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IEC 62930

Edition 1.0 2017-12

INTERNATIONAL STANDARD

Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC

INTERNATIONAL
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ELECTRIC CABLES FOR PHOTOVOLTAIC SYSTEMS WITH A VOLTAGE RATING OF 1,5 kV DC

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FDIS	Report on voting
20/1764/FDIS	20/1777/RVD

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INTRODUCTION

This document specifies cables for use in photovoltaic (PV) systems for installation at the direct current (DC) side. These cables are suitable for permanent outdoor long-term use under variable demanding climate conditions. Relatively stringent requirements are set for these products in line with the expected usage conditions.

During the writing of this document, the work of IEC TC 64 (Electrical installations and protection against electric shock) and IEC TC 82 (Solar photovoltaic energy systems) on the design and installation of PV systems has been taken into account.

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ELECTRIC CABLES FOR PHOTOVOLTAIC SYSTEMS WITH A VOLTAGE RATING OF 1,5 kV DC

1 Scope

This document applies to single-core cross-linked insulated power cables with cross-linked sheath. These cables are for use at the direct current (DC) side of photovoltaic systems, with a rated DC voltage up to 1,5 kV between conductors and between conductor and earth. This document includes halogen free low smoke cables and cables that can contain halogens.

The cables are suitable to be used with Class II equipment as defined in IEC 61140.

The cables are designed to operate at a normal continuous maximum conductor temperature of 90 °C. The permissible period of use at a maximum conductor temperature of 120 °C is limited to 20 000 h.

NOTE The expected period of use under normal usage conditions as specified in this document is at least 25 years.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60216-1, *Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-2, *Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria*

IEC 60227-2:1997, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 2: Test methods*

IEC 60245-2:1994, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 2: Test methods*

IEC 60228:2004, *Conductors of insulated cables*

IEC 60332-1-2:2004, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*
IEC 60332-1-2:2004/AMD1:2015

IEC 60364-5-52, *Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

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IEC 60719, *Calculation of the lower and upper limits for the average outer dimensions of cables with circular copper conductors and of rated voltages up to and including 450/750 V*

IEC 60811-401:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 401: Miscellaneous tests – Thermal ageing methods – Ageing in an air oven*

IEC 60811-403, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 403: Miscellaneous tests – Ozone resistance test on cross-linked compounds*

IEC 60811-404, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 404: Miscellaneous tests – Mineral oil immersion tests for sheaths*

IEC 60811-501, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds*

IEC 60811-503, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 503: Mechanical tests – Shrinkage test for sheaths*

IEC 60811-504, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 504: Mechanical tests – Bending tests at low temperature for insulation and sheaths*

IEC 60811-505, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 505: Mechanical tests – Elongation at low temperature for insulations and sheaths*

IEC 60811-506, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 506: Mechanical tests – Impact test at low temperature for insulations and sheaths*

IEC 60811-507, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 507: Mechanical tests – Hot set test for cross-linked materials*

IEC 61034-2, *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 62230, *Electric cables – Spark-test method*

IEC 62440:2008, *Electric cables with a rated voltage not exceeding 450/750 V – Guide to use*

IEC 62821-1:2015, *Electric cables – Halogen-free, low smoke, thermoplastic insulated and sheathed cables of rated voltages up to and including 450/750 V – Part 1: General requirements*

IEC 62821-2:2015, *Electric cables – Halogen-free, low smoke, thermoplastic insulated and sheathed cables of rated voltages up to and including 450/750 V – Part 2: Test methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
type test
T
tests required to be carried out before supplying a type of cable covered by IEC 62930 on a general commercial basis, in order to demonstrate satisfactory performance characteristics to meet the intended application

Note 1 to entry: Type tests are of such a nature that, after they have been made, they need not be repeated unless changes are made in the cable materials, design or type of manufacturing process which might change the performance characteristics.

3.2
sample test
S
tests carried out on samples of completed cable, or components taken from a completed cable adequate to verify that the finished product meets the design specifications

3.3
routine test
R
tests carried out on all production cable lengths to demonstrate their integrity

3.4
halogen free material
material containing no more than a defined impurity level of halogens

4 Rated voltage

The cables specified by this document are in particular designed for use at the direct current (DC) side of photovoltaic-systems, with a rated DC voltage up to 1,5 kV between conductors as well as between conductor and earth.

Annex A provides further guidance on voltage ratings.

5 Requirements for the construction of cables

5.1 Conductors

5.1.1 Material

The conductors shall be copper, and in accordance with IEC 60228.

The wires of conductors shall be tin coated. The wires shall be covered with a continuous layer of tin coating.

There shall be no visible gaps in the continuous layer, when examined with normal or corrected vision.

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5.1.2 Construction

The class of the conductor shall be Class 5 in accordance with IEC 60228 for cable that is directly connected to PV modules. Class 2 conductors are allowed for cables intended for fixed installation and not directly connected to the PV modules.

The nominal cross-sectional areas for each conductor class are given in Table 1.

5.1.3 Separator between conductor and insulation

A non-metallic separator may be applied between the conductor and the insulation. If a non-metallic separator is applied in a halogen free low smoke cable, it shall be halogen free.

5.1.4 Check of construction

Compliance with the requirements of 5.1.1, 5.1.2 and 5.1.3, including the requirements of IEC 60228, shall be checked by inspection and by measurement.

5.2 Insulation

5.2.1 Material

The insulation material shall be a cross-linked compound and fulfil the requirements as specified in Table B.1 in Annex B.

5.2.2 Application to the conductor

The insulation shall be applied by extrusion, such that it fits closely on the conductor, but it shall be possible to remove it without damage to the insulation itself, to the conductor or to the tin coating. It is permitted to apply the insulation in a single layer, or in a number of non-separable layers. Where more than one layer is used, all testing shall be carried out on the complete insulation as though it were a single layer.

NOTE Insulation applied in more than one layer does not conform to the definition of “double insulation” given, for instance, in IEC 61140.

Compliance shall be checked by inspection and by manual test.

5.2.3 Thickness

The average of the measured values, rounded to 0,1 mm, shall be not less than the specified value for each size shown in Table 1.

The smallest value measured shall not fall below 90 % of the specified value by more than 0,1 mm, i.e.:

$$t_m \geq 0{,}9t_s - 0{,}1$$

where:

t_m is the minimum insulation thickness at any point in millimetres;

t_s is the specified insulation thickness, in millimetres.

Compliance shall be checked using the test given in 1.9 of IEC 60245-2:1994.

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5.3 Sheath

5.3.1 Material

The sheath material shall be a cross-linked compound and fulfil the requirements as specified in Table B.1 in Annex B.

5.3.2 Application

The sheath shall be applied homogeneously by extrusion. It is permitted to apply the sheath in a single layer, or in a number of non-separable layers. Where more than one layer is used, all testing shall be carried out on the complete sheathing as though it were a single layer.

The application of the sheath shall give the finished cable a practically circular shape.

A non-metallic separator may be applied under the sheath. If a non-metallic separator is applied in a halogen free low smoke cable, it shall be halogen free.

5.3.3 Thickness

The average of the measured values, rounded to 0,1 mm, shall be not less than the specified value for each size shown in Table 1.

The smallest value measured shall not fall below 85 % of the specified value by more than 0,1 mm, i.e.:

$$t_m \geq 0{,}85 t_s - 0{,}1$$

where:

t_m is the minimum sheath thickness at any point in millimetres;

t_s is the specified sheath thickness, in millimetres.

Compliance shall be checked using the test given in 1.10 of IEC 60245-2:1994.

5.3.4 Colour

The sheath shall be coloured black, unless otherwise agreed between manufacturer and customer. The colour shall be throughout the whole of the sheath.

5.4 Multi-core cables and additional elements

Multi-core constructions are allowed provided that all cores are individually sheathed and comply with all requirements set in this document.

Any additional element shall comply with all material requirements set in this document.

6 Marking

6.1 General

The sheath of the cable shall be marked by printing, embossing or indenting.

6.2 Indication of origin

Cables shall be provided with an identification of origin consisting of the continuous marking of the manufacturer's name or trademark, or (if legally protected) identification number.

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6.3 Code marking

The cables with halogen free insulation and sheath shall be marked 62930 IEC 131 for cables with conductor Class 5 and 62930 IEC 132 for cables with conductor Class 2.

Cables with insulation and/or sheath that may contain halogens shall be marked 62930 IEC 133 for cables with Class 5 and 62930 IEC 134 for cables with conductor Class 2.

6.4 Additional marking

Halogen free low smoke cables shall be marked “HALOGEN FREE LOW SMOKE”.

6.5 Nominal cross-sectional area of conductor

Cables shall be marked with the nominal cross-sectional area, for example ‘2,5 mm^2’.

6.6 Continuity of marking

Each specified marking shall be regarded as continuous if the distance between the end of the mark and the beginning of the next identical mark does not exceed 550 mm.

NOTE 1 A 'specified marking' is any mandatory marking covered by this document.

NOTE 2 Other marking, such as that required under recognized voluntary third party approval schemes, can also follow the requirements of 6.6.

Figure 1 shows an example of the marking as used on the outer sheath of the cable.

Dimensions in millimetres

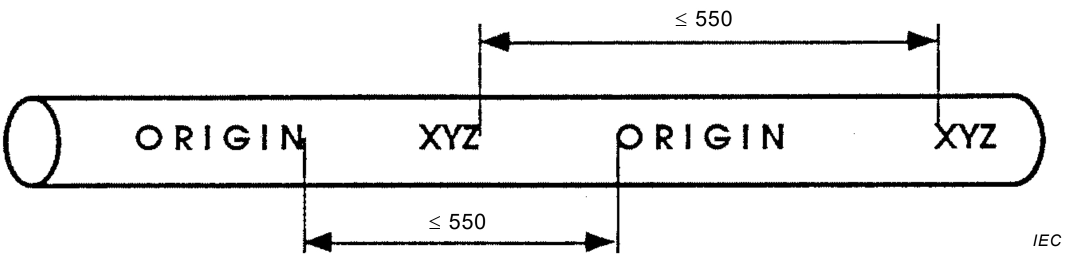

Figure 1 – Example of marking as used on the outer sheath of the cable

6.7 Additional requirements

6.7.1 Durability

Printed markings shall be durable. Compliance with this requirement shall be checked by the test given in 1.8 of IEC 60245-2:1994.

6.7.2 Legibility

All markings shall be legible.

7 Requirements for completed cables

7.1 General

The tests to be carried out on cables specified in this document shall be as scheduled in Table 3, which refers to the relevant clauses of the standard specifying the requirements and test methods as well as the category of each test which applies, i.e. type test (T); sample test (S) or routine test (R) (as defined in Clause 3).

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Requirements for tests not previously specified are as given in 7.2 to 7.3.

7.2 Electrical tests - check for absence of faults on the insulation or on the complete cable

The cable shall be tested during manufacturing for faults in accordance with IEC 62230. In case checking of the insulation only is impossible, testing shall be performed on the complete cable.

No fault shall be detected.

7.3 Non electrical tests - overall diameters and ovality

Informative values on maximum overall diameters of the cables are given in Table 1 and Table 2. Ovality of the cables shall be limited: the difference between any two values of the overall diameter of a sheathed cable at the same cross-section shall not exceed 15 % of the upper limit given for the overall diameter in Table 1 and Table 2.

Table 1 – Dimensional and insulation resistance values for class 5 conductor cables

Nominal cross sectional area of conductor	Thickness of insulation Specified value	Thickness of sheath Specified value	Mean overall diameter Upper value [a] Class 5	Minimum insulation resistance at 20 °C	Minimum insulation resistance at 90 °C
mm^2	mm	mm	mm	MΩ·km	MΩ·km
1,5	0,7	0,8	5,4	1 050	1,05
2,5	0,7	0,8	5,9	862	0,862
4	0,7	0,8	6,6	709	0,709
6	0,7	0,8	7,2	610	0,610
10	0,7	0,8	8,3	489	0,489
16	0,7	0,9	9,8	393	0,393
25	0,9	1,0	12,2	395	0,395
35	0,9	1,1	14,0	335	0,335
50	1,0	1,2	16,3	314	0,314
70	1,1	1,2	18,7	291	0,291
95	1,1	1,3	20,8	258	0,258
120	1,2	1,3	23,0	249	0,249
150	1,4	1,4	25,7	260	0,260
185	1,6	1,6	28,7	268	0,268
240	1,7	1,7	32,3	249	0,249
300	1,8	1,8	35,6	237	0,237
400	2,0	2,0	40,6	230	0,230

[a] Indicative values, for information only.

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Table 2 – Dimensional and insulation resistance values for class 2 conductor cables

Nominal cross sectional area of conductor	Thickness of insulation Specified value	Thickness of sheath Specified value	Mean overall diameter Upper value [a] Class 2	Minimum insulation resistance at 20 °C	Minimum insulation resistance at 90 °C
mm^2	mm	mm	mm	MΩ·km	MΩ·km
16	0,7	0,9	9,5	374	0,374
25	0,9	1,0	11,8	384	0,384
35	0,9	1,1	13,2	327	0,327
50	1,0	1,2	15,1	317	0,317
70	1,1	1,2	17,3	291	0,291
95	1,1	1,3	19,6	251	0,251
120	1,2	1,3	21,6	244	0,244
150	1,4	1,4	24,0	254	0,254
185	1,6	1,6	27,0	261	0,261
240	1,7	1,7	30,4	243	0,243
300	1,8	1,8	33,5	231	0,231
400	2,0	2,0	37,7	227	0,227

[a] Indicative values, for information only.

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Table 3 – Tests for cables to IEC 62930

Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
1	Electrical tests					
1.1	Measurement of the resistance of conductor		60228:2004	Annex A		T, S
1.1.1	Values to be obtained max.	Ω/km			IEC 60228	
1.2	Voltage test on completed cable with AC or DC		60245-2:1994	2.2		T, S
1.2.1	Test conditions:					
	- minimum length of the sample	m			20	
	- minimum period of immersion in water	h			1	
	- temperature of the water	°C			20 ± 5	
1.2.2	Voltage applied (AC) or	kV			6,5	
	Voltage applied (DC)	kV			15	
1.2.3	Duration of application of voltage, min.	min			5	
1.2.4	Result to be obtained				No breakdown	
1.3	Check for absence of faults on the insulation (or on completed cable)		62230			R
1.3.1	Result to be obtained				No fault shall be detected	
1.4	Measurement of insulation resistance		60227-2:1997	2.4		
1.4.1	Cables at 20 °C					T, S
1.4.1.1	Test conditions:					
	- length of sample	m			5	
	- minimum period of immersion in water	h			2	
	- temperature of the water	°C			20 ± 2	
1.4.1.2	Values to be obtained	MΩ·km			Min. as stated in Table 1	
1.4.2	Cables at 90 °C		60227-2:1997	2.4		T
1.4.2.1	Test conditions:					
	- length of sample	m			5	
	- minimum period of immersion in hot water	h			2	
	- temperature of the water	°C			90 ± 2	
1.4.2.2	Values to be obtained	MΩ·km			Min. as stated in Table 1	

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Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
1.5	Long term resistance of insulation to DC		62821-2:2015	5.1.1		T
1.5.1	Test conditions:					
	- length of sample	m			5	
	- duration of test	h			240	
	- water temperature	°C			85 ± 5	
	- DC voltage applied	kV			1,8	
1.5.2	Result to be obtained [c]				No breakdown and no signs of damage	
1.6	Surface resistance of sheath		62821-2:2015	5.1.3		T
1.6.1	Test conditions:					
	- voltage applied, DC	V			100 to 500	
	- duration of test	min			1	
1.6.2	Values to be obtained	Ω			$\geq 1{,}0 \times 10^9$	
2	Constructional and dimensional tests					
2.1	Conductor					T
2.1.1	Construction of conductor				IEC 60228	
2.1.2	Checking continuity of tin		62930:–	5.1.1	No visible gaps	
2.2	Insulation					T, S
2.2.1	Insulation thickness	mm	60245-2:1994	1.9	Not less than stated in 5.2.3 of IEC 62930:–	
2.3	Sheath					T, S
2.3.1	Sheath thickness	mm	60245-2:1994	1.10	Not less than stated in 5.3.3 of IEC 62930:–	
2.4	Ovality					T, S
2.4.1	Ovality value	%	60245-2:1994	1.11	As stated in 7.3.1 of IEC 62930:–	
2.5	Sheath colour					T, S
2.5.1	Visual examination				5.3.4 of IEC 62930:–	
2.6	Sheath marking					T, S
2.6.1	Visual examination and measurement				Clause 6 of IEC 62930:–	

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Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
3	Insulation material				Table B.1 of IEC 62930:–	T
4	Sheath material				Table B.1 of IEC 62930:–	T
5	Compatibility test		60811-401:2012	4.2.3.4		T
5.1	Test conditions:					
	- duration of test	h			168	
	- temperature	°C			135 ± 2	
5.2	Result to be obtained				Table B.1 of IEC 62930:–	
6	Cold impact test		60811-506			T
6.1	Test conditions				Annex C of IEC 62930:–	
6.2	Results to be obtained				No cracks	
7	Ozone resistance on complete cable		60811-403			T
7.1	- temperature	°C			25 ± 2	
	- duration	h			24	
	- Ozone concentration (by volume)	%			(250 to 300) × 10^{-4}	
7.2	Result to be obtained [b]				No cracks	
8	Weathering/UV resistance on sheath		62930:–	Annex E		T
8.1	Test conditions				Annex E of IEC 62930:–	
8.2	Result to be obtained				Annex E of IEC 62930:–	
9	Dynamic penetration test		62930:–	Annex D		T
9.1	Test conditions				Annex D of IEC 62930:–	
9.2	Result to be obtained				Annex D of IEC 62930:–	
10	Damp heat test		60068-2-78			T
10.1	Test conditions:					
	- temperature	°C			90 ± 2	
	- duration	h			1 000	
	- relative humidity min.	%			85	
	- reconditioning period	h			16 to 24	
10.2	Results to be obtained on the sheath:					
	- for tensile strength, variation maximum	%			−30[a]	
	- for elongation at break, variation maximum	%			−30[a]	

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Ref No.	Test	Unit	Test method described in		Requirements	Category of test
			IEC	Clause		
11	Shrinkage test on sheath		60811-503			T
11.1	Test conditions:					
	- temperature	°C			120 ± 2	
	- duration of each cycle	h			1	
	- length of sample	mm			300	
11.2	Results to be obtained:					
	- maximum shrinkage	%			2	
12	Test for vertical flame propagation on complete cable		60332-1-2			T
12.1	Result to be obtained				Annex A of IEC 60332-1-2:2004	
13	Smoke emission of complete cable [d]		61034-2			T
13.1	Result to be obtained					
	- light transmittance, min.	%	61034-2		60	
14	Assessment of halogens for all non-metallic materials [d]		62821-1:2015	Annex B		T
14.1	Result to be obtained				Annex B of IEC 62821-1:2015	

[a] No positive value of variation defined.

[b] Any cracks near the fixing point on the mandrel and/or near the clamps when using test strips shall be disregarded.

[c] Discoloration of the insulation should be ignored.

[d] For halogen free low smoke cables only.

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Annex A
(normative)

Guide to use

A.1 Use of cables for PV systems

General guidance information given in IEC 62440 shall be used. In addition, the following information and those from Table A.1, Table A.2 and Table A.3 shall be taken into account for the products specified in this document.

The DC voltage rating of the cables is 1,5 kV, both between conductors as well as between conductors and earth. The maximum permitted operating DC voltage of the systems, in which the cables specified in this document are applied, shall not exceed 1,8 kV.

The AC voltage rating of the specified cables is 1/1 kV (U_0/U). The rated voltage in an AC system is expressed by the combination of two values U_0/U, expressed in (kilo)volts, where:

– U_0 is the r.m.s. value between any insulated conductor and earth;

– U is the r.m.s. value between any two phases.

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Table A.1 – Intended use of cables for PV systems (environmental conditions)

Shape of cable	Round
Conductor construction	Class 5 or Class 2
1 Duty [a]	
1.1 Heavy	+
2 Presence of water	
2.1 Condition AD 7 [b]	+
3 Corrosive or polluting substances	
3.1 Condition AF 3 [b]	+
4 Impact	
4.1 Condition AG 2 [b]	+
5 Vibrations	
5.1 Condition AH 3 [b]	Class 5 + Class 2 –
6 Flora	
6.1 Condition AK 2 [b]	–
7 Fauna	
7.1 Condition AL 2 [b]	–
8 Outdoor use	
8.1 Condition AN 3 [b]	+
8.2 Permanent [c]	+
9 Frequent flexing	–
10 Frequent torsion	–
"+" = acceptable "–" = not suitable	
[a] See Annex C of IEC 62440:2008 for definitions.	
[b] See Annex A of IEC 62440:2008 for definitions.	
[c] See Annex B of IEC 62440:2008 for definitions.	

Table A.2 – Recommended use of cables for PV systems

Construction	Recommended use	Comments
Cables for PV systems	Intended for use in PV installations e.g. according to IEC 60364-7-712. They are intended for permanent use outdoor and indoor. Cables with class 5 conductors are suitable for free movable, free hanging and fixed installation while class 2 conductors are limited to fixed installations where no flexing e.g. engagement or disengagement of the connector is expected. It is also permitted to install the cables in conduit or trunking systems. They are not intended for direct burial. Halogen free low smoke cables are intended to reduce the risks for people and goods in the event of fire, for example in buildings. Suitable for the application in/at equipment with protective insulation (protection class II). They are inherently short-circuit and earth fault proof according to IEC 60364-5-52.	For recommended bending radii see Table 3 of IEC 62440:2008. Max. storage temperature: +45 °C Min. temperature for installation and handling: −25 °C

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Table A.3 – Current carrying capacity of PV cables

Nominal cross sectional area of conductor	Current carrying capacity according to method of installation		
	Single cable free in air	Single cable on a surface	Two loaded cables touching, on a surface
mm^2	A	A	A
1,5	31	30	24
2,5	42	40	33
4	57	54	45
6	72	69	58
10	98	96	80
16	132	130	107
25	183	174	138
35	227	215	171
50	287	273	209
70	361	344	269
95	433	411	328
120	508	483	382
150	590	560	441
185	671	638	506
240	808	767	599
300	913	866	693
400	1 098	1 041	825
Ambient temperature: 30 °C (see Table A.4 for other ambient temperatures).			
Maximum conductor temperature: 90 °C.			

Table A.4 – Current rating conversion factors for different ambient temperatures

Ambient temperature °C	Conversion factor
0	1,22
10	1,15
20	1,08
30	1,00
40	0,91
50	0,82
60	0,71
70	0,58

A.2 Groups

For installation in groups, the reduction factors for current rating according to IEC 60364-5-52 shall apply.

A.3 Short-circuit-temperature

The permitted short-circuit-temperature is 250 °C for a maximum period of 5 s.

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Annex B
(normative)

Requirements for insulation and sheathing materials

Table B.1 – Requirements for insulation and sheathing materials

Ref no.	Tests	Unit	Test method standard	Type of compound	
				insulation	sheath
1	**Mechanical characteristics** [e]				
1.1	Properties before ageing [c]		IEC 60811-501		
1.1.1	Values to be obtained for tensile strength				
	- median, min.	N/mm^2		8,0	8,0
1.1.2	Values to be obtained for the elongation at break				
	- median, min.	%		125	125
1.2	Properties after ageing in oven		IEC 60811-401		
1.2.1	Test conditions: [c]				
	- temperature	°C		150 ± 2	150 ± 2
	- duration of treatment	h		7 × 24	7 × 24
1.2.2	Values to be obtained for tensile strength				
	- variation, maximum	%		−30[a]	−30[a]
1.2.3	Values to be obtained for the elongation at break				
	- variation, maximum	%		−30[a]	−30[a]
1.3	Hot set test [c]		IEC 60811-507		
1.3.1	Test conditions:				
	- temperature	°C		200 ± 3	200 ± 3
	- time under load	min		15	15
	- mechanical stress	N/cm^2		20	20
1.3.2	Values to be obtained				
	- elongation under load, max.	%		100	100
	- permanent elongation after cooling, max.	%		25	25
1.4	Thermal endurance		IEC 60216-1 and IEC 60216-2		
1.4.1	Test conditions: [c]				
	Elongation at break shall be performed.				
	- temperature index corresponding to 20 000 h			≥ 120	≥ 120
	- elongation at break, min.	%		50	50

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Ref no.	Tests	Unit	Test method standard	Type of compound	
				insulation	sheath
1.5	Bending at low temperature		IEC 60811-504		
	Insulated conductor/cable overall diameter ≤ 12,5 mm				
1.5.1	Test conditions:				
	- temperature	°C		−40 ± 2	−40 ± 2
	- duration	h		b	b
1.5.2	Results to be obtained:			No cracks	No cracks
1.6	Elongation at low temperature		IEC 60811-505		
	Insulated conductor/cable overall diameter > 12,5 mm				
1.6.1	Test conditions: [c]				
	- temperature	°C		−40 ± 2	−40 ± 2
	- duration	h		b	b
1.6.2	Values to be obtained:				
	- elongation at break, min.	%		30	30
1.7	Sheath resistance against acid and alkaline solution		IEC 60811-404		
1.7.1	Test conditions [d]				
	- acid solution: N-Oxalic acid				
	- alkaline solution: N-Sodium hydroxide				
	- temperature	°C			23 ± 2
	- duration of treatment	h			7 × 24
1.7.2	Values to be obtained for tensile strength				
	- variation, maximum	%			±30
1.7.3	Values to be obtained for the elongation at break, min.	%			100
1.8	Compatibility test		4.2.3.4 of IEC 60811-401:2012		
1.8.1	Test conditions:				
	- temperature	°C		135 ± 2	135 ± 2
	- duration of treatment	h		7 × 24	7 × 24
1.8.2	Values to be obtained for tensile strength				
	- variation, maximum	%		±30	−30[a]
1.8.3	Values to be obtained for the elongation at break				
	- variation, maximum	%		±30	−30[a]

[a] No positive value for variation defined.

[b] See test method in column 4.

[c] This test shall be performed on test samples of insulation and sheath compound obtained from completed cables.

[d] N means 1 Normal concentration.

[e] If the insulation and sheath stick together and it is not possible to prepare separated specimens for insulation and sheath according to IEC 60811-501, the tubular test piece shall be tested and the results applied to both insulation and/or sheath as required.

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Annex C
(normative)

Cold impact test

The cold impact test shall be performed at −40 °C according to IEC 60811-506, but the mass of hammer, the mass of steel intermediate piece and height shall comply with Table C.1.

Table C.1 – Parameters for cold impact test

Cable diameter, D mm	**Mass of hammer** g	**Mass of steel intermediate piece** g	**Height** mm
$D \leq 15$	1 000	200	100
$15 < D \leq 25$	1 500	200	150
$D > 25$	2 000	200	200

The cable shall be inspected with normal or corrective vision without magnification. No cracks shall be determined.

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Annex D
(normative)

Dynamic penetration test

A test apparatus suitable for pull testing (or an equivalent apparatus) shall be operated in pressure modus and shall be equipped with a measuring device which is able to record the force of penetration of the spring-steel-needle through the insulation or sheath of a completed cable (see Figure D.1). A circuit with low voltage, which is interrupted at the moment when the needle penetrates the sheath and the insulation and makes contact with the conductor, shall be added.

The test shall be performed at room temperature. The force applying to the needle shall be increased continuously with 1 N/s until contact with the conductor has been made. Four tests on each sample shall be performed and the force at the moment of contact shall be recorded. After each test, the sample shall be moved forward and shall be turned clockwise for 90°.

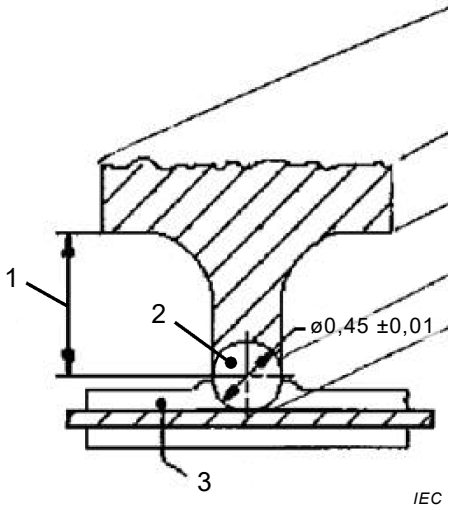
The mean value of the four test results shall not be less than the minimum value F in newtons determined with the following formula:

$$F = 150 \sqrt{d_L}$$

where

d_L is the diameter of conductor according to IEC 60719, in mm.

Dimensions in millimetres



Key

1 shoulder with sufficient depth for testing the insulation

2 needle of spring steel

3 sample

Figure D.1 – Arrangement for dynamic penetration test

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Annex E
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Weathering/UV resistance test

This test is to determine the UV stability of the sheathing material of the cable in the condition as manufactured. This is done by means of measuring tensile strength and elongation at break in the condition as manufactured and after exposure to ultraviolet light and water.

The testing apparatus is equipped with the following:

– a ray source consisting of a xenon arc lamp with borosilicate filters so that the typical irradiance should be 60 W/m^2 ± 15 % with a spectrum between 300 nm and 400 nm;

– a means to provide automatic control of temperature, humidity and cycles;

– a generator of deionized water with a conductivity not greater than 5 µS/cm; the rate of flow should be sufficient to guarantee that all the test specimens can be washed.

– a means to control the irradiance.

A sample of the finished cable shall be selected to prepare 10 test pieces in accordance with IEC 60811-501.

Five test pieces shall be exposed to the treatment for 720 h in 360 cycles of 120 min defined as follows:

a) 102 min of dry radiation exposure at a temperature of (60 ± 3) °C and relative humidity of (50 ± 10) %, followed by

b) 18 min of rain exposure, without radiation, at a temperature of (50 ± 3) °C without control of the relative humidity.

NOTE Additional information on weathering/UV resistance testing can be found in ISO 4892-1 and ISO 4892-2.

After the exposure, the test specimens shall be removed from the equipment and conditioned at ambient temperature for at least 16 h.

The five exposed test pieces and the five not exposed test pieces shall be tested separately and in close succession for tensile strength and elongation at break. The respective median values shall be calculated from the five tensile-strength and elongation at break values obtained for the conditioned test pieces and shall be divided by the median values of the five tensile-strength and elongation at break values obtained for the unconditioned test pieces.

The tensile-strength and elongation at break after 720 h (360 cycles) of exposure shall be at least 70 % of the values measured on not exposed test pieces.

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ISO 4892-2 , *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

3, rue de Varembé
PO Box 131
CH-1211 Geneva 20
Switzerland

Tel: + 41 22 919 02 11
Fax: + 41 22 919 03 00
info@iec.ch
www.iec.ch

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