79	0.69	0.62
	4	0. 86	0.80	0.73	0.65	0.58	0.89	0.81	0.74	0.65	0.58	0.90	0.82	0.74	0.65	0.58	0.91	0.82	0.75	0.65	0.58
	5	0.84	0.76	0.70	0.61	0.55	0.85	0.77	0.70	0.61	0.55	0.87	0.78	0.71	0.62	0.55	0.87	0.79	0.71	0.62	0.55
	6	0.82	0.74	0.68	0.59	0.53	0.83	0.75	0.68	0.60	0.53	0.83	0.76	0.69	0.60	0.53	0.85	0.76	0.69	0.60	0.53
	8	0.79	0.71	0.65	0.57	0.51	0.80	0.72	0.65	0.57	0.51	0.81	0.72	0.65	0.57	0.51	0.81	0.73	0.66	0.57	0.51
	10	0.77	0.69	0.63	0.55	0.49	0.78	0.70	0.63	0.55	0.49	0.79	0.70	0.63	0.55	0.49	0.79	0.71	0.64	0.55	0.49

The conversion factor f_2 must be applied only together with conversion factor f_1.

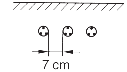
(continued)

Table 13-58 (continued)

1	*2*	*3*					*4*					*5*					*6*				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
Mass-impregnated cables 0.6/1 kV 3.6/6 kV 6/10 kV 12/10 kV 18/30 kV	1	0.93	0.94	0.95	0.91	0.85	1.00	1.00	1.00	0.92	0.85	1.09	1.06	1.01	0.92	0.85	1.19	1.10	1.03	0.93	0.85
	2	0.89	0.89	0.86	0.77	0.71	0.95	0.93	0.87	0.78	0.71	1.01	0.95	0.88	0.78	0.71	1.05	0.97	0.89	0.79	0.71
	3	0.86	0.84	0.77	0.69	0.62	0.90	0.85	0.78	0.69	0.62	0.95	0.86	0.79	0.69	0.62	0.96	0.87	0.79	0.69	0.62
	4	0. 84	0.80	0.73	0.65	0.58	0.88	0.81	0.74	0.65	0.58	0.91	0.82	0.74	0.65	0.58	0.91	0.82	0.75	0.65	0.58
	5	0.82	0.77	0.70	0.61	0.55	0.86	0.77	0.70	0.61	0.55	0.87	0.78	0.71	0.62	0.55	0.87	0.79	0.71	0.62	0.55
	6	0.81	0.74	0.68	0.59	0.53	0.83	0.75	0.68	0.60	0.53	0.85	0.76	0.69	0.60	0.53	0.85	0.76	0.69	0.60	0.53
	8	0.78	0.71	0.65	0.57	0.51	0.80	0.72	0.65	0.57	0.51	0.81	0.73	0.66	0.57	0.51	0.82	0.73	0.66	0.57	0.51
	10	0.77	0.69	0.63	0.55	0.49	0.78	0.70	0.63	0.55	0.49	0.79	0.70	0.64	0.55	0.49	0.79	0.71	0.64	0.55	0.49

The conversion factor f_2 must be applied only together with conversion factor f_1.

Table 13-59



Conversion factor f_2, cables laid in ground
Three-core cables in three-phase systems (as per DIN VDE 0276-1000)

1	2	3					4					5					6				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
VPE cables[1] 0.6/1 kV 6/10 kV		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
	1	1.02	1.03	0.99	0.94	0.89	1.06	1.05	1.00	0.94	0.89	1.09	1.06	1.01	0.94	0.89	1.11	1.07	1.02	0.95	0.89
PVC cables[1] 0.6/1 kV with $S_n \geq 35$ mm²	2	0.95	0.89	0.84	0.77	0.72	0.98	0.91	0.85	0.78	0.72	0.99	0.92	0.86	0.78	0.72	1.01	0.94	0.87	0.79	0.72
	3	0.86	0.80	0.74	0.68	0.62	0.89	0.81	0.75	0.68	0.62	0.90	0.83	0.77	0.69	0.62	0.92	0.84	0.77	0.69	0.62
	4	0.82	0.75	0.69	0.63	0.57	0.84	0.76	0.70	0.63	0.57	0.85	0.78	0.71	0.63	0.57	0.86	0.78	0.72	0.64	0.57
	5	0.78	0.71	0.65	0.59	0.53	0.80	0.72	0.66	0.59	0.53	0.81	0.73	0.67	0.59	0.53	0.82	0.74	0.67	0.60	0.53
	6	0.75	0.68	0.63	0.56	0.51	0.77	0.69	0.63	0.56	0.51	0.78	0.70	0.64	0.57	0.51	0.79	0.71	0.65	0.57	0.51
	8	0.71	0.64	0.59	0.52	0.47	0.72	0.65	0.59	0.52	0.47	0.73	0.66	0.60	0.52	0.47	0.74	0.66	0.60	0.53	0.47
	10	0.68	0.61	0.56	0.49	0.44	0.69	0.62	0.56	0.50	0.44	0.70	0.63	0.57	0.50	0.44	0.71	0.63	0.57	0.50	0.44
PVC cables[1] 0.6/1 kV with $S_n < 35$ mm² 3.6/6 kV		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
	1	0.91	0.92	0.94	0.94	0.89	0.98	0.99	1.00	0.94	0.89	1.04	1.03	1.01	0.94	0.89	1.13	1.07	1.02	0.95	0.89
	2	0.86	0.87	0.85	0.77	0.72	0.91	0.90	0.86	0.78	0.72	0.97	0.93	0.87	0.78	0.72	1.01	0.94	0.88	0.79	0.72
	3	0.82	0.80	0.75	0.68	0.62	0.86	0.82	0.76	0.68	0.62	0.91	0.84	0.77	0.69	0.62	0.92	0.84	0.78	0.69	0.62
	4	0.80	0.76	0.70	0.63	0.57	0.84	0.77	0.71	0.63	0.57	0.86	0.78	0.72	0.63	0.57	0.87	0.79	0.73	0.64	0.57
	5	0.78	0.72	0.66	0.59	0.53	0.81	0.73	0.67	0.59	0.53	0.81	0.74	0.68	0.59	0.53	0.82	0.75	0.68	0.60	0.53
	6	0.76	0.69	0.64	0.56	0.51	0.77	0.70	0.64	0.56	0.51	0.78	0.71	0.65	0.57	0.51	0.79	0.72	0.65	0.57	0.51
	8	0.72	0.65	0.59	0.52	0.47	0.73	0.66	0.60	0.52	0.47	0.74	0.67	0.61	0.52	0.47	0.75	0.67	0.61	0.53	0.47
	10	0.69	0.62	0.57	0.49	0.44	0.70	0.63	0.57	0.50	0.44	0.71	0.64	0.58	0.50	0.44	0.71	0.64	0.58	0.50	0.44

The conversion factor f_2 must be applied only together with conversion factor f_1.

(continued)

[1] In direct-current systems, these factors are also valid for single-core cables for 0.6/1 kV.

Table 13-59 (continued)

1	*2*	*3*					*4*					*5*					*6*				
Type	Number of systems	Specific thermal resistance of soil in K · m/W 0.7					1.0					1.5					2.5				
Mass-impregna-ted cables		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
Belted cables 0.6/1 kV	1	0.94	0.95	0.97	0.94	0.89	1.00	1.00	1.00	0.94	0.89	1.06	1.05	1.01	0.94	0.89	1.13	1.07	1.02	0.95	0.89
3.6/6 kv	2	0.89	0.89	0.85	0.77	0.72	0.94	0.92	0.86	0.78	0.72	0.99	0.93	0.87	0.78	0.72	1.01	0.94	0.88	0.79	0.72
Single lead sheathed (SL)	3	0.84	0.81	0.76	0.68	0.62	0.89	0.83	0.77	0.68	0.62	0.91	0.84	0.78	0.69	0.62	0.92	0.85	0.79	0.69	0.62
cables	4	0.82	0.77	0.71	0.63	0.57	0.85	0.78	0.72	0.63	0.57	0.86	0.79	0.73	0.63	0.57	0.87	0.80	0.73	0.64	0.57
3.6/6 kV 6/10 kV	5	0.80	0.73	0.67	0.59	0.53	0.81	0.74	0.68	0.59	0.53	0.82	0.75	0.69	0.59	0.53	0.83	0.76	0.69	0.60	0.53
	6	0.77	0.70	0.65	0.56	0.51	0.79	0.71	0.65	0.56	0.51	0.79	0.72	0.66	0.57	0.51	0.80	0.73	0.66	0.57	0.51
	8	0.73	0.66	0.61	0.52	0.47	0.74	0.67	0.61	0.52	0.47	0.75	0.68	0.62	0.52	0.47	0.75	0.68	0.62	0.53	0.47
	10	0.70	0.63	0.58	0.49	0.44	0.71	0.64	0.58	0.50	0.44	0.72	0.65	0.59	0.50	0.44	0.72	0.65	0.59	0.50	0.44
PVC cables 6/10 kV		load factor					load factor					load factor					load factor				
		0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00	0.5	0.6	0.7	0.85	1.00
Mass-impregna-ted cables	1	0.90	0.91	0.93	0.96	0.91	0.98	0.99	1.00	0.96	0.91	1.05	1.04	1.03	0.97	0.91	1.14	1.09	1.04	0.97	0.91
Belted cables 6/10 kV	2	0.85	0.85	0.85	0.81	0.76	0.93	0.92	0.89	0.82	0.76	0.98	0.95	0.90	0.82	0.76	1.03	0.96	0.90	0.82	0.76
H cables	3	0.80	0.79	0.78	0.72	0.66	0.87	0.86	0.80	0.72	0.66	0.93	0.86	0.80	0. 73	0.66	0.95	0.87	0.81	0.73	0.66
6/10 kV 12/20 kV	4	0.77	0.77	0.74	0.67	0.61	0.85	0.81	0.75	0.67	0.61	0.89	0.82	0.75	0.68	0.61	0.90	0.82	0.76	0.68	0.61
18/30 kV	5	0.75	0.75	0.70	0.63	0.57	0.84	0.77	0.71	0.63	0.57	0.85	0.77	0.71	0.63	0.57	0.86	0.78	0.72	0.64	0.57
Single lead	6	0.74	0.73	0.67	0.60	0.55	0.81	0.74	0.68	0.60	0.55	0.82	0.74	0.68	0.61	0.55	0.83	0.75	0.69	0.61	0.55
sheathead (SL) cables	8	0.73	0.69	0.63	0.56	0.51	0.77	0.70	0.64	0.56	0.51	0.77	0.70	0.64	0.57	0.51	0.78	0.71	0.64	0.57	0.51
12/20 kV 18/30 kV	10	0.71	0.66	0.60	0.53	0.48	0.74	0.67	0.61	0.54	0.48	0.74	0.67	0.61	0.54	0.48	0.75	0.67	0.61	0.54	0.48

The conversion factor f_2 must be applied only together with conversion factor f_1.

13.2.3 Selection and protection

Protection against overload (DIN VDE 0100-430 and Supplement 1 to DIN VDE 0100-430)

If overloading of the circuits, e.g. socket outlets, motors, is anticipated, the overload protection system must meet the following conditions:

$$I_b \leq I_n \leq I_z \qquad (1)$$

$$I_2 \leq 1.45 \cdot I_z \qquad (2)$$

Here:

I_b Prospective operating current of circuit

I_z Current rating of wire or cable

I_n Rated current of protection system
Note, with adjustable protective devices I_n is the set value

I_2 The current that trips the protection system under the conditions specified for the device (conventional tripping current I_2)

(This trip value is also designated by other symbols in some equipment regulations.)

The rated current I_n may equal the current-carrying capacity I_z when overload protection equipment is used, to which $I_{2} \leq$ 1.45 I_n applies. This property is included in miniature circuit-breakers (DIN VDE 0641-11 (VDE 0641 Part 11), circuit-breakers (DIN EN 60947-2 (VDE 0660 Part 101) Table VI) and fuses (DIN VDE 0636-21 A4/Draft1989-05).

The current-carrying capacity of cables depending on the varying laying and operating conditions can be found in the tables in Section 13.2.2. For fixed installation of plastic-insulated cables and lines in buildings, Table 13-60 gives the permissible current-carrying capacity and also the rated current magnitudes of the protection devices suitable for overload protection.

Protection in the event of short circuit (DIN VDE 0100-430 and Supplement 5 to DIN VDE 0100)

The same types of protection devices as for overload protection come under consideration for protection of cables in the event of short circuit.

To protect in case of short circuit, the breaking capacity of the protection device must be at least equal to the greatest current in the event of a galvanic short circuit at the installation site. However, a lower breaking capacity is permissible if the device is backed up by another which has the necessary capacity. In this case, the characteristics of the two devices must be coordinated so that the downstream device and the protected cable cannot be damaged (energy throughput, weld resistance, dynamic strength of current paths).

The prerequisite for effective protection in the event of a short circuit is that the fault current reaches the trip value of the short-circuit protection device. This means that the resistance of the cable, i.e. its length, must not exceed a specified limit value. The upstream loop impedance between the power source and the protection device must be taken into account here.

The tables 13-61 and 13-62 can be used to determine the maximum lengths of PVC-insulated conductors ensuring the permitted break times *t* in the event of short circuits, for a variety of protective devices required only to respond to short circuits.

Examples of the permissible maximum lengths for short-circuit protection with fuses are given in Tables 13-61 and 13-62. There are additional tables on this subject in Supplement 5 to DIN VDE 0100.

The permissible break time *t* for short circuits lasting up to 5 s can be approximately determined with the following equation.

$$t = \left(\frac{k \cdot S}{I}\right)^2$$

- *t* permissible break time after fault in s
- *S* conductor cross-section in mm^2
- *I* current on dead short-circuit in A
- *k* constant, with values (see Tables 5-3 and 5-4) of 115 for PVC-insulated copper conductor, 76 for PVC-insulated aluminium conductor, 141 for rubber-insulated copper conductor, 87 for rubber-insulated aluminium conductor, 115 for soft solder joints in copper conductor.

If the permissible break times are very short (< 0.1 s), the product $k^2 \cdot S^2$ obtained from the equation must be greater than the value $I^2 \cdot t$ stated by the manufacturer of the current-limiting device.

These protection devices, depending on the performance data, can provide both overload and short-circuit protection. However, there are devices such as contactors with overcurrent tripping or backup fuses that are not suitable for both functions.

Protection with direct contact

The same conditions as with protection of cables and lines against overload by short circuit currents also apply for protection with indirect contact (see also Section 5.1.2). The protection device must disconnect the protected component of an installation from the system within the period defined in the standard (0.1 s, 0.2 s, 0.4 s or 5 s) to prevent excessively high touch voltages from occurring. If in the event of a double fault the IT-System network is tripped by a protection device with time/current characteristic, a minimum fault current must also be ensured in this case. This requires a maximum length for the cables and lines in question.

Voltage drop (DIN VDE 0100-520 (VDE 0100 Part 520)

A constant service voltage is essential for proper functioning of much equipment. For this reason, cables and lines must be rated to ensure that the permissible voltage drop is not exceeded (see also Section 2.4 and 6.1.6). This case also requires maximum values for the lengths of cables and lines, based on the expected load current.

Note

There may be different maximum values for cable and line lengths when selecting the protection devices for the three different cases. In general, the limit value must be calculated separately for all three criteria and the lowest value of the current circuit must be taken (Supplement 5 to DIN VDE 0100).

Table 13-60

Current-carrying capacity I_z in A of cables and lines for permanent installation in buildings (DIN VDE 0298-4)
Assignment of rated currents of overload protection devices I_n in A, whose tripping current I_2 must be $I_2 \leq 1.45\ I_n$ (Supplement 1 to DIN VDE 0100-430)

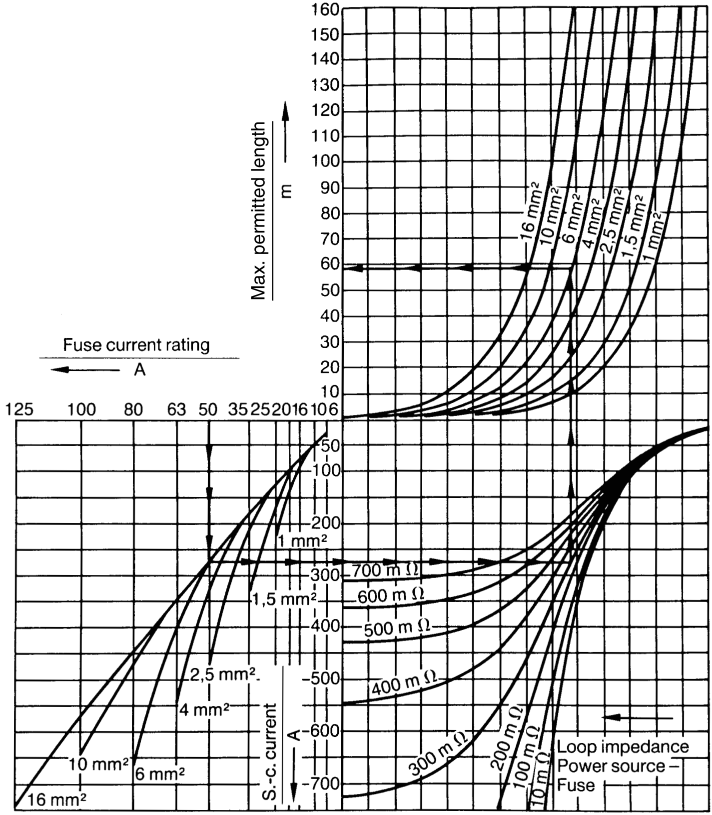
	Identification code																							
Cable type	NYM, NYBUY, NHYRUZY, NYIF, NYIFY, H07V-U, H07V-R, H07V-K Maximum operating temperature 70 °C																NYY, NYCWY, NYKY, NYM, NYMZ, NYMT, NYBUY, NHYRUZY							
Ambient temperature	Reference temperature 25 °C																							
Mode of operation	Continuous operation																							
Mode of cable laying[1]	Group A				Group B1				Group B2				Group C				Group E							
Number of loaded cores	2		3		2		3		2		3		2		3		2		3					
Nom. cross section mm² copper	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n	I_z	I_n				
1.5	16.5[2]	16	14	13[2]	18.5	16	16.5	16	16.5	16	15	13[2]	21	20	18.5	16	21	20	19.5	16				
2.5	21	20	19	16	25	25	22	20	22	20	20	20	28	25	25	25	29	25	27	25				
4	28	25	25	25	34	32[2]	30	25	30	25	28	25	37	35[2]	35[8]	35[2]	39	35[2]	36	35[2]				
6	36	35[2]	33	32[2]	43	40[2]	38	35[2]	39	35[2]	35	35[2]	49	40[2]	43	50	51	50	46	40[2]				
10	49	40[2]	45	40[2]	60	50	53	50	53	50	50	50	67	63	63	63	70	63	64	63				
16	65	63	59	50	81	80	72	63	72	63	65	63	90	80	81	80	94	80	85	80				
25	85	80	77	63	107	100	94	80	95	80	82	80	119	100	102	100	125	125	107	100				
35	105	100	94	80	133	125	118	100	117	100	101	100	146	125[2]	126	125[2]	154	125[2]	134	125[2]				
50	126	125[2]	114	100	160	160[2]	142	125[2]	—	—	—	—	—	—	—	—	—	—	—	—				
70	160	160[2]	144	125[2]	204	200[2]	181	160[2]	—	—	—	—	—	—	—	—	—	—	—	—				
95	193	160[2]	174	160[2]	246	200[2]	219	200[2]	—	—	—	—	—	—	—	—	—	—	—	—				
120	223	200[2]	199	160[2]	285	250[2]	253	250[2]	—	—	—	—	—	—	—	—	—	—	—	—				

[1] See Table 13-65.
[2] Miniature circuit-breakers and fuses are not available in all cases with the rated currents given here. If necessary, the next lowest standard quantity must be used.

Fig. 13-9
Nomogram for determining max. permissible wire or cable lengths with single-phase short circuits in 380/220 V networks for fuses to DIN VDE 0636 responding only to short-circuit currents, and PVC-insulated wires up to 16 mm² Cu (to DIN VDE 100-430).

Example:

Fuse current rating	50 A
Wire cross-section	6 mm²
Loop impedance	300 mΩ
Max. permitted length	58 m



Example:

Rated current of the miniature circuit-breaker 50 A
Wire cross-section 10 mm²
Loop impedance 400 mΩ
Max. permitted line length 110 m

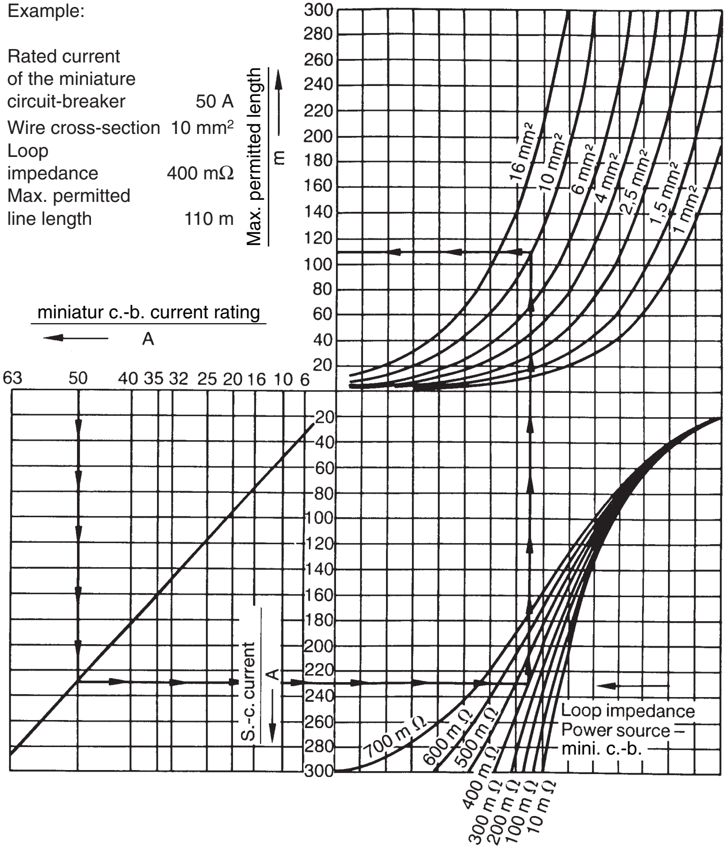
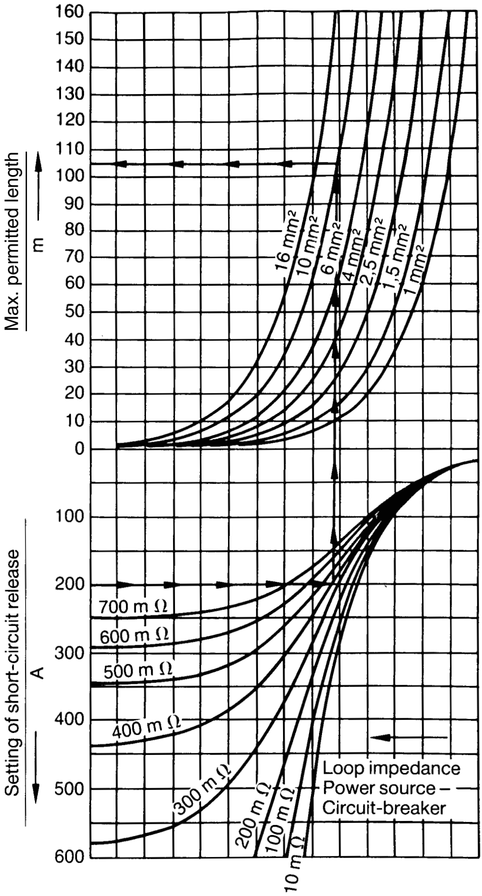


Fig. 13-10a

Nomogram for determining max. permissible wire or cable lengths with single-phase short circuits in 380/220 V networks for miniatur circuit-breaker to DIN VDE 0641 responding only to short circuits, and PVC-insulated wires up to 16 mm² Cu (to DIN VDE0100-430).



Example:

Setting of short-circuit release	200 A
Wire cross-section	10 mm^2
Loop impedance	400 mΩ
Max. permitted line length (to DIN VDE 0100-430)	105 m

Fig. 13- 10b

Nomogram for determining max. permissible wire or cable lengths with single-phase short circuits in 380/220 V networks for circuit-breakers to DIN VDE 0660 responding only to short circuits, and PVC-insulated wires up to 16 mm^2 Cu.

Table 13-61

Maximum permissible cable and line lengths
Copper conductor, insulation PVC or rubber (as in Supplement 5 to VDE 0100)
Fuse, duty class gG as per IEC 60 269-1 (≙ VDE 0636 Part 10)
Nominal voltage of the installation: 400 Volt, 50 Hz
Tripping after 5 s or after the permissible short-circuit temperature is reached

Conductor nominal cross-section	Rated current of protection device	Minimum short-circuit current	Loop impedance before the protection device mΩ								
			10	50	100	200	300	400	500	600	700
			Maximum permissible length l_{max}								
mm²	A	A	m	m	m	m	m	m	m	m	m
1.5	6	27	270	269	267	264	261	258	255	252	249
	10	47	155	154	152	149	146	143	140	137	134
	16	65	112	111	109	106	103	100	97	94	91
	20	126	58	57	55	52	49	46	43	40	36
	25	135	54	53	51	48	45	42	39	36	32
2.5	10	47	253	251	249	244	239	234	229	224	219
	16	65	183	181	178	173	169	164	159	154	148
	20	85	139	138	135	130	125	120	115	110	105
	25	110	108	106	103	98	93	88	93	78	73
	32	165	72	70	67	63	57	52	47	42	36
4	16	65	297	294	290	282	274	266	258	250	241
	20	85	227	224	220	212	204	196	187	179	171
	25	110	175	172	168	160	152	144	135	127	118
	32	150	128	125	121	113	105	96	88	79	71
	40	190	101	98	94	86	77	69	60	51	42
	50	280	68	65	61	53	45	36	27	18	8
6	20	85	342	337	331	319	307	294	282	270	257
	25	110	264	259	253	241	229	216	204	191	178
	32	150	193	188	182	170	158	145	132	119	106
	40	190	152	147	141	129	116	104	91	77	64
	50	260	111	106	100	87	75	62	48	35	20
	63	330	87	82	76	64	57	38	24	10	0
10	25	110	441	433	423	403	382	361	340	319	298
	32	150	323	315	305	284	264	242	221	199	178
	40	190	255	246	236	216	195	173	152	130	107
	50	260	185	177	167	146	125	103	81	58	34
	63	320	150	142	132	111	89	67	44	20	0
	80	440	108	100	90	69	46	23	0	0	0
16	32	150	512	499	483	450	417	384	350	315	280
	40	190	404	391	374	341	308	274	240	205	169
	50	260	294	281	265	231	198	163	127	91	54
	63	320	238	225	209	175	141	106	69	32	0
	80	440	172	159	143	109	73	37	0	0	0
	100	580	130	117	100	65	29	0	0	0	0

Table 13-62

Maximum permissible cable and line lengths
Copper conductor, insulation PVC, XLPE or EPR (as in Supplement 5 to VDE 0100)
Fuse, duty class gG as per IEC 60 269-1 (≙ VDE 0636 Part 10)
Nominal voltage of the installation: 400 Volt, 50 Hz
Tripping after 5 s or after the permissible short-circuit temperature is reached

Conductor nominal cross-section	Rated current of protection device	Minimum short-circuit current	Loop impedance before the protection device in mΩ				
			10	50	100	200	300
			Maximum permissible length l_{max}				
mm²	A	A	m	m	m	m	m
25	63	320	374	354	328	275	221
	80	440	271	250	224	170	115
	100	580	204	183	157	102	46
	125	750	157	136	109	54	0
	160	930	125	104	77	21	0
35	80	440	372	343	307	233	157
	100	580	280	251	215	140	52
	125	750	215	186	149	73	0
	160	930	172	143	106	28	0
	200	1350	116	87	49	0	0
	250	1600	97	67	29	0	0
50	100	580	376	337	288	187	83
	125	750	289	249	200	97	0
	160	930	231	191	141	38	0
	200	1350	156	116	65	0	0
	250	1600	130	90	39	0	0
70	125	750	408	352	281	136	0
	160	930	326	270	199	53	0
	200	1350	220	164	92	0	0
	250	1600	184	127	54	0	0
	315	2200	130	73	0	0	0
95	160	930	438	361	265	70	0
	200	1350	296	219	122	0	0
	250	1600	246	169	72	0	0
	315	2200	174	97	0	0	0
	400	2750	135	58	0	0	0
120	200	1350	362	267	148	0	0
	250	1600	302	207	88	0	0
	315	2200	213	118	0	0	0
	400	2750	165	70	0	0	0
150	200	1350	426	314	174	0	0
	250	1600	355	243	103	0	0
	315	2200	250	139	0	0	0
	400	2750	195	83	0	0	0
	500	3900	129	17	0	0	0

13.2.4 Installation of cables and wires

When installing cables and wires, one must make sure that throughout their anticipated useful life their performance and reliability are not diminished by such factors as:

– Grouping, external heat sources (which reduce current-carrying capacity)
– Mechanical, thermal and chemical action
– Nature of soil (laying in sand or stone-free ground)
– Earth movement, vibration, tremors
– Dynamic stressing due to fault currents
– Leakage currents and corrosion

When pulling cables, the maximum tensile forces in Table 13-63 (always referred to the conductor's total nominal cross-section area; shielding or concentric conductors are disregarded) must not be exceeded. The same maximum tensile forces are applicable when pulling three single-core cables simultaneously with a single cable grip. In the case of three factory-stranded single-core cables, the forces are valid for three cables, but for only two cables in the case of three non-stranded single-core cables. The bending radii to be observed are shown in Table 13-64.

Single-core cables in trefoil formation can be fixed in the same way as multi-core cables, when run through conduits of steel they must be contained in the same tube. With single-core cables or wires in AC or three-phase systems, clips of plastic or non-magnetic metal must be used so that the fixing system does not create a closed conductive loop.

Commonly used methods of laying wires are described in DIN VDE 0298-4, see Table 13-65.

Cables and wires must be arranged or marked so as to be clearly identifiable at any later date.

While pulling cables insulated or sheathed with PVC, the cable temperature must not drop below a limit of – 5 °C; whereas for XLPE cables (with PE sheath) a limit of – 20 °C is allowed. The lowest admissible cable temperature when pulling paper insulated mass cables is + 5 °C.

If outside temperatures are lower, it is advisable to store the cables in a heated area (e. g. 24 h at 20 °C) or warm them as necessary before laying.

The coding of insulated and bare conductors according to DIN 40705 is shown in Table 13-66.

For further guidelines on the laying of cables and wires, see Sections 6.1.7 and 15.4.2, also DIN VDE 0298-1 and 0298-3.

Table 13-63

Calculation of max. permitted pulling forces

1 Pulling method	2 Cable type	3 Formula	4 Factor
With pulling eye on conductors	All cable types	$P = \sigma \cdot A$	$\sigma = 50$ N/mm^2 (Cu conductor) $\sigma = 30$ N/mm^2 (Al conductor)
With cable grip	Plastic-insulated cable, without metal sheath and without armouring (e. g. NYY, NYSY, NYSEY, N2XSY, etc.)	$P = \sigma \cdot A$	$\sigma = 50$ N/mm^2 (Cu conductor) $\sigma = 30$ N/mm^2 (Al conductor)
	All wire-armoured cables (e. g. NYFGY, NAYFGY etc.)	$P = K \cdot d^2$	$K = 9$ N/mm^2
	Cable without armour for tensile stresses:		
	Single-core cables (e. g. NKBA, NYKY, NKLEY etc.)	$P = K \cdot d^2$	K = 3 N/mm^2
	Three-core SL cables (e. g. NEKEBA, NAEKEBA etc.)	$P = K \cdot d^2$	$K = 1$ N/mm^2

A = conductor cross section (mm^2)
d = cable diameter (mm)

Table 13-64

Minimum bending radii

Cable	Paper-insulated cable		Plastic-insulated cable	
	With lead sheath	With smooth Al sheath	$U_0 = 0.6$ kV	$U_0 > 0.6$ kV
Single-core	$25 \times d$	$30 \times d$	$15 \times d$	$15 \times d$[1)]
Multicore	$15 \times d$	$25 \times d$	$12 \times d$	$15 \times d$
Many-core			$12 \times$ d	

d = Cable diameter (mm)

1) For stranded cables: diameter over laid-up conductor

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Table 13-65

Methods of cable laying to DIN VDE 0298 Part 4

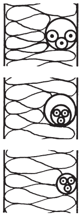
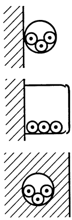
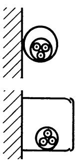
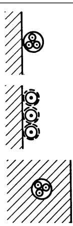
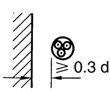
A		Laying in insulated walls (including floor) – single-core non-sheathed cables in electrical ducts or conduits (including closed floor ducts) – multicore lines and single-core sheathed wires in electrical ducts or conduits – multicore lines and single-core sheathed wires in walls
B 1		Laying on walls or under plaster – single-core non-sheathed cables in electrical ducts or conduits on the wall (including ventilated floor ducts) – single-core non-sheathed cables, single-core sheathed cables, multicore lines in electrical conduits in walls (including ceiling)
B 2		Laying on walls – multicore non-sheathed cables in electrical ducts or conduits on the wall or floor
C		Direct laying – multicore lines and single-core sheathed cables on the wall or on the floor (including open or ventilated ducts) – multicore lines in walls (including ceilings)
E		Laying exposed in air, i.e. thermal dissipation is ensured without hindrance – where the lines are installed > 0.3 d from the wall (d = external diameter of the line) – with lines installed side by side spaced at a minimum of twice the line diameter, – with lines installed above one another with a vertical spacing of a minimum of twice the line diameter

Table 13-66

Alphanumeric codes and symbols in relation to colour coding of insulated and bare conductors (to DIN 40705, February 1980)

Conductor designation		Coding Alpha-numeric	Symbol	Colour
AC network	phase 1	L 1		[1]
	phase 2	L 2		[1]
	phase 3	L 3		[1]
	neutral	N		Light blue[4]
DC network	positive	L +	+	[1]
	negative	L –	–	[1]
	middle	M		Light blue[4]
Protective conductor		PE		Green/ yellow[3]
Neutral conductor with protective function		PEN		Green/ yellow[3]
Earth		E		[1] [2]

[1] Colour code not specified.
[2] Earth wires must be coded green/yellow if connecting protective conductor to earth.
[3] This colour code must not be used for any other conductor.
[4] If there is no neutral conductor, the light blue conductor in multi-core wires and cables may be used for other purposes apart from the protective conductor.

13.2.5 Cables for control, instrument transformers and auxiliary supply in high-voltage switchgear installations

Certain preferred types of cable are used for electrically connecting spatially separated system components. Their selection must take account of the following technical requirements:

- Number of cores according to function,
- Cross-section of cores according to required power rating, cable length and permitted voltage drop and also ambient circumstances,
- Earthing conditions,
- Protection against transient overvoltages,
- Protection against mechanical damage.

Preferred cable type[1)]	Transmission function
NYY-J	control, signalling, current and voltage transformers and auxiliary voltage supply. They are used where no special protection against mechanical damage is required. There is no option for reducing transient overvoltages. The yellow-green conductor must be earthed at both ends with the shortest possible connection.
YBY	control, signalling, current and voltage transformers and auxiliary voltage supply. They are used where enhanced protection against mechanical damage is required. This type of cable is preferred in switchgear installations manufactured for export. There are limited options for reducing transient overvoltages. The yellow-green conductor and also the galvanized steel cable sheath must be earthed at both ends with the shortest possible connection.
NYCY	control, signalling, current and voltage transformers and auxiliary voltage supply. There are limited options for reducing transient overvoltages. The concentric copper conductor must be earthed at both ends with the shortest possible connection.
YCY	control, signalling, current and voltage transformers and auxiliary voltage supply. Braided shield with 80% coverage. Preferred use where reducing transient overvoltages is essential, e.g. connections for electronic equipment. The concentric copper conductor must be earthed with the shortest possible connection (preferably through the PG bolts). There is only limited mechanical protection.

1) to DIN VDE 0271

Table 13-67 a to d lists the preferred cables used in high-voltage switching installations, including core coding and the principal mechanical data. The cables marked with an asterisk (*) are usually not available ex-stock, but have technical and economic advantages in the switchgear field. Minimum production lengths and early ordering are points to remember with these cables.

For high and extra-high-voltage switching stations and also extensive systems, cross sections and voltage drops should be verified by calculation; this requirement applies particularly to current transformer circuits and control circuits, see Sections 2.4 and 6.1.6.

Table 13-67

Preferred control and auxiliary supply cables 0.6/1 kV for high-voltage switching stations

Core number and cross-section	Core coding NYY-J Number	Coloured*	Mech. data External diameter mm[1]	Weight kg/km[1]	Functions Control Inter-locking position indic. etc.	Current trans-former	Voltage trans-former	Infeed AC/DC (Power supply)
5 × 2.5		GNGE/SW/ HBL/BR/SW	16	390				●
7 × 2.5	1-6	GNGE	16	470	●			
14 × 2.5	1-13	GNGE	21	640	●			
24 × 2.5	1-23	GNGE	26	1 030	●			
5 × 4		GNGE/SW/ HBL/BR/SW	18	530				●
5 × 6		GNGE/SW/ HBL/BR/SW	20	670				●
5 × 10		GNGE/SW/ HBL/BR/SW	22	920				●

[1] Typical values

Core number and cross-section	Core coding YCY NYCY Number	Coloured*	Mech. data External diameter mm[1]	Weight kg/km[1]	Functions Control Inter-locking position indic. etc.	Current trans-former	Voltage trans-former	Infeed AC/DC (Power supply)
5 × 2.5/2.5	1-5	SW/HBL/ BR/SW	16	400			●	●
7 × 2.5/2.5	1-7		18	520	●			
16 × 2.5/6	1-16		24	960	●			
24 × 2.5/10	1-24		28	1 370	●			
5 × 4/4	1-5	SW/HBL/ BR/SW	18	560		●	●	●
5 × 6/6	1-5	SW/HBL/ BR/SW	20	720		●	●	●
5 × 10/10*	1-5	SW/HBL/ BR/SW	22	990		●	●	●
5 × 16/16*	1-5		25	1 499		●		

(continued)

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Table 13-67 (continued)

Core number and cross-section	Core coding YBY-J Number	Coloured*	Mech. data External diameter mm[1)]	Weight kg/km[1)]	Functions Control Inter-locking position indic. etc.	Current trans-former	Voltage trans-former	Infeed AC/DC (Power supply)
5 × 2.5		GNGE/SW/ HBL/BR/SW	17	480			●	●
7 × 2.5	1-6	GNGE	18	560	●			
14 × 2.5	1-13	GNGE	22	800	●			
24 × 2.5	1-23	GNGE	28	1 230	●			
30 × 2.5	1-29	GNGE	30	1 440	●			
5 × 4		GNGE/SW/ HBL/BR/SW	19	640		●	●	●
5 × 6		GNGE/SW/ HBL/BR/SW	21	750		●	●	●
5 × 10		GNGE/SW/ HBL/BR/SW	23	1 150		●	●	●
5 × 16		GNGE/SW/ HBL/BR/SW	25	1 410		●	●	●

Core number and Cross-section	Core coding NYY-O Number	Coloured*	Mech. Data External diameter mm[1)]	Weight kg/km[1)]	Functions Battery installation
1 × 50		SW	16	630	●
1 × 95		SW	20	1 130	●
1 × 120		SW	21	1 370	●

● Preferred variation

1) Typical values

* in general not available from stock

The listed cable types can also be replaced by a halogen-free design (Type NHX...) if required.

*Abbreviations:

GNGE = green/yellow (**G**rü**n**-**Ge**lb)

SW = black (**S**ch**w**arz)

HBL = light blue (**H**ell**bl**au)

BR = brown (**Br**aun)

13.2.6 Telecommunications cables

With centralized network management, all the remotely controlled and monitored switching facilities produce measurements and signals which are converted by telecontrol systems and transmitted to the dispatching centre. As a rule, all the transmitted measurements are gathered centrally in a marshalling cubicle and sent via cable links to the telecontrol system. Multipair telecommunication cables of type J-Y(ST)Y 0.8 are preferred for this purpose

For technical data, types and dimensions of these cables see Tables 13-68 and 13-69.

These cables can be used for telecontrol, measurement and signalling, and also for telephony, but not for power transmission. In accordance with VDE 0800 Part 1, they can be used in dry and humid areas, and also outdoors if permanently installed.

They are protected against external electrical interference by a static shield of plastic-coated metal foil. Inside the cable there is also a bare solid copper screening wire in contact with the static shield throughout its length.

This wire has a diameter of 0.4 mm for up to 10 pairs, and 0.6 mm for more than 10 pairs.

The screening wire must be connected to earth at one end of the cable. The individual cores are colour-coded and laid up in pairs. The individual pairs/wires are identified by coding the cores from the outside inwards, see next page.

Coding of cores

2-pair cables are coded as follows:

1st pair (tracer pair)	Core a = red / Core b = black
2nd pair	Core a = white / Core b = yellow

and for all other cables

1st pair (tracer pair)	Core a = red / Core b = blue
2nd pair	Core a = white / Core b = yellow
3rd pair	Core a = white / Core b = green
4th pair	Core a = white / Core b = brown
5th pair	Core a = white / Core b = black

and this sequence then repeats.

Table 13-68

Telecommunications cables. Technical data

Conductor diameter				mm	0.6	0.8
Loop resistance	at 20 °C		max.	Ω/km	130	73.2
Insulation resistance			min.	MΩ · km	100	100
Effective capacitance	at 800 HZ		max.	nF/km	120[1)]	120[1)]
Line attenuation (planning guideline)	at 800 HZ			dB/km	1.74	1.13
Capacitive coupling	at 800 HZ	k_1	max.	pF/100 m	300[2)]	
		$k_{9\ldots12}$	max.	pF/100 m	100[3)]	
Test voltage	Wire/wire			U_{eff} V	800	
	Wire/shield			U_{eff} V	800	
Service voltage	(peak value)		max.	V	300	
Permitted temperature range	when laying			°C	– 5 to + 50	
	before and after laying			°C	– 30 to + 70	
Permitted bending radius				min.	7.5 × Cable diameter	

1) For cables with two pairs, the values can be 20 % higher
2) 20 % of the value – but at least 1 value – may be up to 500 pF
3) 10 % of the value – but at least 4 values (related) – may be up to 300 pF

Table 13-69

Telecommunications cables. Types J-Y(St)Y – Dimensions

Number of pairs	Wire dia. mm	Wall thickness of outer sheath mm	Outside dia. approx. mm	Weight approx. kg/km	Number of pairs	Wire dia. mm	Wall thickness of outer sheath mm	Outside dia. approx. mm	Weight approx. kg/km
2	2 x 0.6	1 0	5.0	37	2	2 x 0.8	1.0	6.4	58
4		1.0	6.4	53	4		1.0	8.7	91
6		1.0	7.4	74	6		1.2	10.4	134
10		1.0	8.6	102	10		1.2	12.8	198
16		1.2	10.6	158	16		1.2	15.1	294
20		1.2	10.9	176	20		1.2	16.5	349
24		1.2	11.7	205	24		1.4	18.2	424
30		1.2	13.2	260	30		1.4	20.0	512
40		1.2	14.7	330	40		1.4	22.5	657
50		1.4	16.1	400	50		1.6	25.3	826
60		1.4	17.4	470	60		1.6	27.3	968
80		1.6	20.4	668	80		1.8	31.3	1285
100		1.6	22.2	805	100		2.0	34.9	1597

13.2.7 Data of standard VDE, British and US cables

The outside diameters and weights of certain selected cables are given in Tables 13-70 to 13-73.

Tables 13-74 and 13-75 compare the principal cross-sections according to AWG, SWG and VDE standards. The conversion of circular mils and square inches into square millimetres is shown in Table 13-76.

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Table 13-70

Outside diameters in mm and weights (typical) in kg/km of single-core cables, bracket data = shield cross-section in mm²

Core no. and cross-section mm²	NYY 0.6/1 kV mm kg/km	N2XSY 6/10 kV mm kg/km	NA2XSY 6/10 kV mm kg/km	N2XSY 12/20 kV mm kg/km	NA2XSY 12/20 kV mm kg/km	N2XSY 18/30 kV mm kg/km	NA2XSY 18/30 kV mm kg/km
1 × 25	13	—	—	—	—	—	—
	380	—	—	—	—	—	—
1 × 35 (16)	14	22	25	26	—	—	—
	470	790	690	930	—	—	—
1 × 50 (16)	15	23	26	27	30	32	36
	630	940	760	1 090	860	1 280	1 100
1 × 70 (16)	17	24	27	29	32	34	37
	840	1 160	870	1 350	950	1 590	1 250
1 × 95 (16)	19	26	29	30	33	36	39
	1 110	1 430	950	1 600	1 070	1 890	1 380
1 × 120 (16)	21	28	30	32	35	37	40
	1 350	1 670	1 050	1 870	1 180	2 150	1 510
1 × 150 (25)	23	29	32	33	37	39	42
	1 650	2050	1 230	2 250	1 380	2 570	1 770
1 × 185 (25)	24	31	34	35	38	41	44
	2 010	2 400	1 380	2 670	1 520	2 930	1 930
1 × 240 (25)	27	33	37	37	41	43	46
	2 570	2 950	1 520	3 200	1 740	3 550	2 270
1 × 300 (25)	30	36	39	40	43	46	49
	3 250	3 650	1 830	3 900	1 960	4 250	2 530
1 × 400 (35)	33	39	42	43	46	49	51
	4 030	4 550	2 240	4 800	2 390	5 200	2 950
1 × 500 (35)	37	42	45	47	49	52	55
	5 120	5 700	2 500	6 000	2 810	6 400	3 350

Table 13-71 Outside diameters in mm and weights (typical) in kg/km of three-core cables, bracket data = shield cross-section in mm²

Core no. and cross-section	NYY 0.6/1 kV Outside dia. kg/km	NYCY 0.6/1 kV Outside dia. kg/km	NYCWY 0.6/1 kV Outside dia. kg/km	NYFY 3.6/6 kV Outside dia. kg/km	NYSEY 6/10 kV Outside dia. kg/km
3 × 1.5 (1.5)	13	14	—	—	—
	240	270	—	—	—
3 × 2.5 (2.5)	14	15	—	—	—
	290	330	—	—	—
3 × 4 (4)	15	16	—	—	—
	390	435	—	—	—

Continued on next page

Table 13-71 (continued)

Outside diameters in mm and weights (typical) in kg/km of three-core cables, bracket data = shield cross-section in mm^2

Core no. and cross-section mm^2	NYY 0.6/1 kV mm kg/km	NYCY 0.6/1 kV mm kg/km	NYCWY 0.6/1 kV mm kg/km
3 × 6 (6)	17	18	—
	480	550	—
3 × 10	18	—	20
	650	—	770
3 × 16	21	—	22
	870	—	1 050
3 × 25 (16)	24	—	26
	1 320	—	1 510
3 × 35 (16)	25	—	27
	1 325	—	1 800
3 × 50 (16)	28	—	—
	1 780	—	—
3 × 50 (25)	31	—	32
	2 140	—	2 350
3 × 70 (16)	31	—	—
	2 480	—	—
3 × 70 (35)	34	—	35
	2 910	—	3 100
3 × 95 (16)	35	—	—
	3 320	—	—
3 × 95 (50)	38	—	39
	3 900	—	4 200
3 × 120 (16)	39	—	—
	4 070	_	—
3 × 120 (70)	42	—	43
	4 900	—	5 300
3 × 150 (25)	42	—	—
	4 950	—	—
3 × 150 (70)	46	—	47
	4 750	—	6 500
3 × 185 (95)	52	—	51
	7 350	—	7 710
3 × 240 (120)	57	—	55
	10 000	—	9 700

Table 13-72

Outside diameters in mm and weights (typical) in kg/km of 3 1/2, 4- and 5-core cables, bracket data = shield cross-section in mm^2

Core no. and cross-section mm^2	NYY 0.6/1 kV mm kg/km
3 × 25 (16)	27 1 570
3 × 35 (16)	27 1 600
3 × 50 (25)	31 2 140
3 × 70 (35)	34 2 910
3 × 95 (50)	38 3 900
3 × 120 (70)	42 4 900
3 × 150 (70)	46 5 750
3 × 185 (95)	52 7 350
3 × 240 (120)	57 9 400
3 × 300 (150)	64 11 950

Core no. and cross-section mm^2	NYY 0.6/1 kV mm kg/km	NYCWY 0.6/1 kV mm kg/km	NYCY 0.6/1 kV mm kg/km
4 × 1.5	14 270	— —	15 310
4 × 2.5	15 330	— —	16 380
4 × 4	17 450	— —	18 530
4 × 6	18 570	— —	19 670
4 × 10 (10)	20 780	21 900	
4 × 16 (16)	22 1 070	24 1 250	
4 × 25 (16)	27 1 640	28 1 690	
4 × 35 (16)	28 1 800	30 2 200	
4 × 50 (25)	31 2 400	35 3 050	
4 × 70 (35)	35 3 300	39 4 050	
4 × 95 (50)	40 4 400	44 5 350	
4 × 120 (70)	44 5 400	48 6 850	
4 × 150 (70)	49 6 650	53 8 250	

Core no. and cross-section mm^2	NYY 0.6/1 kV mm kg/km
5 × 1.5	15 310
5 × 2.5	16 330
5 × 4	18 520
5 × 6	20 670
5 × 10	22 920
5 × 16	24 1 290
5 × 25	27 1 890

Table 13-73

Outside diameters in mm and weights (typical) in kg/km of multi-core cables

Core no.	NYY-J 0.6/1 kV 1.5 mm² mm kg/km	2.5 mm² mm kg/km	YBY-J 0.6/1 kV 2.5 mm² mm kg/km	NYCY 0.6/1 kV 1.5/1.5 mm² mm kg/km	2.5/2.5 mm² mm kg/km
5 ×	15	16	17	—	—
	310	390	480	—	—
7 ×	16	17	18	17	18
	370	470	560	420	520
10 ×	19	20	—	20	21
	510	650	—	560	720
12 ×	19	21	—	20	22
	550	720	—	610	790
14 ×	20	21	22	21	—
	610	640	800	660	—
16 ×	21	22	—	—	24
	670	860	—	—	960
19 ×	22	24	—	23	26
	750	990	—	820	1 120
21 ×	21	24	—	—	—
	670	920	—	—	—
24 ×	23	26	28	26	28
	750	1 030	1 230	1 040	1 370
30 ×	25	27	—	—	—
	890	1 230	—	—	—
40 ×	28	31	30	—	—
	1 150	1 590	1 440	—	—

Table 13-74

Cross-sections of electrical conductors.
Comparison between AWG and VDE standards

VDE	American Wire Gauge (AWG)						
			Cross-sections			Diameter[1)]	
mm²	AWG		mm²	sq. in.	cir. mils	mm	inches
150	000 000	= 6/0	170.50	0.2641	336 400	14.73	0.5800
120	00 000	= 5/0	135.35	0.2094	266 773	13.12	0.5165
95	0 000	= 4/0	107.21	0.1662	211 600	11.68	0.4600
—	000	= 3/0	85.01	0.1318	167 772	10.40	0.4096
70	00	= 2/0	67.43	0.1045	133 079	9.27	0.3648
50	0	= 1/0	53.52	0.0829	105 625	8.25	0.3249
—	1		42.41	0.0657	83 694	7.35	0.2893
35	2		33.62	0.0521	66 358	6.54	0.2576

Continued on next page

Table 13-74 (continued)

Cross-sections of electrical conductors.
Comparison between AWG and VDE standards

VDE		American Wire Gauge (AWG)				
			Cross-sections		Diameter[1)]	
mm²	AWG	mm²	sq. in.	cir. mils	mm	inches
25	3	26.66	0.0413	52 624	5.83	0.2294
—	4	21.15	0.0328	41 738	5.19	0.2043
16	5	16.77	0.0260	33 088	4.62	0.1819
—	6	13.30	0.0206	26 244	4.11	0.1620
10	7	10.55	0.0163	20 822	3.66	0.1443
—	8	8.37	0.0130	16 512	3.26	0.1285
6	9	6.63	0.0103	13 087	2.91	0.1144
—	10	5.26	0.0081	10 384	2.59	0.1019
4	11	4.17	0.0065	8 226	2.30	0.0907
—	12	3.31	0.0051	6 529	2.05	0.0808
2.5	13	2.63	0.0041	5 184	1.83	0.0720
—	14	2.08	0.0032	4 109	1.63	0.0641
1.5	15	1.65	0.0026	3 260	1.45	0.0571
—	16	1.31	0.0020	2 581	1.29	0.0508
1	17	1.04	0.0016	2 052	1.15	0.0452
0.75	18	0.82	0.0013	1 624	1.02	0.0403
—	19	0.65	0.0010	1 289	0.91	0.0359
0.50	20	0.52	0.0008	1 024	0.81	0.0320

1) Single solid conductor

Table 13-75

Cross-sections of electrical conductors.
Comparison between SWG and VDE standards

VDE		British Standard Wire Gauge (SWG)				
			Cross-sections		Diameter[1)]	
mm²	SWG	mm²	sq. in.	cir. mils	mm	inches
120	7/0	126.67	0.1963	250 000	12.70	0.500
95	6/0	109.09	0.1691	215 298	11.78	0.464
95	5/0	94.57	0.1465	186 634	10.97	0.432
—	4/0	81.07	0.1256	160 000	10.16	0.400
70	3/0	70.17	0.1087	138 480	9.45	0.372
—	2/0	61.36	0.0951	121 094	8.84	0.348
50	0	53.20	0.0824	104 990	8.23	0.324
—	1	45.60	0.0707	90 000	7.62	0.300
35	2	38.59	0.0598	76 157	7.01	0.276
—	3	32.18	0.0499	63 507	6.40	0.252
—	4	27.27	0.0423	53 817	5.89	0.232
25	5	22.78	0.0353	46 965	5.39	0.212
—	6	18.68	0.0290	36 865	4.88	0.192

1) Single solid conductor

Continued on next page

Table 13-75 (continued)

Cross-sections of electrical conductors.
Comparison between SWG and VDE standards

VDE		British Standard Wire Gauge (SWG)				
		Cross-sections			Diameter[1)]	
mm²	SWG	mm²	sq. in.	cir. mils	mm	inches
16	7	15.69	0.0243	30 964	4.47	0.176
16	8	12.97	0.0201	25 596	4.06	0.160
—	9	10.51	0.0162	20 742	3.66	0.144
10	10	8.30	0.0130	16 380	3.25	0.128
—	11	6.82	0.0110	13 459	2.95	0.116
6	12	5.48	0.0085	10 815	2.64	0.104
—	13	4.29	0.0065	8 466	2.34	0.092
4	14	3.24	0.0050	6 394	2.03	0.080
—	15	2.63	0.0041	5 190	1.83	0.072
2.5	16	2.08	0.0038	4 105	1.63	0.064
—	17	1.59	0.0025	3 138	1.42	0.056
1.5	18	1.17	0.0018	2 309	1.22	0.048
1	19	0.81	0.0013	1 599	1.02	0.040
0.75	20	0.66	0.0010	1 303	0.91	0.036
—	21	0.52	0.0008	1 026	0.81	0.032

1) Single solid conductor

Table 13-76

Conversion of circular mils into square millimetres and square inches

MCM	sq. in.	mm²	MCM	sq. in.	mm²
50	0.0393	25.3	550	0.4320	279.8
100	0.0785	50.7	600	0.4712	304.0
150	0.1178	76.0	650	0.5105	329.4
200	0.1571	101.3	700	0.5498	354.7
250	0.1063	126.7	750	0.5890	380.0
300	0.2356	152.0	800	0.6283	406.3
350	0.2749	177.3	850	0.6676	430.7
400	0.3142	202.7	900	0.7069	456.0
450	0.3534	228.0	950	0.7461	481.4
500	0.3927	253.4	1 000	0.7854	506.7

1 circular mil (MCM) is the cross-section area of a wire of 1 mil diameter.

Conversion formulae:			
	1 mil	$= 10^{-3}$ inch	= 0.0254 mm diameter
	1 CM	$= 10^{-3}$ MCM	= 0.0005067 mm²
	1 MCM	= 1000 CM	= 0.5067 mm²
	1 mm	= 39.4 mils	
	1 mm²	= 1973.5 Circ mils	
	1 inch	= 1000 mils	= 25.4 mm
	1 inch²	= 1273200 circ mils	= 645.16 mm²

13.2.8 Power cable accessories for low and medium-voltage

Definitions, standards

Power cable accessories as defined in DIN VDE 0278, are fittings for the termination or jointing of power cables, in either open or enclosed form. The design and construction of the cable accessories is determined by the service voltage, type of cable and place of installation. Further information is given in DIN VDE 0105, DIN VDE 0220-100, 0220-2 and 0220-3 and also in DIN VDE 0291-1 and 0291-2.

The following definitions are laid down in DIN VDE 0289-6.

Sealing end is a fitting designed to terminate and seal the end of a cable and to provide suitable means for connecting the cable conductor to an electrical machine, switchgear component or an overhead line. The sealing end commences where the cable construction is modified by the fitting of sealing end components. It ends at the point of connection to the apparatus or at any intermediate component connecting a number of sealing ends together.

Jointing box is a fitting designed to connect two or more cables together. Over the length of the joint the fitting fulfills all the functions of the original cable. The span of the joint starts and ends where the construction of the cable is modified or changed by the fitting of joint components. A distinction is made between straight-through, transition and branch jointing boxes.

Plug-in or screw-in cable termination is a fitting which provides a shielded and sealed connection between a cable and electrical equipment. This fitting consists of two components, a plug connection fitted to the cable end and a receptacle permanently attached to the equipment. Depending on the type of fitting, the connection of the conductors is made either by plugging or screwing the two components together. The insulating components are of matching conical form. The connection or disconnection of either type of termination may only be made when the cable is dead. The surfaces of the insulating cones form an interface within the dielectric material. Depending on

Fig. 13-11 shows an example of a shielded plug-in cable termination using the protruding cone system.

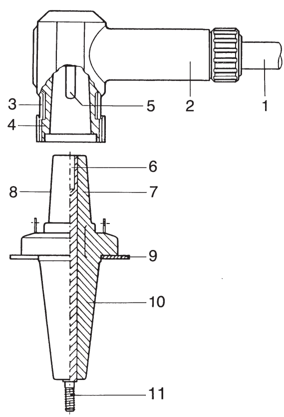


Fig. 13-11

Plug-in cable termination – components of a plug-in unit of the protruding cone type:

1 Cable, 2 Cable plug fitting, 3 Metallic enclosing, 4 Insulating cone, 5 Contact pin, 6 Contact socket (5 + 6 provide the connection between the conductors), 7 Insulating cone, 8 Protruding cone surface, 9 Apparatus enclosure, 10 Apparatus bushing, 11 Terminal bolt whether the fixed part has an external conical protrusion or an internal conical recess, the fitting is said to be of the *protruding or inside cone type*.

Required attributes of sealing ends and jointing boxes:

– lasting and dependable connection of cable conductors one with another or with an item of electrical equipment.

  Methods of connection: crimping, clamping, bolting and plugging (multi-contacts)

– electrical field control within the fitting

  At voltages of 12 kV and above, cables are manufactured with a semiconductive layer (insulation screen) over the insulation. In order to achieve the additional insulation required within the fitting, this conducting layer must be cut back for a certain distance. The electrical field at this point must be controlled if inadmissibly high field strengths are to be avoided (Fig. 13-12). Three methods of field control are available.

  – geometric field control
  – resistive field control
  – refractive field control

  The most common method used is geometric field control (Fig. 13-13) which is also used in high-voltage equipment. A stress cone (deflector) fitted at the point of discontinuity enlarges the field cross-section, distorting the field and reducing the field stress within the fitting. In the case of resistive (ohmic) control, the exposed insulation within the fitting is covered for part of its length with a conducting material having a non-linear characteristic. The capacitive discharge currents flowing through the voltage-dependent resistance ensure an even distribution of voltage and field strength.

  Refractive field control is similar to the resistive method but the resistive layer is replaced by a layer of material having a higher dielectric constant than the cable insulation. The change in dielectric characteristic causes the field lines to be distorted (broken), providing control of the electrical field.

13

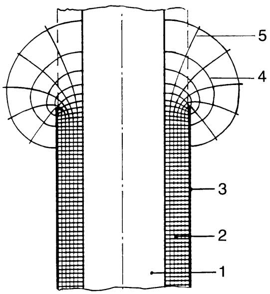


Fig. 13-12

Distribution of electrical field (uncontrolled) at the end of the conducting sheath in the insulation of medium-voltage cables:

1 Conductor, 2 Insulation, 3 Insulation screen, 4 Field lines, 5 Lines of equipotential

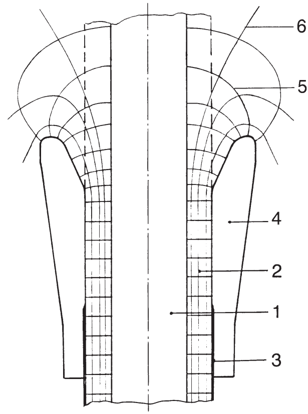


Fig. 13-13

Geometric field control:

1 Conductor, 2 Insulation, 3 Outer conducting layer, 4 Stress cone (deflector), 5 Field lines, 6 Lines of equipotential

– establish an adequate level of insulation within the fitting

  The internal insulation must be such that even after thermal (load changes) and dynamic (short-circuit) cycling stresses it remains free of cavities and fully in contact with the cable insulation (free from corona discharges) and meets all test voltage requirements (DIN VDE 0278-629-1).

– maintain a reliable level of insulation external to the fitting

  The external insulation must be capable of withstanding all environmental influences (e.g. UV radiation, ozone, chemically aggressive pollutants) and, like the internal insulation, be resistant to aging. Resistance to tracking and creepage currents is of particular importance in sealing end design.

– resistance to mechanical stresses

  Cable fittings must be designed to accommodate all thermal (material expansion) and dynamic influences (movement due to short-circuit forces) which may arise, and remain fully functional. Where increased stresses due to short-circuits are expected, additional measures (e.g. phase supports, heavier clamps) must be taken to exclude or limit the influence on cables or equipment components.

– easy to install, maintenance-free

  To minimize installation time and reduce the risk of erection mistakes, the fittings are designed so that a considerable degree of pre-assembly can be performed in the factory and site work limited to a few non-critical operations. The materials used should reduce maintenance (e.g. cleaning and the consequent expensive down time) to a minimum, or eliminate it completely.

Additional requirements for transition joint boxes

– separation of insulating media

  Design measures must ensure that impregnating liquid from a paper-insulated cable cannot come in contact with plastic-insulated cable.

– regeneration of impregnated paper-insulated cables

  As the paper-insulated cable is thermally and mechanically stressed during the making of a joint, the fitting should provide a reservoir of impregnating oil to ensure that the cable can regenerate.

Additional requirements for enclosed cable terminations

– earthed external surfaces, touch-proof

– greater immunity to environmental influences, e.g. watertight

– simple, repetitive making and breaking of the connection.

Choice of material, design features and installation methods are examined on the basis of a number of fittings in common use.

Design and construction of low-voltage accessories

Because of the low voltages and field strengths involved, the insulation level of low-voltage accessories, which is decisive in medium-voltage equipment, is only of minor importance in the design of low-voltage fittings. Of greater importance in low-voltage equipment is mechanical stability and resistance to the ingress of water.

Today, through-joints are generally made using the heat-shrink sleeving technique. Fig. 13-14a shows a 1 kV heat-shrink joint. Branch and house connection joints use almost exclusively cast epoxy resin insulation. Fig. 13-14b illustrates a typical 1 kV house connection joint using compact terminals and epoxy resin insulation. Only in extreme environmental conditions is heat-shrink sleeving used to seal the cable sheath termination and insulate the conductors in the transition zone between the phase insulation and the cable lug.

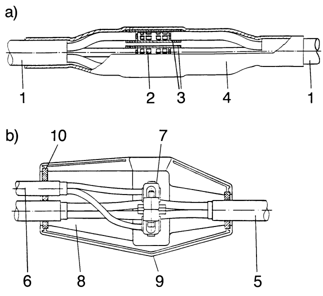


Fig. 13-14

Low-voltage cable joints:
a) 1 kV heat-shrink through joint
b) 1 kV house connection
1 PVC cable (e.g. NAYY), 2 Crimp connector, 3 Internal (phase) heat-shrink sleeves, 4 External heat-shrink sleeve, 5 Through cable, 6 House connection cable, 7 Compact terminal block,8 Epoxy resin filling, 9 Plastic housing

Design and construction of medium-voltage accessories

For medium-voltage equipment, silicone rubber has become the most widely used material for sealing ends, cable joints and enclosed terminations. The techniques used are described on the basis of selected examples. Only with transition joints are designs still in use in which, as well as push-on techniques, a stress cone of impregnated crepe paper is manually manufactured on site, analogous to the dielectric of paper-insulated cables. Table 13-77 lists the most commonly used fittings for voltages from 12 to 36 kV, showing their general construction (outlines) and main dimensions.

Silicone rubber possesses a number of decisive advantages in comparison with other insulating materials available for push-on cable fittings. It is also being increasingly used in high-voltage equipment. The long-term flexibility and a low modulus of elasticity of the material mean that it can be readily assembled without the use of tools: it adapts readily and lastingly to the shape of the insulating material over which it is fitted (e.g. phase conductor insulation, epoxy components). Silicone rubber is water-repellent, and free of chemically active carbon. The result is sealing ends with external insulating surfaces which are essentially maintenance-free.

The *multirange indoor end seal designed for push-on installation* of silicone rubber is suitable for usage under severe indoor conditions because of its exterior shape (see Fig. 13-15).

The elasticity of silicone rubber allows up to five cable cross-sections to be covered with one size insulating body. To prevent moisture from entering the cable, after compressing the cable lug a sealing hose is slid over the cable end to the corresponding upper section of the insulating body. The electrical field at the edge of the outer field limit of the cable is controlled by a deflector embedded in the insulating body (field control funnel). How to fit the end seals to the cross-section area and insulation rating is stamped on the insulating body. The insulating body is slid onto the prepared cable end with the aid of a lubricant.

Special tools (sheath cutter and stripping tool) have been developed for preparing modern XLPE cables with polyethylene (PE) outer sheath and fix bonded insulation screen, reducing the task to a few simple, time-saving operations.

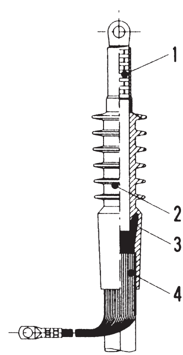


Fig. 13-15

24 kV push-on indoor-type cable sealing end of silicone rubber:
1 Crimped cable lug, 2 Insulator, 3 Deflector, 4 Wire screen

Multirange techniques are also in use with straight joints. Fig. 13-17a shows the design of a 24 kV joint of silicone rubber, which like the multirange end seals can also handle up to five conductor cross-sections with one joint size. In this case, the electrical field is controlled refractively with a continuous internal field control tube followed by the insulation tube. At the end there is a conductive tube, which forms the outer screening of the joint with the woven copper band installed at the construction site. All three tubes are extruded together in one process. A heat-shrink tube is used as external protection for the straight joint; as an alternative it can be protected by wrapping it with a special corrosion protection coating.
This multirange joint not only covers several cross-sections but it is also possible to use centric screwed connectors instead of compression connectors, so long as they are fitted with a snap-off head. These screwed connectors can also be used for several cross sections.

In older parts of established distribution systems, impregnated paper-insulated cables will have been in service for many years. Depending on how long it has been in service, the paper insulation may be brittle and the impregnation dry. If the cable remains undisturbed in service, this aging is of no importance. However, if a joint has to be fitted, the cable must be moved, bent and heated. The brittle paper insulation may break and, if the impregnation has dried, the damaged section will remain dry. The result is corona discharge in the void and a predictable cable joint failure.

If internal joints with an oil reservoir are used, as shown in Figs. 13-16 b and 13-16 c, the region of the paper cable near the joint can be impregnated and any cracks in the paper insulation can thereby be neutralized.

In the design of the classical transition joint (Fig. 13-16b) with a stress cone of impregnated crepe paper, an oil-resistant wrap is installed on the core of the plastic-insulated cable to block penetration of the impregnation material. A step in the compression connector prevents the impregnation material from penetrating the wires of the plastic-insulated cable. The use of crepe papers to manufacture stress cones ensures simple, fast and safe assembly. Three internal joints are placed in a moulded protective joint impregnated with bituminous compound (SP compound).

Using push-on technique (Fig. 13-16c) with transition joints allows users to take advantage of prefabricated components and the resulting shorter installation times compared to conventional joints. In this design, an insulating body of silicone rubber takes on the function of the classical stress cone, including sealing. The insulating body has a sealing lip on the side facing the plastic-insulated cable. There is a corresponding one-piece sealing unit on the metal sheath of the paper cable. The two sealing units together with a copper pipe form the internal joint with a bonding reservoir. In this case, three internal joints can also be installed in one cast protective joint with SP compound. An “open” design with shrink tubes on the paper insulated cable cores and the internal joint assembly is also possible.

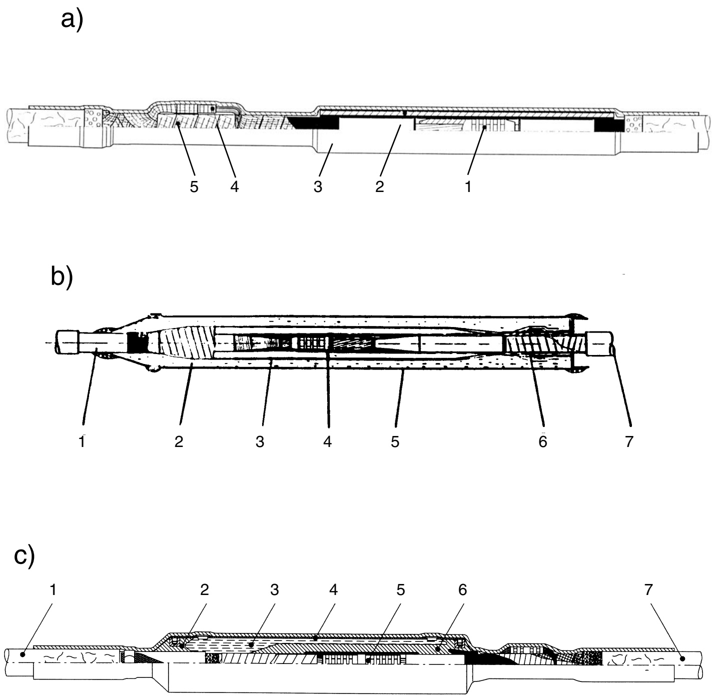


Fig.13-16

a) Multirange straight joint 24 kV type SEV 24 to connect single-core XLPE cables: 1 Connector, 2 Insulator, 3 Shrink tube, 4 Screen connection, 5 Woven copper band

b) Transition joint (single core inner sleeve) type KEü to connect paper insulated cables with single core XLPE cables: 1 Paper insulated cable, 2 Insulating compound, 3 Stress cone made of crepe paper, 4 Compression connector, 5 Joint sleeve, 6 Sealing wrap made of self-bonding silicone tape, 7 XLPE cable

c) Transition joint 24 kV made of silicone rubber type SEHDVü20 to connect paper-insulated cables with single-core XLPE cables: 1 Paper insulated cable, 2 Sealing unit, 3, Insulating compound, 4 Cooper sleeve, 5 Compression connector, 6 Prefabricated insulator, 7 XLPE cable

Single-core XLPE cables are jointed to distribution transformers and encapsulated switchgears with plug-in sealing ends. Inside cone and protruding cone systems are distinguished here.

In an inside cone system, the device connection component comprises a socket with a conical hole which receives the plug connection of silicone rubber. The pressure required for dielectric strength at the face between the silicone body and the socket is maintained by a pressure spring, which absorbs the increase in volume of the cable insulation and the insulating body when the load changes (Fig. 13-17a).

In the protruding cone system, the plug-in sealing end is inserted into a conical passage extending from the device. The insulating body of silicone rubber has an external conductive coating. As an option, plug-in end seals for the external conical system can be fitted with a metal housing as electric shock protection (Fig. 13-17b).

The insulation level of the plug-in end seals of both systems is independent of the environment and maintenance-free.

The dimensions of the device connection components for the protruding and inside cone system are standardized in DIN 47636, DIN 47637 and in EN 50181.

Tests for medium-voltage fittings

The requirements for fittings are specified in the regulations DIN VDE 0278-628 (test procedure), DIN VDE 0278-629-1 (testing requirements for cable fittings for extruded plastic-insulated cables) and DIN VDE 0278-629-2 (testing requirements for cable fittings for cables with impregnated paper insulation).

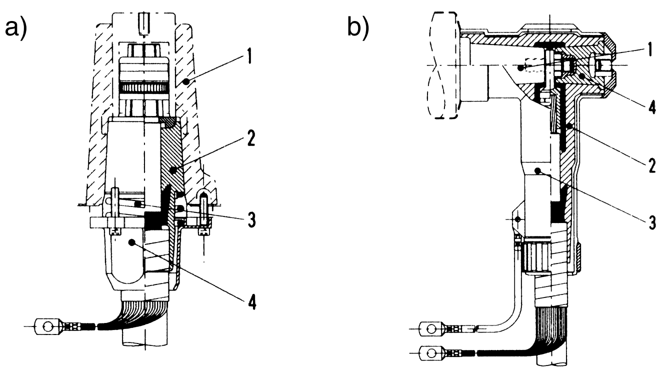


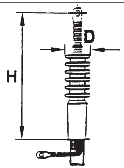
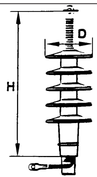
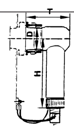
Fig. 13-17

a) Inside cone connector 24 kV made of silicone rubber type SEIK23: 1 Inside cone bushing, 2 Insulating body, 3 Compression spring, 4 Metal housing

b) Protruding cone T-shaped connector 24 kV type SEHDT23.1: 1 Protruding cone bushing, 2 Insulating body, 3 Metal housing, 4 Sealing piece

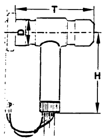
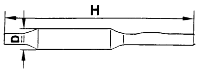
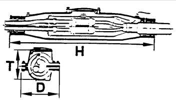
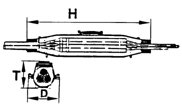
Table 13-77

Construction (outlines and main dimensions) of the most common fittings (sealing ends, through- and transition joints) for 12 – 36 kV cables

Cable cross-section	mm^2	35			150			240			500		
Main dimensions	mm	H	D	T	H	D	T	H	D	T	H	D	T
	Indoor sealing end for XLPE single-core cable												
	12 kV	270	35	—	295	40	—	310	40	—	330	46	—
	24 kV	280	57	—	305	62	—	320	62	—	340	69	—
	36 kV	320	77	—	350	77	—	360	83	—	385	105	—
	Outdoor sealing end for XLPE single-core cable												
	12 kV	330	120	—	315	105	—	330	110	—	350	120	—
	24 kV	290	105	—	315	110	—	330	110	—	350	120	—
	36 kV	425	133	—	455	138	—	465	144	—	485	151	—
	Plug-in elbow sealing end for XLPE single- core cable												
	12 kV	225	61	109	260	74	130	—	—	—	—	—	—
	24 kV	225	61	109	260	74	130	—	—	—	—	—	—

Continued on next page

Table 13-77 (continued)

Cable cross-section	mm²	35			150			240			500		
Main dimensions mm	mm	H	D	T	H	D	T	H	D	T	H	D	T
	Plug-in T-shaped sealing end for XLPE single-core cable												
	12 kV	—	—	—	255	88	190	255	88	190	275	89	280
	24 kV	255	70	190	255	88	190	255	88	190	290	89	280
	36 kV	—	—	—	290	89	280	290	89	280	290	89	280
	Joint box for XLPE single-core cable												
	12 kV	1000	45	—	1000	45	—	1000	50	—	1000	65	—
	24 kV	1000	50	—	1000	50	—	1000	55	—	1000	70	—
	36 kV	—	—	—	1000	55	—	1000	65	—	1000	70	—
	Transition joint for connecting XLPE single-core cable with belted or H-type cable												
	12 kV	—	—	—	1350	328	275	1350	328	275	—	—	—
	Transition jointing box for connecting XLPE single-core cable to three-core shielded cable												
	24 kV	1350	328	275	1350	328	275	1550	328	268	—	—	—
	36 kV	—	—	—	1350	328	275	1550	328	268	—	—	—

13.3 Safe working equipment in switchgear installations

The following implements are required for safe working in indoor and outdoor switching stations:

- Earthing and short-circuiting devices to DIN VDE 0683 Part 1.
- Insertion plates (insulating guard plates) to DIN VDE 0681-8 (VDE 0681 Part 8).
- High-voltage detector to DIN VDE 0681-4 (VDE 0681 Tel 4).
- Fuse tongs for voltages from 1 to 30 kV to DIN VDE 0681-3 (VDE 0681 Part 3).
- Warning signs to DIN 40008 Part 2; they must conform to DIN VDE 0105-100 (VDE 0105 Part 100).

As per DIN EN 50 110-1 (VDE 0105 Part 1), the dead status allowing safe access to any part of the switching installation should be established and secured with the following measures (“5 Safety Rules”):

- Disconnecting
- Securing against reclosing
- Testing for absence of voltage
- Earthing and short-circuiting
- Covering or fencing off adjacent live parts

In general, the above sequence should be followed. Reasonable non-conformances can be specified in plant manuals. The following information applies to the measures:

Disconnecting

The equipment used for disconnecting must conform to the isolating distance requirements specified in DIN EN 60129 (VDE 0670 Tel 2). Such equipment can be in the form of

- disconnectors,
- switch disconnectors,
- fuse disconnectors,
- fuse-bases,
- draw-out switching devices whose isolating contact configurations meet the isolating distance requirements

The specifications for isolating distances are also met by equipment having air gaps of at least 1.2 times the minimum clearances in Table 1 of DIN VDE 0101, e.g. isolating links or wire loops.

A segregation may be used in place of an isolating distance.

Securing against reclosing

Warning or prohibition signs must be displayed to guard against reclosing. In addition, switchgear mechanisms must be blocked or tripping disabled.

Testing for absence of voltage

The voltage detector specified in DIN VDE 0681-4 (VDE 0681 Part 4) is used to detect non-hazardous absence of voltage in air-insulated switchgear installations.

The voltage testers (voltage detectors) to DIN VDE 0681-4 (VDE 0681 Part 4) show a clear indication "voltage present" when the line-to-earth voltage of the station component being tested has at least 40% of the nominal voltage of the voltage detector. To ensure that interference fields do not influence the indication, minimum lengths for the extension part are defined in the above standard.

The detectors fall into three categories:

Voltage detector "for indoors only"
For use indoors with lighting levels of up to 1000 lux.

Voltage detector "not for use in rain, snow, etc."
Can be used indoors and outdoors, but not in rain, snow, etc.

Voltage detector "for use in rain, snow, etc."
Can be used indoors and outdoors in all weathers.

The instructions of operating these devices must be strictly followed.

In gas-insulated switch disconnector panels, the test for absence of voltage can be conducted directly at the T-shaped plug-in end seals with voltage detectors.

As per VDE 0105 Part 1 Section 9, the test for absence of voltage of a switchbay can also be indicated with signal lamps if the change in the indication is visible during the disconnection process. The use of a make-proof earthing switch as an option for testing for absence of voltage should not be adopted as the general operational practice.

In gas-insulated switchgear and increasingly also with metal-clad air-insulated switchgear, the absence of voltage is tested with a capacitively coupled low-voltage display device. The coupling capacitors are continuously connected to the high-voltage conductor and are generally integrated into current transformers, resin insulators or bushings. The display devices may be permanently fixed to the installation or connected to the coupling capacitor with plug connectors. With appropriate subcapacitors, this forms a voltage divider connected to earth, to the tap of which the low-voltage display device – measuring against earth – is connected. Depending on the design of the display device, high-resistance, low-resistance and more recently medium-resistance systems are distinguished. VDE 0682 Part 415 (currently in draft form) is applicable to this type of testing for absence of voltage.

Earthing and short-circuiting

The earthed and short-circuited condition must be visible from the working position. The ground connection can be made either with an earthing switch incorporated in the switching bay, or with an earthing and short-circuiting device. An earthing truck is a possibility for metal-clad switchgear with draw-out switching devices.

Fig. 13-18 illustrates the earthing of a busbar with earthing truck and earthing cable in a metal-clad panel after the circuit-breaker has been withdrawn.

The lower isolating contact and the cable are earthed and shorted over the permanently installed earthing switch.

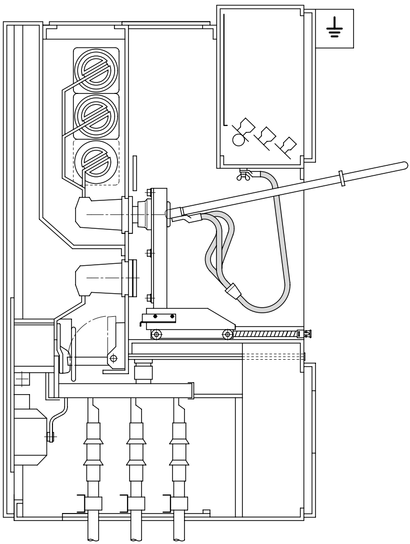


Fig. 13-18

Earthing the busbar system in a metal-clad panel of draw-out design, e.g. Type ZS1, with earthing truck and earthing cable.

In gas-insulated switchgear, the feeder circuits are preferably earthed over the circuit-breaker (in closed position) connected to an earthing switch, which does not have a short-circuit current-making capacity.

The cable can in addition be separately earthed with the cable plug in disconnected position by means of a portable earthing device.

Using the earthing device

Observing the 5 safety rules (DIN EN 50110-1 (VDE 0105 Part 1), the earthing cable (Fig. 13-19) is first screwed to the specially marked fixed earthing point. To be safe, the 3 phase conductors are then checked for voltage with the voltage detector. The individual phase conductors are then discharged by touching the feeder lines with the earthing cable. Finally, the earthing cable is placed on the earthing pin of the respective phase conductor, and firmly screwed in place.

The earthing device must be removed again in the reverse order before the earthed feeder is put back in operation.

Earthing devices fittings are also available for direct connecting to the disconnector bolts of switchgear installations with draw-out circuit-breakers.

The earthing and short-circuiting devices are designed to withstand one exposure to the maximum permissible short-circuit stress. Having been fully subjected to this stress, they must be discarded.

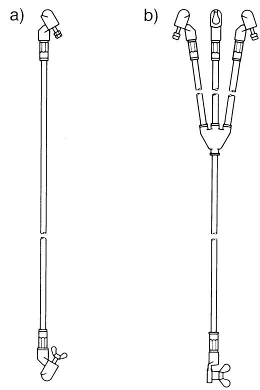


Fig. 13-19

Earthing devices to DIN 57683

a) Earthing and short-circuiting device for 20 and 25 mm dia. spherical fixed points, single-phase, cable cross-section 16 to 150 mm

b) Earthing and short-circuiting device for 20 and 25 mm dia. spherical fixed points, three-phase model, cable cross-section 16 to 150 mm

Covering or fencing off adjacent live parts

Work may be carried out in the vicinity of live parts only if precautions against direct contact (DIN EN 50110-1 (VDE 0105 Part 1) have been taken in the form of

– protection by cover or barrier, or
– protection by distance.

Before working on an outgoing feeder with fixed apparatus, a plate is inserted in the open busbar disconnector. This guards against contact with live parts on the busbar side. Provided the cable side is dead (beware of dangerous reverse voltages), work can proceed on the feeder apparatus after attaching the earthing device. Special care is called for in the case of transformers connected in parallel on the low-voltage side.