

Electrical Cable Sizing Criteria

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1. General

The present specification deals with the selection criteria for the medium voltage and low voltage cables.

The selection shall be performed considering:

- Operating current condition
- Voltage drop
- Short circuit current condition
- Type of cable installation

2. Site Conditions

Maximum Ambient Temperature	48 °C
Minimum Ambient Temperature	1 °C
Humidity	62 %
Elevation above sea level	135 m

3. Reference Documents and Standards

- Electrical Design Criteria
- MV Cables Technical Specification
- LV and Control Cables Technical Specification

IEC 60502-1

Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV) – Part 1: Cables for rated voltages of 1 kV ($U_m = 1.2$ kV) and 3 kV ($U_m = 3.6$ kV)

IEC 60502-2

Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV) – Part 2: Cables for rated voltages from 6 kV ($U_m = 7.2$ kV) up to 30kV ($U_m = 36$ kV)

IEC 60364-5-52

Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems

IEC 60947-2

Low-voltage switchgear and control gear – Part 2: Circuit-breakers

IEC 61200-53

Electrical installation guide – Part 53:

Selection and erection of electrical equipment – Switchgear and control gear

IEC 60364-4-43

Low-voltage electrical installations –Part 4-43: Protection for safety – Protection against overcurrent

4. Cables Technical Data

The cables technical data is specified at “Cable Characteristic Table”. The meaning of any designation at “cable characteristic table” is explained below (items from (1) to (7)):

(1) Cable cross section

It specifies the number of cores forming the cable and also cross section of each single conductor (mm^2); neutral/protective conductor is considered too.

(2) Conductor material

It defines the material of the conductor (e.g. Cu, Al).

(3) Insulation material

It is the code to specify the insulation material (e.g. XLPE, EPR, and PVC).

(4) Cable rated voltage

It specifies the voltage cable ($U_0/U/ U_m$):

U_0 : is the rated voltage between conductor and earth or metallic screen for which the cable is designed.

U : is the rated voltage between conductors for which the cable is designed.

U_m : is the maximum value of the "highest system voltage" for which the equipment may be used.

(5) Resistance

It is the resistance of the conductor, in (Ohm/Km) at the insulation temperature limit.

(6) Reactance

It is the reactance of the conductor, in (Ohm/Km), at the rated frequency and according to the type of installation.

(7) Rated current

It is the rated current “ I_0 ” of the cable (in Amperes) specified from the applicable standards, under the installation condition and the reference ambient temperature.

5. Cable Sizing

The following items shall be considered:

- a) Short circuit capacity
- b) Continuous current carrying capacity
- c) Voltage drops in normal condition & transient conditions.

d) Any special operating conditions stated in electrical design criteria and/or other project specifications

The largest size of cables as determined from a, b, c and d shall be used.

a) Short circuit capacity

Maximum short circuit current shall be considered for determining cable short circuit capacity. The fault clearing time under short circuit conditions of power cables connected to circuit breakers shall be calculated by the followings:

- 1) The backup relay operating time at maximum fault level
- 2) 0.05 second to cover variation of settings
- 3) The circuit breaker operating time

Where power cables are protected by fuses, its cut off time shall be considered.

b) Continuous current carrying capacity (I_0)

Continuous current carrying capacity depends on the maximum permissible continuous conductor temperature and various types of cable installation. When applying that temperature, cable terminations and associated equipment shall have the ability to withstand the temperature without damage and to dissipate the heat due to cable temperature.

c) Voltage drop

The overall voltage drop in power cables will be limited to maximum 5% at full load and will not exceed 15% during motor starting . This voltage drop is from the main/source to the end consumer.

The nominal system voltage, the maximum impedance of each component and the full load current of each cable are used for voltage drop calculations.

5.1. Continuous Current Carrying Capacity (I_0)

Continuous current carrying capacity can be obtained from Annex A :Table B.2 & Table B.6 of IEC 60502-2 for MV Cables and Annex B Table B.52.2, Table B.52.3, Table B.52.4, Table B.52.5 & Table B.52.10 & Table B.52.12 of IEC 60364-5-52 for LV Cables.

Different methods of installation for LV Cables are explained in Annex B Table B.52.1 from IEC 60364-5-52.

5.1.1. Maximum Allowed Current Carrying Capacity (I_z)

It is maximum current that can be continuously carried by the cable at the specified installation conditions. The maximum allowable current carrying capacity (I_z) is obtained by multiplying the cable rated current “ I_0 ” by the total derating factor (Kt), as follows:

$$I_z = Kt \times I_0 \text{ (A)}$$

Where:

I_z : maximum allowable current carrying capacity (A)

I_0 : cable rated current (A)

K_t : total derating factor

Total derating factor for continuous current carrying capacity depends on two factors which are calculated as below:

$$K_t = K_1 \times K_2 \times 0.95$$

Where:

K_1 : Ambient temperature and relevant correction factor

K_2 : Derating factor relevant to the type of installation

K_1 which is the correction factor of cable design for an ambient temperature can be deduced as follows:

➤ MV Cables

The correction factors for ambient air temperatures other than 30°C and ambient ground temperature other than 20°C are obtained from Annex A Table B.10 & Table B.11 from IEC 60502-2.

➤ LV Cables

The correction factors for ambient air temperatures other than 30°C and ambient ground temperature other than 20°C are obtained from Annex B Table B.52.14 & Table B.52.15 from IEC 60364-5-52.

K_2 which is the derating factor relevant to type of installation can be deduced as follows:

➤ MV cables

The K_2 for groups of more than one circuit in each phase is obtained from Annex A Table B.22 & Table B.23 from IEC 60502-2.

➤ LV cables

The K_2 for groups of more than one circuit in each phase is obtained from Annex B Table B.52.17, Table B.52.18, Table B.52.19, Table B.52. & Table B.52.21 from IEC 60364-5-52.

5.2. Voltage Drop

The unitary voltage drop (DV) is obtained by the following formula:

- For an AC system

$$\Delta V = L \cdot I \cdot \frac{(R \cos \phi + X \sin \phi) 100}{V_1} [\%]$$

$$V_1 = V / \sqrt{3} \quad 3 \text{ ph or } 3 \text{ ph} + N$$

$$V_1 = V / 2 \quad 1 \text{ ph}$$

Voltage drop is expressed as a percentage (%).

- For a DC system

$$\Delta V = \frac{2L \cdot I^2 R}{V} [\%]$$

Where:

V : Line to line voltage of the system (V)

R : Cable resistance (Ohm/Km)

X : Cable reactance (Ohm/Km)

ϕ : Power factor angle

L : One-way length of conductor (Km)

I : Phase load current (A)

5.3. Maximum Short Circuit Current

For cables and insulated conductors, all current caused by a short-circuit occurring at any point of the circuit shall be interrupted in a time not exceeding that which brings the insulation of the conductors to the permitted limit temperature.

1) For operating times of protective devices up to 0.1s where asymmetry of the current is important and for current-limiting devices, “ $K^2 S^2$ ” shall be greater than the value of the let-through energy “ $I^2 t$ ” quoted by the manufacturer of the protective device.

Therefore, the protective device shall be selected while let-through energy of the protective device ($I^2 t$) is lower or equal to the withstand energy of the cable ($K^2 S^2$):

$$I^2 t \leq K^2 S^2$$

Where:

$I^2 t$: is the specific let-through energy of the protective device which can be read on the curves supplied by the manufacturer

S : is the cable cross section (mm^2), in case of conductors in parallel, it is the cross section of a single conductor

K : is a factor that depends on the cable insulating and conducting material (according to table 1)

2) For short-circuits duration greater than 0.1 s up to 5 s, the time, in which a given short-circuit current will raise the insulation of the conductors from the highest permissible temperature in normal duty to the limit temperature can, as an approximation, be calculated from the formula:

$$S = \frac{I_f \sqrt{t}}{K}$$

Where:

S : is the minimum cross-sectional area of the conductor (mm²)

t : is the maximum duration of the fault (Sec)

K : is a factor depending on the materials of the cable (according to table1)

I_f : maximum short circuit current (A)

Property/ condition	Type of conductor insulation							
	PVC Thermoplastic		PVC Thermoplastic 90°C		EPR XLPE Thermosetting	Rubber 60 °C Thermosetting	Mineral PVC Sheathed Cable unsheathed	
Conductor cross-sectional area (mm ²)	< 300	> 300	< 300	> 300				
Initial temperature °C	70		90		90	60	70	105
Final temperature °C	180	140	180	140	250	200	180	250
Conductor material								
Copper	115	100	100	85	140	80	115	1.35 115 [*]
Aluminium	76	66	66	57	94	53	-	-
Two solid cores (wire in copper conductors)	115	-	-	-	-	-	-	-

^{*} This value shall be used for two cores, exposed to touch

Table 1- Values of K for conductors according to IEC 60364-4-43, table 43A

For the duration “ t ” of the fault, three different values can be used to deal with different C.B. opening times, according to the selectivity study.

In this project following “ t ” values in seconds are considered according to manufacture catalogue:

➤ LV Cables (<1000V)








Item	Descriptipn	ta (Sec)
1	Fault clearance time (FCT) for MCCB and MPCB with fixed short circuit release time	0.1
2	Fault clearance time (FCT) for ACB and MCCB with adjustable short circuit release time	0.2
3	Fault clearance time (FCT) for incoming line from transformer	1

➤MV Cables

Item	Descriptipn	ta (Sec)
1	Fault clearance time (FCT) for outgoing (motor and transformer) feeders	0.25
2	Fault clearance time (FCT) for Interconnection feeders	0.6
3	Fault clearance time (FCT) for incoming line from transformer	1

6. Annex A Standard references for MV cables

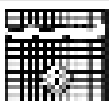
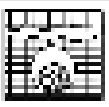

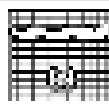

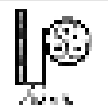
**Table B.3 – Current ratings for single-core cables with XLPE insulation –
 Rated voltage 2,5/3 kV (U_m = 3,3 kV) 3C
 Copper conductor**

Nominal cross-sectional area ¹⁾	3-core cables with 3-core lead		In single-way cables		In air		
	Triplex	Triplex lead	Triplex lead	Two leadship cables	Triplex	1-1-1 cable	Flat (3-core)
							
mm ²	A	A	A	A	A	A	A
10	80	110	110	90	110	100	100
16	110	150	150	120	150	140	140
25	150	200	200	160	200	200	210
35	200	280	280	230	280	280	290
50	280	380	380	320	380	380	400
70	380	520	520	440	520	520	550
95	520	700	700	600	700	700	750
120	700	950	950	820	950	950	1000
150	950	1300	1300	1100	1300	1300	1350
185	1300	1800	1800	1500	1800	1800	1900
240	1800	2500	2500	2000	2500	2500	2650
300	2500	3500	3500	2800	3500	3500	3700
370	3500	4800	4800	3800	4800	4800	5100
450	4800	6500	6500	5200	6500	6500	7000
550	6500	9000	9000	7200	9000	9000	9500

Maximum conductor temperature: 90 °C
 Ambient air temperature: 30 °C
 Reference conductor: 20 °C
 Earthed system: 0.8 kV
 Thermal stability (1 h): 1.8 kA/300
 Thermal stability of cable (max): 1.2 kA/300
 Current limited by both ends

¹⁾ Current limited by both ends for cables with XLPE insulation (CENELEC).

**Table B.6 – Current rating for three-core XLPE insulated cables –
 Rated voltage 0.6/1 kV to 10/10 kV –
 300 pF/3 conductor, 2700000 and 4700000**

Nominal area of conductor	Water cooled			Air cooled		
	Plastic filled in ground	Insulated cable	IEC 60287	Plastic filled in ground	Insulated cable	IEC 60287
						
mm ²	A	A	A	A	A	A
16	130	97	108	107	98	110
25	139	102	112	113	103	114
35	147	107	116	116	107	117
50	151	110	119	119	110	120
70	155	113	121	121	113	122
95	158	115	123	123	115	124
120	160	117	124	124	117	125
150	162	118	125	125	118	126
190	164	120	126	126	120	127
240	165	121	127	127	121	128
300	166	122	127	127	122	128
370	167	123	128	128	123	129
450	168	124	128	128	124	129
540	168	124	128	128	124	129
640	169	125	129	129	125	130
750	169	125	129	129	125	130
870	170	126	129	129	126	130
1000	170	126	129	129	126	130

Maximum conductor temperature: 90 °C
 Air conductor temperature: 50 °C
 Ground temperature: 20 °C
 Depth of laying: 0.8 m
 Thermal resistivity of soil: 1.0 K m/W
 Thermal resistivity of structures (cable): 1.0 K m/W

* Current rating calculated for cables with type of insulation 4700000

Table B.10 – Correction factors for ambient air temperatures other than 20 °C

Maximum allowable temperature (°C)	Ambient air temperature (°C)							
	20	25	30	35	40	45	50	55
70	1.14	1.08	1.03	0.98	0.92	0.87	0.82	0.77

Table B.11 – Correction factors for ambient ground temperatures other than 20 °C

Maximum allowable temperature (°C)	Ambient ground temperature (°C)							
	10	15	20	25	30	35	40	50
60	1.51	1.37	1.26	1.17	1.09	1.02	0.97	0.92

**Table 10.20 – Reaction of 1,1,1,1-tetrafluoroethane (R134a) with 1,1,1,2-tetrafluoroethane (R134b) –
 The test apparatus and test conditions are given in Table 10.19. The test results are given in Table 10.20.**

Reaction of 1,1,1,1-tetrafluoroethane (R134a) with 1,1,1,2-tetrafluoroethane (R134b)		Number of tests	Volume of 1,1,1,1-tetrafluoroethane (R134a)					
			1	2	3	4	5	6
Cylinder configuration	Vertical	1	0.0	0.00	0.01	0.10	0.01	0.10
		4	0.0	0.01	0.02	0.11	0.01	0.08
		4	0.0	0.00	0.01	0.10	0.01	0.08
	Horizontal	1	0.0	0.00	0.01	0.10	0.01	0.01
		5	0.0	0.00	0.01	0.10	0.01	0.01
		5	0.0	0.00	0.01	0.10	0.01	0.01
Cylinder configuration	Vertical	1	0.0	0.0	0.04	0.10	0.0	0.04
		7	0.0	0.0	0.04	0.10	0.04	0.04
	Horizontal	1	0.0	0.01	0.04	0.08	0.08	0.08
		2	0.0	0.01	0.04	0.07	0.07	0.07
		3	0.0	0.01	0.04	0.07	0.07	0.07
		4	0.0	0.01	0.04	0.07	0.07	0.07
Cylinder configuration	Vertical	1	0.0	0.00	0.01	0.10	0.01	0.10
		3	0.0	0.00	0.01	0.10	0.01	0.10
		3	0.0	0.00	0.01	0.10	0.01	0.10
	Horizontal	1	0.0	0.00	0.01	0.10	0.01	0.01
		3	0.0	0.00	0.01	0.10	0.01	0.01
		3	0.0	0.00	0.01	0.10	0.01	0.01






NOTE 1: Values were obtained from a series of tests and a total of 100 tests were carried out. The values are given as percentages of the total.

NOTE 2: Values are given for the total amount of 1,1,1,1-tetrafluoroethane (R134a) which was present in the test apparatus at the time of the test. The values are given as percentages of the total amount of 1,1,1,1-tetrafluoroethane (R134a) which was present in the test apparatus at the time of the test.

NOTE 3: Values are given for the total amount of 1,1,1,1-tetrafluoroethane (R134a) which was present in the test apparatus at the time of the test. The values are given as percentages of the total amount of 1,1,1,1-tetrafluoroethane (R134a) which was present in the test apparatus at the time of the test.

NOTE 4: Values are given for the total amount of 1,1,1,1-tetrafluoroethane (R134a) which was present in the test apparatus at the time of the test. The values are given as percentages of the total amount of 1,1,1,1-tetrafluoroethane (R134a) which was present in the test apparatus at the time of the test.

Table D-20—Reduction factors for groups of trapezoidal threads on single-core cables
 (Values to be applied to the cable carrying capacity for one strand of single-core cables in free air)

Method of installation		Number of layers	Number of strands strands/strand (s)			Values to be applied to reduction factor
			1	2	3	
Fully coated steel cables (Table 1)		1	0.88	0.8	0.67	Values to be applied to reduction factor
		2	0.88	0.67	0.6	
		3	0.88	0.68	0.70	
Fully coated galvanized steel cables (Table 1)		1	1.00	0.67	0.60	Values to be applied to reduction factor
		2	1.00	0.68	0.65	
		3	0.87	0.68	0.68	
Fully coated steel cables (Table 1)		1	1.00	0.68	0.60	Values to be applied to reduction factor
		2	0.87	0.68	0.68	
		3	0.88	0.68	0.68	
Fully coated galvanized steel cables (Table 1)		1	1.00	0.68	0.68	Values to be applied to reduction factor
		2	1.00	0.68	0.68	
		3	0.87	0.68	0.68	
Fully coated galvanized steel cables (Table 1)		1	1.00	0.68	0.68	Values to be applied to reduction factor
		2	0.87	0.68	0.68	
		3	0.88	0.68	0.68	

NOTE 1: The values given in this table apply to the cables specified in Table D-19 and are based on the assumption that the number of strands is greater than 2 (s > 2).

NOTE 2: The values given for single-core cables are based on the assumption that the cables are made of steel or galvanized steel. Values for cables made of other materials may be obtained by multiplying the values for steel cables by the appropriate material factor.

NOTE 3: The values given for cables with galvanized steel strands are based on the assumption that the reduction factor is based on a strand diameter of 100,000.

NOTE 4: The values given for fully coated galvanized steel cables are based on the assumption that the cables are made of steel. For cables made of galvanized steel, the values should be reduced.

NOTE 5: For cables with three strands, the cable is made of steel or galvanized steel, the values should be reduced by 10% if the cables are made of galvanized steel.

7. Annex B Standard references for MV cables

Table B.52.1 – Installation reference methods forming basis of Table B.52.1 (continued) – varying capacities








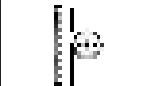


Reference method of installation		Tested reference							
		Current carrying capacity for single circuits					Ambient temperature (°C)	Group (Table B.52.1)	
		Horizontal installation	Vertical installation		At 90° to vertical				
		Number of cores					Number of cables		
3	4	5	6	7					
1	2	3	4	5	6	7	8	9	
	1 cables bundled in cable tray (see Table B.52.1) normally installed vertically	81	8.110 (Cat. 7)	8.020 (Cat. 7)	8.100 (Cat. 7)	8.000 (Cat. 7)	-	8.010 (Cat. 7)	8.010 (Cat. 7)
	Multiple cables in cable tray (see Table B.52.1) normally installed vertically	82	8.110 (Cat. 7)	8.020 (Cat. 7)	8.100 (Cat. 7)	8.000 (Cat. 7)	-	8.010 (Cat. 7)	8.010 (Cat. 7) 110% 8.010 (Cat. 7) 90% 8.010 (Cat. 7)
	1 cable bundled in cable tray (see Table B.52.1) normally installed vertically	83	8.110 (Cat. 7)	8.020 (Cat. 7)	8.100 (Cat. 7)	8.000 (Cat. 7)	-	8.010 (Cat. 7)	8.010 (Cat. 7)
	Multiple cables in cable tray (see Table B.52.1) normally installed vertically	84	8.110 (Cat. 7)	8.020 (Cat. 7)	8.100 (Cat. 7)	8.000 (Cat. 7)	-	8.010 (Cat. 7)	8.010 (Cat. 7)
	Multiple cables in cable tray (see Table B.52.1) normally installed vertically	85	8.110 (Cat. 7)	8.020 (Cat. 7)	8.100 (Cat. 7)	8.000 (Cat. 7)	25% 8.010 (Cat. 7) 75% 8.010 (Cat. 7)	8.010 (Cat. 7)	8.010 (Cat. 7)
	Multiple cables in cable tray (see Table B.52.1) normally installed vertically	86	8.110 (Cat. 7)	8.020 (Cat. 7)	8.100 (Cat. 7)	8.000 (Cat. 7)	-	8.010 (Cat. 7)	8.010 (Cat. 7)

Table B.10.1 (continued)

Reference number and location	Table standard						
	General description and title					Date of publication	Country of origin
	Standard number		Standard title		Date of publication		
	3	4	5	6		7	8
 1981-1982-1983 Copper (Cu) and Cadmium (Cd) in copper	27	EN 112	EN 112	EN 112	1982	EN 112	
 1982-1983 Copper (Cu) and Cadmium (Cd) in copper	28	Copper EN 112 Cadmium EN 112	Copper EN 112 Cadmium EN 112	EN 112 EN 112 EN 112	1982-83	EN 112	
 1982-1983 Copper (Cu) and Cadmium (Cd) in copper	29	Copper EN 112 Cadmium EN 112	Copper EN 112 Cadmium EN 112	EN 112 EN 112 EN 112	1982-83	EN 112	
 1982-1983 Copper (Cu) and Cadmium (Cd) in copper	30	Copper EN 112 Cadmium EN 112	Copper EN 112 Cadmium EN 112	EN 112 EN 112 EN 112	1982-83	EN 112	

**Table B.52.2 – Current-carrying capacities in amperes
for conductors of installation in Table B.52.1
PVC-insulated (flexible) conductors, copper or aluminum –
Conductor temperature: 70 °C, ambient temperature: 30 °C in air, 20 °C in ground**















Number of cores, cross-sectional area of conductor mm ²	Installation methods of Table B.52.1						
	SI	SI	SI	SI	C	SI	SI
							
1	2	3	4	5	6	7	8
Cross-section							
1.5	14.5	14	17.8	16.5	17.5	25	25
2.5	19.5	18.5	24	22	23	29	28
4	26	25	31	30	30	37	36
6	34	32	41	39	40	49	48
10	48	45	57	55	55	68	66
16	67	62	78	75	75	93	90
25	88	82	101	98	98	121	118
35	109	102	125	121	120	147	143
50	139	131	161	155	155	188	183
70	181	171	210	202	202	250	243
95	232	220	272	262	262	324	314
120	293	279	343	330	330	407	395
150	365	349	427	412	412	507	493
185	459	440	534	516	516	633	617
240	591	569	693	672	672	826	803
300	747	722	885	861	861	1064	1037

Table B.52.3 – Current-carrying capacities in amperes
for methods of installation in Table B.52.1 –
XLPE or CPE insulation, one loose conductor/cable on a uniform-
cross-section temperature 90 °C, ambient temperature 30 °C to 40 °C, 20 °C to ground

Nominal cross-section conductor mm ²	Installation methods of Table B.52.1						
	A1	A2	B1	B2	C	D1	D2
1	2	3	4	5	6	7	8
1.5	19	11.5	21	20	21	28	27
2.5	25	15	28	26	26	33	32
4	30	20	32	30	30	38	37
6	35	24	36	34	34	42	41
10	44	27	42	39	39	48	47
16	53	31	49	46	46	56	55
25	62	35	56	53	53	64	63
35	71	39	63	60	60	72	71
50	80	43	70	67	67	80	79
70	89	47	77	74	74	88	87
95	98	51	84	81	81	96	95
120	107	55	91	88	88	104	103
150	116	59	98	95	95	112	111
185	125	63	105	102	102	120	119
240	134	67	112	109	109	128	127
300	143	71	119	116	116	136	135

**Table B.52.4 – Ground-wiring capacities in copper
for methods of installation in Table B.52.1 –
PVC-insulated, three-core conductors of aluminum –
Conductor temperature: 70 °C, ambient temperature: 30 °C in air, 30 °C in ground**

Nominal cross-sectional area of conductor in mm ²	Methods of installation of Table B.52.1							
	01	02	03	04	05	06	07	
								
1	2	3	4	5	6	7	8	
Copper								
1.5	11.8	11	10.1	9	12.0	10	14	
2.5	16	17.5	21	20	14	24	24	
4	24	23	23	27	22	26	32	
6	31	24	24	24	31	28	47	
10	43	33	33	33	43	38	64	
16	59	47	45	47	59	51	79	
25	71	61	59	61	71	63	95	
35	82	71	70	71	82	74	110	
50	101	89	87	87	101	91	138	
70	121	107	107	107	121	110	160	
95	144	130	129	129	144	132	190	
120	168	154	153	153	168	155	228	
150	215	194	192	192	215	200	286	
185	241	221	219	219	241	224	328	
240	280	261	258	258	280	260	398	
300	321	299	296	296	321	298	458	

**Table B.52.5 – Ground-wiring capacities in copper
for methods of installation in Table B.52.1 –
XLPE or EPB insulation, three-core conductors of aluminum –
conductor temperature: 90 °C, ambient temperature: 30 °C in air, 30 °C in ground**








Nominal cross-sectional area of conductor in mm ²	Methods of installation of Table B.52.1							
	01	02	03	04	05	06	07	
								
1	2	3	4	5	6	7	8	
Copper								
1.5	11	10.5	9	7.5	11	9	13	
2.5	16	15	13	11	16	14	20	
4	24	23	19	16	24	21	30	
6	31	29	24	20	31	27	38	
10	43	41	33	27	43	38	52	
16	59	56	45	37	59	51	69	
25	71	67	54	45	71	62	84	
35	82	77	63	52	82	71	97	
50	101	95	78	64	101	88	119	
70	121	114	94	77	121	106	143	
95	144	135	111	91	144	126	168	
120	168	157	128	105	168	147	206	
150	215	202	167	138	215	189	260	
185	241	226	187	155	241	211	290	
240	280	263	216	178	280	246	348	
300	321	302	247	203	321	281	408	

Table B.52.10 – Current-carrying capacities in amperes
 for installations and feeds in Thermal and Table B.52.1 –
 PVC insulation, copper conductors –
 Conductor temperature: 70 °C, reference ambient temperature: 30 °C

Number of cores multicore cables or conduits mm ²	Insulation numbers of Table B.52.1						
	BS 6346 (1991)		Single-core cables				
	Type A (solid conductors)	Type B (solid conductors)	Type A (solid conductors)	Type B (solid conductors)	Type A (solid conductors)		Type B (solid conductors)
					Twisted	Stranded	
Method P	Method B	Method P	Method B	Method P	Method B	Method P	Method B
1	1	2	3	4	5	6	8
2.5	12	12.5	–	–	–	–	–
4	16	16	–	–	–	–	–
6	21	21	–	–	–	–	–
10	30	30	–	–	–	–	–
16	42	42	–	–	–	–	–
25	55	54	65	65	74	65	74
35	70	70	80	80	90	80	90
50	85	85	95	95	105	95	105
70	110	110	120	120	130	120	130
95	140	140	150	150	160	150	160
120	175	175	185	185	195	185	195
150	215	215	225	225	235	225	235
185	265	265	275	275	285	275	285
240	335	335	345	345	355	345	355
300	415	415	425	425	435	425	435
370	505	505	515	515	525	515	525
450	–	–	460	460	470	460	470
550	–	–	560	560	570	560	570
670	–	–	680	680	690	680	690
810	–	–	820	820	830	820	830

NOTE 1: Cable conductors are defined as cables up to and including 10 mm². Values for larger cables relate to special conditions and may vary if a special temperature is used.

NOTE 2: All values are in amperes (A).

Table B.52.12 - Current-carrying capacities in amperes
 for insulations methods E, F and G of Table B.52.1 -
 XLPE or EPB insulation, copper conductors -
 Conductor temperature 90 °C, reference ambient temperature 30 °C

Conductor cross-section (mm ²)	See also the reference in Table B.52.1					
	Method E		Method F			
	Insulation		Conductor			
	Type of conductor	Type of insulation	Type of conductor	Type of insulation	Type of conductor	
					Twisted	Stranded
	Method E	Method F	Method E	Method F	Method E	Method F
	1	2	1	2	1	2
1.5	24	24	—	—	—	—
2.5	26	27	—	—	—	—
4	28	29	—	—	—	—
6	30	31	—	—	—	—
10	33	34	—	—	—	—
16	36	37	—	—	—	—
25	40	41	—	—	—	—
35	43	44	44	45	44	45
50	46	47	46	47	46	47
70	50	51	50	51	50	51
95	54	55	54	55	54	55
120	58	59	58	59	58	59
150	62	63	62	63	62	63
185	67	68	67	68	67	68
240	73	74	73	74	73	74
300	79	80	79	80	79	80
370	85	86	85	86	85	86
450	91	92	91	92	91	92
560	98	99	98	99	98	99
700	106	107	106	107	106	107
870	114	115	114	115	114	115
1080	123	124	123	124	123	124
1320	132	133	132	133	132	133
1590	141	142	141	142	141	142
1980	151	152	151	152	151	152
2400	161	162	161	162	161	162
2970	171	172	171	172	171	172
3690	181	182	181	182	181	182
4560	191	192	191	192	191	192
5610	201	202	201	202	201	202
6930	211	212	211	212	211	212
8550	221	222	221	222	221	222
10500	231	232	231	232	231	232
12900	241	242	241	242	241	242

NOTE 1 - Circuit breakers are to be used for fault currents up to 10 kA for 100 ms and for fault currents above 10 kA up to 100 ms for 100 ms.

NOTE 2 - I_{n2} is the maximum allowed current in amperes.

Table B.12.14 – Correction factor for ambient air temperatures other than 30 °C to be applied to the current-carrying capacities for cables in the air

Ambient Temperature (T _a)	Insulation			
	PVC	XLPE and DPE	Mineral ¹⁾	
			PVC covered in ducts and exposed to touch 30 °C	Pure not exposed to touch 105 °C
10	1,23	1,15	1,20	1,18
15	1,17	1,12	1,20	1,17
20	1,12	1,08	1,14	1,12
25	1,06	1,04	1,07	1,06
30	1,00	1,00	1,00	1,00
35	0,94	0,95	0,93	0,95
40	0,87	0,91	0,90	0,92
45	0,81	0,87	0,88	0,89
50	0,75	0,82	0,84	0,84
55	0,69	0,78	0,82	0,81
60	0,63	0,73	0,80	0,79
65	–	0,68	–	0,70
70	–	0,63	–	0,65
75	–	0,58	–	0,60
80	–	0,47	–	0,50
85	–	–	–	0,40
90	–	–	–	0,30

¹⁾ For higher ambient temperatures, consult the manufacturer.

Table B.12.15 – Correction factors for ambient ground temperatures other than 30 °C to be applied to the current-carrying capacities for cables in ducts in the ground

Ground Temperature (T _g)	Insulation	
	PVC	XLPE and DPE
10	1,10	1,05
15	1,05	1,02
20	1,00	1,00
25	0,95	0,95
30	0,90	0,92
35	0,84	0,90
40	0,77	0,85
45	0,71	0,80
50	0,63	0,75
55	0,55	0,71
60	0,45	0,65
65	–	0,60
70	–	0,55
75	–	0,45
80	–	0,35

Table B.52.1B – Evaluation of Values 101 results from one circuit, safety added only to the ground – Installation method D2 in Tables B.52.1 to B.52.5 – String method for real time evaluation

NUMBER OF VALUES	Data from real time results				
	MR (operator, 1 min, string)	Quantile alternative	0.1000	0.5000	0.9000
2	0.99	2.75	0.98	0.90	0.90
3	0.97	2.67	0.95	0.80	0.85
4	0.95	2.60	0.94	0.70	0.80
5	0.93	2.55	0.93	0.60	0.80
6	0.91	2.50	0.92	0.50	0.80
7	0.89	2.45	0.91	0.40	0.75
8	0.87	2.40	0.90	0.30	0.75
9	0.85	2.35	0.89	0.20	0.75
10	0.83	2.30	0.88	0.10	0.70
12	0.80	2.25	0.87	0.00	0.70
15	0.77	2.20	0.85	0.00	0.65
20	0.73	2.15	0.84	0.00	0.60

FIGURE 101



FIGURE 102



NOTE 1: Values given apply to an installation type of 101. For other installation types, see Table B.52.1A to B.52.1G. Only when the ground safety is added to the string method (see Table B.52.1B to B.52.1G), the evaluation of a stringing test is not possible. The test is then done by using method D2. A more precise evaluation is possible when using the stringing method (see Table B.52.1A to B.52.1G).

NOTE 2: In case of a broken test string, the test can be done with the conventional method (see Figure 101) or with the stringing method (see Table B.52.1A to B.52.1G).

NOTE 3: The circuit consists of two parallel conductors and a phase conductor (see Figure 101) or two conductors (see Figure 102) and a ground conductor (see Table B.52.1A to B.52.1G).

Table B.52.19 – Reduction factors for more than one circuit, cables laid in ducts in the ground – Installation method C1 in Tables B.52.1 to B.52.5

C) Multiple cables in single-core ducts				
Number of cables	Duct factor (k _{duct})			
	BI (ducts touching)	0,25 m	0,5 m	1,0 m
2	1,0	0,92	0,85	0,78
3	1,0	0,78	0,72	0,66
4	1,0	0,63	0,60	0,56
5	1,0	0,50	0,48	0,46
6	1,0	0,40	0,39	0,38
7	1,0	0,33	0,33	0,33
8	1,0	0,28	0,28	0,28
9	1,0	0,25	0,25	0,25
10	1,0	0,23	0,23	0,23
11	1,0	0,22	0,22	0,22
12	1,0	0,21	0,21	0,21
13	1,0	0,20	0,20	0,20
14	1,0	0,19	0,19	0,19
15	1,0	0,19	0,19	0,19
16	1,0	0,18	0,18	0,18
17	1,0	0,18	0,18	0,18
18	1,0	0,18	0,18	0,18
19	1,0	0,18	0,18	0,18
20	1,0	0,18	0,18	0,18

III. Die folgenden Aufgaben lösen und jeweils alle Ableitungen angeben!

Anzahl der Ableitungen (maximal 20 Punkte für alle Aufgaben)	Anzahl der Ableitungen			
	1. Ableitung	0,1 m	0,2 m	1,0 m
1	0,00	0,00	0,00	0,00
2	0,75	0,40	0,40	0,40
3	1,50	0,70	0,80	0,80
4	0,00	0,00	0,00	0,00
5	1,50	0,70	0,80	0,80
6	1,50	0,70	0,80	0,80
7	1,50	0,70	0,70	0,80
8	0,00	0,00	0,70	0,80
9	1,50	0,70	0,70	0,80
10	1,50	0,70	0,70	0,80
11	1,50	0,70	0,70	0,80
12	1,50	0,70	0,80	0,80
13	1,50	0,70	0,80	0,80
14	0,00	0,00	0,80	0,80
15	1,50	0,70	0,80	0,80
16	0,00	0,00	0,80	0,80
17	1,50	0,70	0,80	0,80
18	0,00	0,00	0,80	0,80
19	1,50	0,70	0,80	0,80
20	0,00	0,00	0,80	0,80

Mathematik 11/12



1. Diagramm



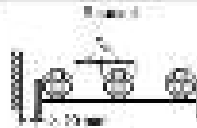
Die Aufgaben 1 bis 10 sind jeweils 2 Punkte wertig. Die Aufgaben 11 bis 15 sind jeweils 3 Punkte wertig. Die Aufgaben 16 bis 20 sind jeweils 4 Punkte wertig. Die Aufgaben 21 bis 25 sind jeweils 5 Punkte wertig. Die Aufgaben 26 bis 30 sind jeweils 6 Punkte wertig. Die Aufgaben 31 bis 35 sind jeweils 7 Punkte wertig. Die Aufgaben 36 bis 40 sind jeweils 8 Punkte wertig. Die Aufgaben 41 bis 45 sind jeweils 9 Punkte wertig. Die Aufgaben 46 bis 50 sind jeweils 10 Punkte wertig.

Die Aufgaben 1 bis 10 sind jeweils 2 Punkte wertig. Die Aufgaben 11 bis 15 sind jeweils 3 Punkte wertig. Die Aufgaben 16 bis 20 sind jeweils 4 Punkte wertig. Die Aufgaben 21 bis 25 sind jeweils 5 Punkte wertig. Die Aufgaben 26 bis 30 sind jeweils 6 Punkte wertig. Die Aufgaben 31 bis 35 sind jeweils 7 Punkte wertig. Die Aufgaben 36 bis 40 sind jeweils 8 Punkte wertig. Die Aufgaben 41 bis 45 sind jeweils 9 Punkte wertig. Die Aufgaben 46 bis 50 sind jeweils 10 Punkte wertig.

Table B.92.20 – Reduction factors for groups of more than one multi-core cable to be applied to reference current-carrying capacity for multi-core cables in flexible – Method of installation II in Tables B.92.8 to B.92.12.

Method of installation II in Tables B.92.8 to B.92.12		Number of cables in group	Number of cables in any one bundle						
			1	2	3	4	5	6	
1. Flexible multi-core cables (see 1)	a		1	1,00	0,88	0,77	0,75	0,75	0,73
			2	1,00	0,87	0,74	0,74	0,73	0,73
			3	1,00	0,86	0,73	0,73	0,71	0,71
			4	1,00	0,85	0,72	0,72	0,70	0,70
			1	1,00	1,00	0,91	0,91	0,91	-
			2	1,00	0,99	0,91	0,91	0,91	-
2. Flexible multi-core cables (see 2)	b		1	1,00	0,88	0,77	0,75	0,75	0,73
			2	1,00	0,88	0,77	0,75	0,73	0,73
			3	1,00	0,87	0,76	0,74	0,72	0,72
			4	1,00	0,86	0,75	0,73	0,71	0,71
			1	1,00	1,00	0,91	0,91	0,91	-
			2	1,00	0,99	0,91	0,91	0,91	-
3. Flexible multi-core cables (see 3)	c		1	0,91	0,84	0,78	0,75	0,75	0,73
			2	0,91	0,83	0,75	0,74	0,73	0,73
			3	0,91	0,82	0,74	0,73	0,71	0,71
			4	0,91	0,81	0,73	0,72	0,70	0,70
			1	0,91	0,91	0,82	0,82	0,82	-
			2	0,91	0,90	0,82	0,82	0,82	-
4. Flexible multi-core cables (see 4)	d		1	1,00	0,87	0,76	0,75	0,75	0,73
			2	1,00	0,86	0,75	0,74	0,73	0,73
			3	1,00	0,85	0,74	0,73	0,71	0,71
			4	1,00	0,84	0,73	0,72	0,70	0,70
			1	1,00	1,00	0,91	0,91	0,91	-
			2	1,00	0,99	0,91	0,91	0,91	-

TABLE B.10 (CONTINUED)

Method of installation in Table A.10.1		Number of lugs or holders	Number of cables per tray or bundle					
			4	5	6	7	8	9
	1	1.00	1.00	1.00	1.00	1.00	—	
	2	1.00	0.90	0.75	0.50	0.50	—	
	3	1.00	0.90	0.50	0.25	0.50	—	
<p>NOTE 1: Values given are averaged for the cable types and range of cable sizes considered in Tables A.10.1 and A.10.2. The nominal value is 0.5 mm (1/8 in.).</p> <p>NOTE 2: Factors apply to long field run groups of cables as shown above and do not apply to one cable run installed in more than one layer. For long run cable trays, factors for each installation may be significantly lower and factors are determined by an approved method.</p> <p>NOTE 3: Values are given for vertical loading. Reduce cable trays of 100 mm (4 in.) and all metal 10 mm (3/8 in.) wide trays (not wall) for close spacing of factors as follows:</p> <p>NOTE 4: Values are given for horizontal loading. Reduce cable trays of 100 mm (4 in.) wide cable trays mounted back to back. The close spacing factors should be reduced.</p>								

MOE M-SOLAR = MODULUS OF ELASTICITY GRADES OF THE FORMER GROUPS OF STEEL-CORR. and is the average of the three measured values (see Table 1) for each steel type. The value of MOE M-SOLAR = MOE M-SOLAR (CORR.) / MOE M-SOLAR.


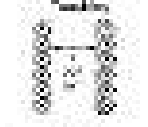
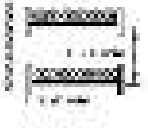


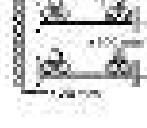
Material/Steel type (Table 1)		Number of specimens tested	Number of specimens with top layer of steel			Mean value of residual elongation of top layer after testing
			1	2	3	
Concrete with 1.5% steel fiber area ratio	F1		1	0.01	0.4	0.01
			2	0.01	0.4	0.01
			3	0.01	0.4	0.01
Concrete with 3% steel fiber area ratio	F2		1	0.01	0.4	—
			2	0.01	0.4	—
Concrete with 5% steel fiber area ratio	F3		1	0.01	0.4	0.01
			2	0.01	0.4	0.01
			3	0.01	0.4	0.01
Concrete with 7.5% steel fiber area ratio	F4		1	0.01	0.4	0.01
			2	0.01	0.4	0.01
			3	0.01	0.4	0.01
Concrete with 10% steel fiber area ratio	F5		1	0.01	0.4	0.01
			2	0.01	0.4	0.01
Concrete with 15% steel fiber area ratio	F6		1	0.01	0.4	0.01
			2	0.01	0.4	0.01
			3	0.01	0.4	0.01

Table D.52.31 (continued)

S.277.1	Make any adjustments required for the applicable period to the amount of contribution shown in Table D.52.31(a) or D.52.32. The adjusted amount is your adjusted contribution.
S.277.2	To determine your adjusted contribution amount for the following categories of contributions, the contributions shown in Table D.52.31(a) and (b) are reduced in order to take into account the following categories of contributions. The adjusted contribution amount is your adjusted contribution and should be determined by an appropriate trustee.
S.277.3	Adjusted contributions for contributions made in the form of cash, property, or other contributions, including 529 plans, for which the adjusted contribution amount should be determined by an appropriate trustee.
S.277.4	Adjusted contributions for contributions made in the form of cash, property, or other contributions, including 529 plans, for which the adjusted contribution amount should be determined by an appropriate trustee.
S.277.5	Adjusted contributions for contributions made in the form of cash, property, or other contributions, including 529 plans, for which the adjusted contribution amount should be determined by an appropriate trustee.
S.277.6	Adjusted contributions for contributions made in the form of cash, property, or other contributions, including 529 plans, for which the adjusted contribution amount should be determined by an appropriate trustee.
S.277.7	Adjusted contributions for contributions made in the form of cash, property, or other contributions, including 529 plans, for which the adjusted contribution amount should be determined by an appropriate trustee.