Totally Integrated Power

Technical Series Edition 12

Cable Burying in ground with SIMARIS design

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Explanations on how to implement cable burying in ground with SIMARIS design in accordance with DIN VDE 0298-4:2013-06 or IEC 60364-5-52:2009-10

When dimensioning cables and wires, SIMARIS design considers the installation method by means of appropriate adjustment factors (Fig. 1). These factors are taken from the relevant standards for cables and wires. The international IEC 60364-5-52 standard and the German one, DIN VDE 0298-4, largely agree in this respect. Since the introduction of the national standard, DIN VDE 0298-4: 2013-06, it brings about greatly differing procedures for burying cables directly in the soil. In this case, DIN VDE 0298-4 refers to the German DIN VDE 0276-603: 2010-03, which does not have an international equivalent. At the international level, IEC 60364-5-52: 2009-10 continues to be valid.

The following sections will demonstrate the differences in these standards concerning direct cable burying in the soil. With the aid of tables presented in the standards, an example is calculated. Since SIMARIS design largely works with the factors from the internationally applicable IEC 60364-5-52 standard (and correspondingly DIN VDE 0298-4; except for direct cable burying), the tables can be employed to convert cable sizing according to SIMARIS design so that it matches the German DIN VDE 0276-603 standard. Tables using conversion factors from DIN VDE 0276-1000, which is referred to DIN VDE 0276-603, must be observed in this context.

Regulations for cable loads in power installations

The international IEC 60364-5-52 standard was adopted as German DIN VDE 0100-520 standard. Subclause 521.3 in DIN VDE 0100-520: 2013-06 among other things refers to the examples of cable and wire installations in DIN VDE 0298-4 and to the adoption of Annex B "Current-carrying capacities" and Table A.52.3: "Examples of methods of installation and the determination of the current-carrying capacity" in the German DIN VDE 0298-4 standard. However, Table 9 of DIN VDE 0298-4 refers to the German DIN VDE 0276-603 concerning the reference installation method of "single- or multi-core cable(s) buried directly in the soil".

This must be seen critically, since different operating conditions have been used as a basis, as briefly summarized in Tab. 1. This affects the permissible current-carrying capacity of cables and wires:

$I_z = I_r \cdot f_{tot}$ (where $f_{tot} = \prod f$)

I_z	current-carrying capacity in the given boundary conditions
I_r	rated current
f_{tot}	product of the individual influencing factors f (see Tab. 1)

	IEC 60364-5-52 (DIN VDE 0298-4)	DIN VDE 0276-603
Load level	1 (continuous load)	0.7 (utility load)
Specific thermal soil resistance	2.5 K m/W (dry soil)	1.0 K m/W (humid soil)
Differentiation of cable design	According to conductor insulation material, single-core/multi-core	According to cable design, conductor insulation material, single-core/multi-core
Conversion factors	Unambiguous correlation between factor and parameter: f_{tot} = f(accumulation) x f(specific thermal soil resistance) x f(soil temperature) x f(harmonics [%])	Complex correlations between a factor and several parameters: f_{tot} = f_1(cable design, soil temperature, specific thermal soil resistance, load level) x f_2(cable design, number of parallel circuits, specific thermal soil resistance, load level, wiring condition) x f(harmonics [%])

Tab. 1: Standard-specific boundary conditions for the determination of cable load capacities

Using the simple conversion factors of DIN VDE 0298-4 or IEC 60364-5-52 will deliver a result which is on the safe side. For more detailed analyses and in consideration of the operating and ambient conditions, the DIN VDE 0276 series of standards can be used (in particular DIN VDE 0276-603 and DIN VDE 0276-1000). However, it must be noted in this context, that carrying out power installations in the vicinity of buildings, if more details are not known, requires the assumption of a load level of 1.0 (continuous load) – not to be confused with a simultaneity factor – and, in case of cable burying, a thermal soil resistance of 2.5 K m/W.

Note:
The operating and ambient conditions for installation in air in accordance with DIN VDE 0276 and reference installation method F in accordance with DIN VDE 0298-4 or IEC 60364-5-52 do not differ, i.e. a load level equal to 1.0 (continuous load) applies and the ambient temperature is 30 °C.

To consider equipment causing harmonics, such as energy saving lamps, charging units, PCs, frequency converter drives and all equipment powered by a PSU, an additional correction factor can be chosen in Simaris design. This procedure follows DIN VDE 0100-520 Addendum 3. This correction factor only applies to distribution circuits and is multiplied in the calculation of ftot.

Proportion of summated power of all equipment causing harmonics	Correction factor for distribution circuits f(harmonics [%])
0 ... 15%	1
> 15 ... 25%	0.95
> 25 ... 35%	0.9
> 35 ... 45%	0.85
> 45 ... 55%	0.8
> 55 ... 65%	0.75
> 65 ... 75%	0.7
> 75%	0.65

Tab. 2: Correction factors for the consideration of harmonics in accordance with DIN VDE 0100-520 Addendum 3

Implementation in SIMARIS design

The reference installation methods of DIN VDE 0298-4 and IEC 60364-5-52 agree to a large extent. They merely differ in respect of burying cables directly in the soil (see Tab. 3).

As demonstrated before, the systematics for determining the current-carrying capacity is slightly different in the DIN VDE 0276 series of standards and DIN VDE 0298-4 and IEC 60364-5-52 respectively. To ensure an internationally uniform procedure, it was determined for SIMARIS design, that the systematics based on IEC 60364-5-52 be applied to the reference installation methods D1 and D2. This means:

- The current-carrying capacity values for cable laying in an electrical conduit or in a duct in the soil, i.e. reference installation method D (DIN VDE 0298-4) and D1 (IEC 60364-5-52) respectively, are identical.
- The current-carrying capacity values for burying cables directly in the soil in accordance with DIN VDE 0276-603 (with the associated conversion factors from DIN VDE 0276-1000) and under the realistic assumption of continuous load and a dry soil with the specific thermal soil resistance of 2.5 K·m/W) deviate by a mere 7% at maximum, and by 2% when averaged, compared to the values resulting from the calculation according to IEC 60364-5-52 for the reference installation method D2. The values for D2 based on IEC 60364-5-52, following a more conservative approach, are below the values based on DIN VDE 0276-603.
- The differences as to current-carrying capacities between bundled single-core cables and multi-core cables can be neglected (the difference is less than 5% for cross sections greater than 16 mm²).
- The harmonic content according to Tab. 2 can be specified in the "Factor ftot selection" window in Simaris design. To do so, the info button next to the reduction factor f_{tot} must be clicked in the "Cables/wires" window (with a blue frame in Fig. 1).

The load capacities for reference installation method D1 and D2 can be seen from Tables A1 to A13 in the Annex.

	DIN VDE 0298-4	IEC 60364-5-52
Cable laying in an electrical conduit or duct in the soil	Reference installation method D (corresponding to D1 in IEC 60364-5-52)	Reference installation method D1
Cable burying directly in the soil	Reference made to DIN VDE 0276	Reference installation method D2

Tab. 3: Installation methods concerning cable burying in the soil in the national and international standard

Attention:
The conversion factors for different thermal soil resistances (DIN VDE 0298-4 Table 20, installation method D) is used in SIMARIS design for both reference installation methods D1 and D2. IEC 60364-5-52 specifies separate correction factors for cable burying directly in the soil (see IEC 60364-5-52 Table B.52.16). However, these correction factors – as compared to determining them with the aid of the DIN VDE 0276 series of standards – will give deviations which are much too great (unrealistically high current-carrying capacities are calculated), so that these correction factors cannot be regarded as correct. Therefore, they are not considered in SIMARIS design either.

DIN VDE 0298-4 and IEC 60364-5-52 do not differ in the correction factors for the thermal soil resistance for cable laying in a conduit or duct in the soil. The conversion factors for a soil temperature deviating from 20 °C and for an accumulation of cables and wires are identical in DIN VDE 0298-4 and IEC 60364-5-52.

Example

Comparability of results for the calculation of the permissible current-carrying capacity of cables and wires using

a) SIMARIS design (on the basis of IEC 60364-5-52 – see Tab. A.1, A.2, A.3, A.5 and A.6 in the Annex. Exception: the same correction factors are taken for the thermal soil resistance of cables and wires buried directly in the soil as for cables and wires laid in electrical conduits or in cable ducts in the soil - see Tab A.4 in the Annex)
b) The factors from the DIN VDE 0276 series of standards (see Tab. A.7 to A.13 in the Annex)

The basic assumptions for calculation are:

- Multi-core cable with copper conductors without concentric line conductor
- PVC insulation
- 4 parallel conductors (three-phase current) spaced out with a clearance of one cable diameter in between
- Conductor cross sections = 240 mm²
- Cables buried directly in the soil at a soil temperature of 20 °C
- Thermal soil resistance = 2.5 K·m/W (dried out soil)
- Load level = 1.0 (continuous load)
- Proportion of summated power of equipment causing harmonics = 0 ... 15 %

a) Calculation in SIMARIS design (see Fig. 1 and 2)
   - From Tab. A.1 and according to the basic assumptions, the current-carrying capacity for installation method D2 is: I_r = 320 A
   - Tab. A.3 gives a correction factor for a soil temperature = 20 °C: f(soil temperature) = 1.0
   - Following IEC 60364-5-52, continuous load is assumed for the building
   - As Tab. A.6 shows for the accumulation of multi-core cables with a spacing of one cable diameter, there is: f(accumulation) = 0.60
   - From Tab. 2 there is: f(harmonics [%]) = 1.0

   In total, the current-carrying capacity is
   $I_z = 4 \cdot 320\ \text{A} \cdot 1.0 \cdot 1.0 \cdot 0.60 \cdot 1.0 = 768\ \text{A}$

b) Calculation based on the DIN VDE 0276 series of standards
   - From Tab. A.7 and according to the basic assumptions, the current-carrying capacity of multi-core conductors without concentric line conductor is Ir = 473 A
   - As Tab. A.9 shows, at a soil temperature of 20 °C (value for PVC with a permissible operating temperature f 70 °C and the specific thermal soil resistance = 2.5 K m/W), the conversion factor f_1 is 0.76
   - As Tab. A.13 shows, assuming 4 circuits and a continuous load = 1.0 (value for PVC with a permissible operating temperature of 70 °C and the specific thermal soil resistance = 2.5 K m/W), the conversion factor f_2 is 0.57
   - f(harmonics [%]) from Tab. 2 = 1.0

   In total, the current-carrying capacity is
   $I_z = 4 \cdot 473\ \text{A} \cdot 0.76 \cdot 0.57 \cdot 0.60 \cdot 1.0 = 820\ \text{A}$

The two results prove that the calculation based on SIMARIS design is on the safe side. The difference of 6% shows that the above simplifications do not entail too significant limitations.

Consideration of the current-carrying capacity in accordance with DIN VDE 0276 in SIMARIS design

In SIMARIS design, it is also possible, if desired, to adjust the current-carrying capacity on the basis of DIN VDE 0276. To do so, the value given for the total correction factor in SIMARIS design, f_{tot}, must be overwritten.

To determine this f_{tot}(DIN VDE 0276):

1. The correction factor, which is identical for both determination methods, for the consideration of harmonics, f(harmonics [%]) must be taken from Tab. 2.
2. The current-carrying capacity I_z(DIN VDE 0276) based on the DIN VDE 0276 series must be determined with the aid of Tables A.7 to. A.13 in analogy to the above example.
3. The basic current-carrying capacity I_{z0}(SIMARIS) must be determined on the basis of Tab. A.1 or Tab. A.2.

With these three values, the following is true:

f_{tot}(DIN VDE 0276) = f(harmonics [%])· I_z(DIN VDE 0276) / [number of circuits · I_{z0}(SIMARIS)]

For the example calculated above, there is a total correction factor for SIMARIS design:

f_{tot}(DIN VDE 0276) = 1.0 · 820 A / [4 · 320 A] = 0.64

This value reflects the previously established difference of about 7% for the example and must then be entered manually in SIMARIS design ("Reduction factor f_{tot}" in Fig. 1). Using it allows to perform the calculation together with the other given values for cables and circuits.

Conclusion

German and international standards agree in the majority of installation methods for cables and wires. This is represented in SIMARIS design. Differences merely come up in terms of cable burying directly in the soil, where the revision of the international IEC 60364-5-52 standard with new correction factors for the specific thermal soil resistance of direct cable burying D2 makes it seem reasonable to question these new values.

SIMARIS design takes advantage of the simpler approach of the international standard, but applies the same factors for the specific thermal soil resistance in installation method D2 as in D1. This is a conservative approach compared to the calculations based on the DIN VDE 0276 series of standards, which leaves some safety margins for the planning. These margins should be kept in mind in the planning process.

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The attachment to this PDF file includes an Excel tool (correction_factors_cable_burying_VDE_0276.xlms) to determine the correction factor f_{tot}(DIN VDE 0276), which can be used in SIMARIS design.

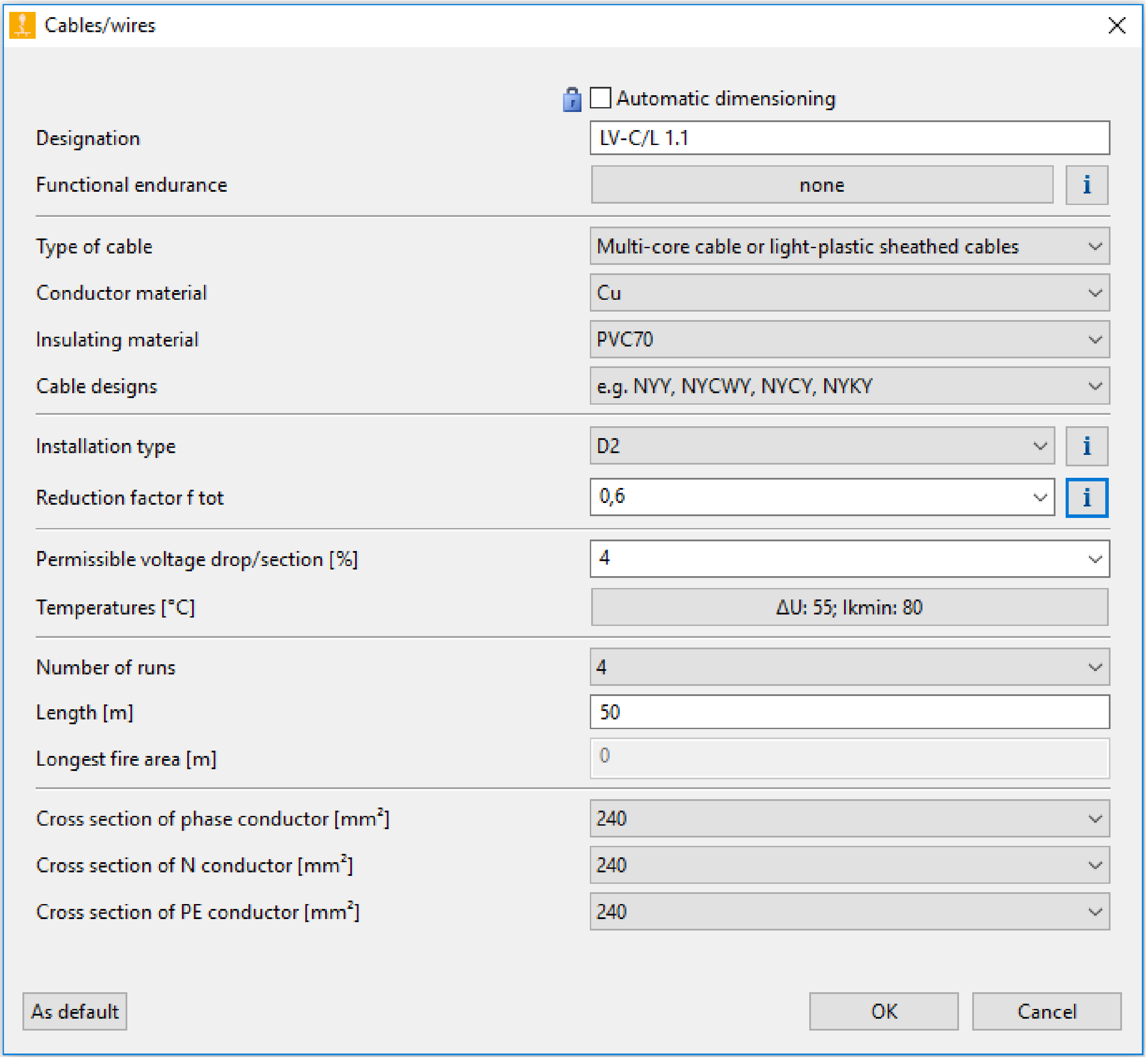


Fig. 1: Screenshot from SIMARIS design showing parameter input for cables and wires

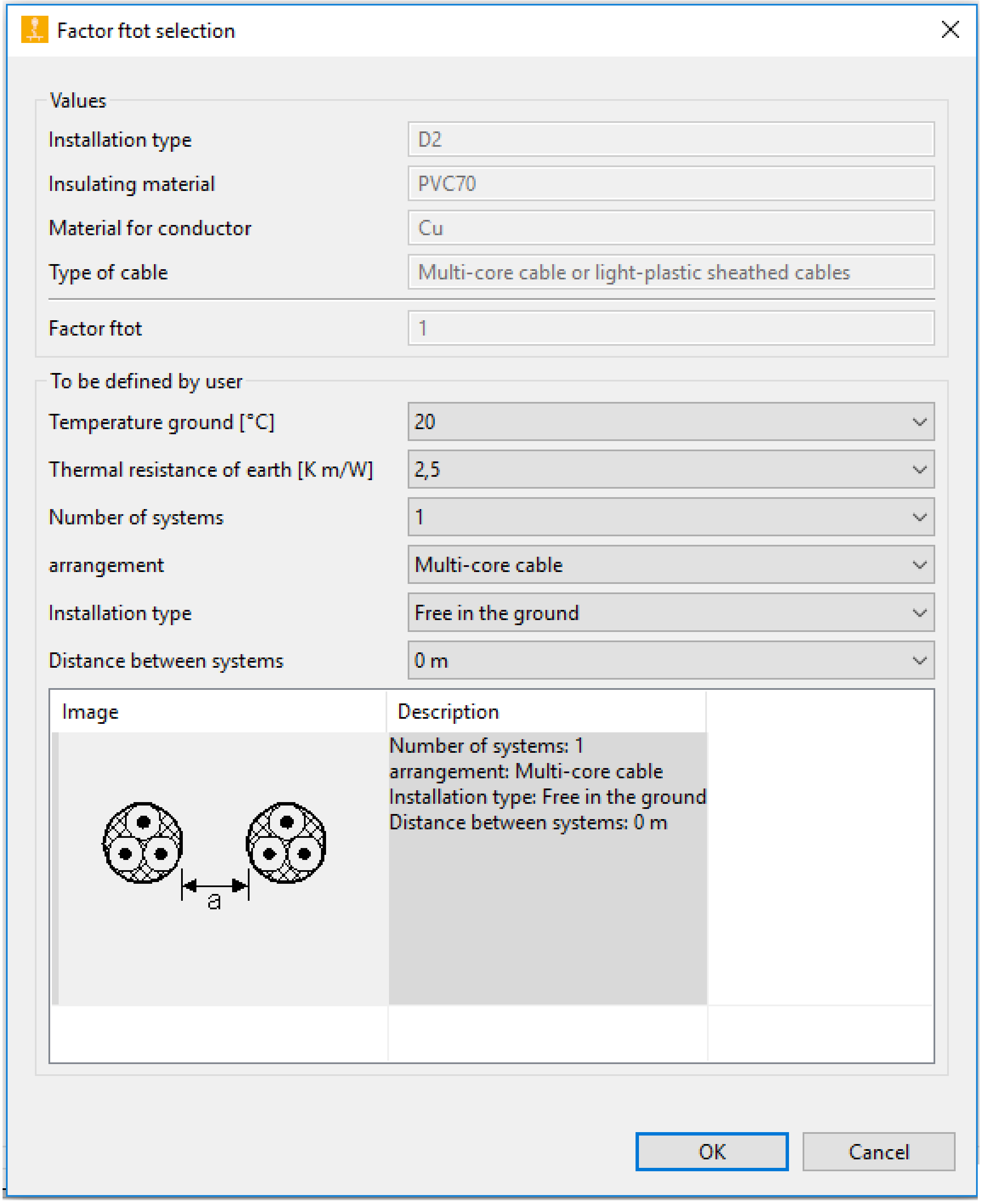
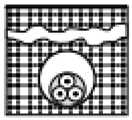
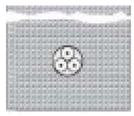
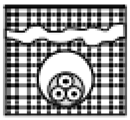
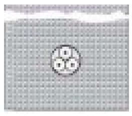


Fig. 2: Screenshot from SIMARIS design showing parameter input for factor f_{tot} (the window is displayed in SIMARIS design by clicking the info button framed in blue in Fig. 1)

Annex

PVC insulation – 70 °C permissible operating temperature and 20 °C soil temperature				
	D1 In the conduit or cable duct in the soil 		D2 Directly in the soil 	
Number of loaded cores	2	3	2	3
Nominal cross section [mm^2]	Current-carrying capacity [A]			
Copper				
1.5	22	18	22	19
2.5	29	24	28	24
4	37	30	38	33
6	46	38	48	41
10	60	50	64	54
16	78	64	83	70
25	99	82	110	92
35	119	98	132	110
50	140	116	156	130
70	173	143	192	162
95	204	169	230	193
120	231	192	261	220
150	261	217	293	246
185	292	243	331	278
240	336	280	382	320
300	379	316	427	359
Aluminium				
2.5	22	18.5	-	-
4	29	24	-	-
6	36	30	-	-
10	47	39	-	-
16	61	50	63	53
25	77	64	82	69
35	93	77	98	83
50	109	91	117	99
70	135	112	145	122
95	159	132	173	148
120	180	150	200	169
150	204	169	224	189
185	228	190	255	214
240	262	218	298	250
300	296	247	336	282

Tab. A.1: Current-carrying capacities of cables with PVC insulation in case of cable burying in the soil, used in SIMARIS design (load level = 1.0 and specific thermal soil resistance = 2.5 K m/W; excerpts from IEC 60364-5-52: Table B.52.2 and B.52.4)

VPE insulation – 90 °C permissible operating temperature and 20 °C soil temperature				
	D1 In the conduit or cable duct in the soil 		D2 Directly in the soil 	
Number of loaded cores	2	3	2	3
Nominal cross section [mm²]	Current-carrying capacity [A]			
Copper				
1.5	25	21	27	23
2.5	33	28	35	30
4	43	36	46	39
6	53	44	58	49
10	71	58	77	65
16	91	75	100	84
25	116	96	129	107
35	139	115	155	129
50	164	135	183	153
70	203	167	225	188
95	239	197	270	226
120	271	223	306	257
150	306	251	343	287
185	343	281	387	324
240	395	324	448	375
300	446	365	502	419
Aluminium				
2.5	26	22	-	-
4	33	28	-	-
6	42	35	-	-
10	55	46	-	-
16	71	59	76	64
25	90	75	98	82
35	108	90	117	98
50	128	106	139	117
70	158	130	170	144
95	186	154	204	172
120	211	174	233	197
150	238	197	261	220
185	267	220	296	250
240	307	253	343	290
300	346	286	386	326

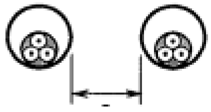
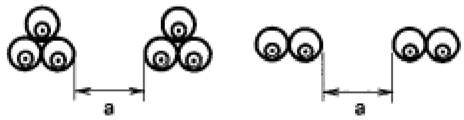
Tab. A.2: Current-carrying capacities of cables with VPE insulation in case of cable burying in the soil, used in SIMARIS design (load level = 1.0 and specific thermal soil resistance = 2.5 K m/W; excerpts from IEC 60364-5-52: Table B.52.3 and B.52.5)

Soil temper-ature [°C]	Permissible operating temperature at conductor:	
	PVC 70 °C	VPE 90 °C
10	1.10	1.07
15	1.05	1.04
20	1.00	1.00
25	0.95	0.96
30	0.89	0.93
35	0.84	0.89
40	0.77	0.85
45	0.71	0.8
50	0.63	0.76
55	0.55	0.71
60	0.45	0.65
65	–	0.6
70	–	0.53
75	–	0.46
80	–	0.38

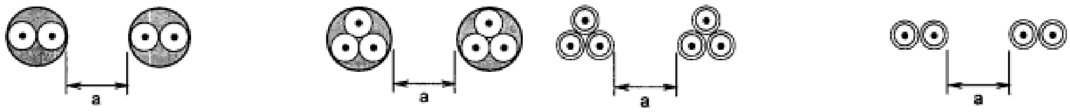
Tab. A.3: Conversion factors for ambient temperatures deviating from 20°C relating to the current-carrying capacity of cables to be buried in the soil (reference installation method D1 and D2; corresponding to IEC 60364-5-52: Table B.52.15)

Specific thermal soil resistance [K m/W]	**0.5**	**0.7**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**
Conversion factor	1.28	1.20	1.18	1.10	1.05	1.00	0.96

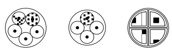
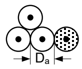
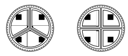
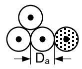
Tab. A.4: Conversion factors in SIMARIS design for specific thermal soil resistances deviating from 2.5 K m/W relating to the current-carrying capacity of cables to be buried in the soil (reference installation method D1 and D2; part of IEC 60364-5-52: Table B.52.16)

Number of circuits	Distance from cable duct to cable duct							
	Multi-core cable 				Single-core cable 			
	Zero (touching)	0.25 m	0.5 m	1.0 m	Zero (touching)	0.25 m	0.5 m	1.0 m
2	0.85	0.90	0.95	0.95	0.80	0.90	0.90	0.95
3	0.75	0.85	0.90	0.95	0.70	0.80	0.85	0.90
4	0.70	0.80	0.85	0.90	0.65	0.75	0.80	0.90
5	0.65	0.80	0.85	0.90	0.60	0.70	0.80	0.90
6	0.60	0.80	0.80	0.90	0.60	0.070	0.80	0.90
7	0.57	0.76	0.80	0.88	0.53	0.66	0.76	0.87
8	0.54	0.74	0.78	0.88	0.50	0.63	0.74	0.87
9	0.52	0.73	0.77	0.87	0.47	0.61	0.73	0.86
10	0.49	0.72	0.76	0.86	0.45	0.59	0.72	0.85
11	0.47	0.70	0.75	0.86	0.43	0.57	0.70	0.85
12	0.45	0.69	0.74	0.85	0.41	0.56	0.69	0.84
13	0.44	0.68	0.73	0.85	0.39	0.54	0.68	0.84
14	0.42	0.68	0.72	0.85	0.37	0.53	0.68	0.83
15	0.41	0.67	0.72	0.84	0.35	0.52	0.67	0.83
16	0.39	0.66	0.71	0.84	0.34	0.51	0.66	0.83
17	0.38	0.65	0.70	0.83	0.33	0.50	0.65	0.82
18	0.37	0.65	0.70	0.83	0.31	0.49	0.65	0.82
19	0.35	0.64	0.69	0.82	0.30	0.48	0.64	0.82
20	0.34	0.63	0.68	0.82	0.29	0.47	0.63	0.81

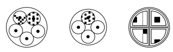
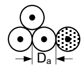
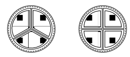
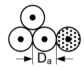
Tab. A.5: Conversion factors for the accumulation of cables in conduits or cable ducts in the soil (reference installation method D1, thermal soil resistance 2.5 K·m/W; corresponding to IEC 60364-5-52: Table B.52.19)

Number of circuits	Cable to cable distance				
	Multi-core cable			Single-core cable	
					
	Zero (touching)	**One cable diameter**	**0.125 m**	**0.25 m**	**0.5 m**
2	0.75	0.80	0.85	0.90	0.90
3	0.65	0.70	0.75	0.80	0.85
4	0.60	0.60	0.70	0.75	0.80
5	0.55	0.55	0.65	0.70	0.80
6	0.50	0.55	0.60	0.70	0.80
7	0.45	0.51	0.59	0.67	0.76
8	0.43	0.48	0.57	0.65	0.75
9	0.41	0.46	0.55	0.63	0.74
12	0.36	0.42	0.51	0.59	0.71
16	0.32	0.38	0.47	0.56	0.68
20	0.29	0.35	0.44	0.53	0.66

Tab. A.6: Conversion factors for the accumulation of cables buried directly in the soil (reference installation method D2, thermal soil resistance 2.5 K·m/W; corresponding to IEC 60364-5-52: Table B.52.18)

PVC insulation – 70 °C permissible operating temperature and 20 °C soil temperature				
	Without concentric line conductor (type A) e.g. N(A)YY		**With** concentric line conductor (type B) e.g. N(A)YCWY, N(A)YCY	
Arrangement	Multi-core 	Single-core, bundled 	Multi-core 	Single-core, bundled 
Number of loaded cores	3	3	3	3
Nominal cross section [mm²]	**Current-carrying capacity [A]**			
Copper				
1.5	27	30	27	31
2.5	36	39	36	40
4	47	50	47	51
6	59	62	59	63
10	79	83	79	84
16	102	107	102	108
25	133	138	133	139
35	159	164	160	166
50	188	195	190	196
70	232	238	234	238
95	280	286	280	281
120	318	325	319	315
150	359	365	357	347
185	406	413	402	385
240	473	479	463	432
300	535	541	518	473
400	613	614	579	521
500	687	693	624	574
630	-	777	-	636
Aluminium				
25	102	106	103	108
35	123	127	123	129
50	144	151	145	153
70	179	185	180	187
95	215	222	216	223
120	245	253	246	252
150	275	284	276	280
185	313	322	313	314
240	364	375	362	358
300	419	425	415	397
400	484	487	474	441
500	553	558	528	489
630	-	635	-	539

Tab. A.7: Current-carrying capacity of cables with PVC insulation buried directly in the soil in accordance with DIN VDE 0276-603: Part 3-G Table 14 (load level 0.7 and specific thermal soil resistance 1.0 K·m/W)

VPE insulation – 90 °C permissible operating temperature and 20 °C soil temperature				
	Without concentric line conductor (type A) e.g. N(A)2XY, N(A)2X2Y		**With** concentric line conductor (type B) e.g. N(A)2XCWY, N(A)2XCW2Y	
Arrangement	Multi-core 	Single-core, bundled 	Multi-core 	Single-core, bundled 
Number of loaded cores	3	3	3	3
Nominal cross section [mm²]	**Current-carrying capacity [A]**			
Copper				
1.5	31	33	31	33
2.5	40	42	40	43
4	52	54	52	55
6	64	67	65	68
10	86	89	87	91
16	112	115	113	117
25	145	148	146	150
35	174	177	176	179
50	206	209	208	211
70	254	256	256	257
95	305	307	307	304
120	348	349	349	341
150	392	393	391	377
185	444	445	442	418
240	517	517	509	469
300	585	583	569	514
400	671	663	637	565
500	758	749	691	623
630	-	843	-	690
Aluminium				
25	112	114	113	116
35	135	136	136	138
50	158	162	159	164
70	196	199	197	201
95	234	238	236	240
120	268	272	269	272
150	300	305	302	303
185	342	347	342	340
240	398	404	397	387
300	457	457	454	430
400	529	525	520	479
500	609	601	584	531
630	-	687	-	587

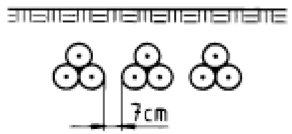
Tab. A.8: Current-carrying capacity of cables with PVC insulation buried directly in the soil in accordance with DIN VDE 0276-603 Part 5-G Table 14 (load level 0.7 and specific thermal soil resistance 1.0 K·m/W)

Permissible operating tempera-ture [°C]	Soil tem-perature [°C]	Specific thermal soil resistance [K m/W]															
		0.7					1.0					1.5					2.5
		Load level					Load level					Load level					Load level
		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
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
70	5	1.29	1.26	1.22	1.15	1.09	1.13	1.11	1.08	1.04	1	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	1.1	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	0.96	0.91	0.9	0.89	0.87	0.85	0.83	0.76
	25	–	–	–	–	–	1.03	1	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	0.8	0.78	0.76	0.68
	35	–	–	–	–	–	–	–	–	–	–	–	–	0.77	0.74	0.72	0.63
	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.59

Tab. A.9: Conversion factors f_1 for burying cables, for all cables, except for PVC cables rated 6/10 kV (excerpt from DIN VDE 0276-1000: Table 4)

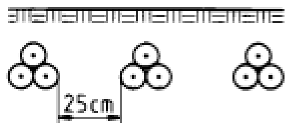
Type	Number of circuits	Specific thermal soil resistance [K m/W]																			
		0.7					1.0					1.5					2.5				
		Load level					Load level					Load level					Load level				
		0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00
VPE cables 0.6/1, 6/10, 12/20, 18/30 [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
	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
	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 0.6/1, 3.6/6, 6/10 [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
	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

Tab. A.10: Conversion factors f_2 for burying cables, bundled arrangement of single-core cables with a clearance of 7 cm (excerpt from DIN VDE 0276-1000: Table 6)



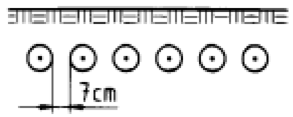
Type	Number of circuits	Specific thermal soil resistance [K m/W]																			
		0.7					1.0					1.5					2.5				
		Load level					Load level					Load level					Load level				
		0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00
VPE cables 0.6/1, 6/10, 12/20, 18/30 [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
	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
	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 0.6/1, 3.6/6, 6/10 [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
	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

Tab. A.11: Conversion factors f_2 for burying cables, bundled arrangement of single-core cables with a clearance of 25 cm (excerpt from DIN VDE 0276-1000: Table 7)



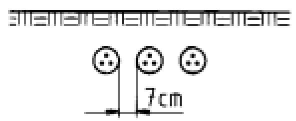
Type	Number of circuits	Specific thermal soil resistance [K m/W]																			
		0.7					1.0					1.5					2.5				
		Load level					Load level					Load level					Load level				
		0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00	0.50	0.60	0.70	0.85	1.00
VPE cables 0.6/1, 6/10, 12/20, 18/30 [kV]	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, 3.6/6, 6/10 [kV]	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

Tab. A.12: Conversion factors f_2 for burying cables, single-core cables with a clearance of 7 cm, side-by-side arrangement (excerpt from DIN VDE 0276-1000: Table 8)



Type	Number of circuits	Specific thermal soil resistance [K m/W]																			
		0.7					1.0					1.5					2.5				
		Load level					Load level					Load level					Load level				
		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	0.50	0.60	0.70	0.85	1.00
VPE cables 0.6/1 kV, 6/10 kV	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
	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
PVC cables 0.6/1 kV with $S_n \geq 35mm^2$	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 0.6/1 kV with $S_n < 35mm^2$	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
3.6/6 kV	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

Tab. A.13: Conversion factors f_2 for burying cables, multi-core cables with a clearance of 7 cm, side-by-side arrangement (excerpt from DIN VDE 0276-1000: Table 9; S_n is the nominal conductor cross section)



Siemens AG

Smart Infrastructure
Electrification & Automation
Mozartstr. 31c
91052 Erlangen
Germany

E-mail: **consultant-support.tip@siemens.com**

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