Specification for 2 PfG 2642/11.17 Requirements for aluminium cables for fixed installation in ground for photovoltaic-systems

Contents

Foreword

This test specification contents requirements evaluated by TUV Rheinland for non-flexible cables having a solid or stranded aluminium conductor for fixed installations in PV-systems.

Caused by market need to save installation cost more and more aluminium cables are installed for fixed installation so they have been considered in this standard

The test standard was created based on IEC 62930 which covers flexible cables having a copper conductor for DC-voltages up to 1500 V.

For aluminium conductors special requirements for termination are to be considered. So only suitable terminals specified for aluminium conductors shall be used. Requirements for such terminals are not part of this standard.

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.

1 Scope

2 PfG 2642/11.17 applies to single-core cables (wires) having a solid or stranded aluminium conductor for fixed installations in PV-systems with a rated voltage up to and including U_0 DC 1,5 kV.

The cables are suitable for use in class II equipment as defined in IEC 61140.

The requirements for the conductor have to be those of classes 1 or 2according to IEC 60228. For other types of conductors (e.g. flexible aluminium conductors not covered by IEC 60228) this standard can be used as a guideline.

This specification covers cables having aluminium conductors and for installation in ground. A guide to use can be found in annex A.

Cables according to this specification are not intended to be installed in or on buildings. Requirements for cables having aluminium conductors for installation not in ground have to comply with another standard (currently under development)

The cables are intended to operate at several continues ambient temperatures, depending on installation method.

This standard includes halogen-free low smoke cables and cables that may contain halogens.

2 Normative references

The following referenced documents are indispensable for the application 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 60364-5-52*, Erection of low voltage installations –Part 5: Selection and erection of electrical equipment –Chapter 52: Wiring systems*

EN 50267-2-1, *Common test methods for cables under fire conditions – Tests on gases evolved during combustion of materials from cables – Part 2-1: Procedures – Determination of the amount of halogen acid gas;*

EN 50267-2-2, *Common test methods for cables under fire conditions – Tests on gases evolved during combustion of materials from cables – Part 2-2: Procedures – Determination of degree of acidity of gases for materials by measuring pH and conductivity;*

EN 50305, *Railway applications – Railway rolling stock cables having special fire performance – Test methods*

EN 50395, *Electrical test methods for low voltage energy cables;*

EN 50396, *Non-electrical test methods for low voltage energy cables;*

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

EN 60216-1*, Electrical insulating materials - Properties of thermal endurance - Part 1: Ageing procedures and evaluation of test results (IEC 60216-1);*

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

EN 60228, *Conductor of insulated cables (IEC 60228)*

EN 60332-1-2, *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)*

EN 60684-2, *Flexible insulating sleeving – Part 2: Methods of test (IEC 60684-2)*

EN 60811-1-1, *Insulating and sheathing materials of electric cables – Common test methods Part 1-1: General application – Measurement of thickness and overall dimensions – Test for determining the mechanical properties (IEC 60811-1-1)*

EN 60811-1-2*, Insulating and sheathing materials of electric and optical cables – Common test methods. Part 1-2: General application. Thermal ageing methods (IEC 60811-1-2)*

EN 60811-1-3*, Insulating and sheathing material of electric and optical cables – Common test methods – Part 1-3: General application – Methods for determining the density – Water absorption tests – Shrinkage test (IEC 60811-1-3)*

EN 60811-1-4*, Insulating and sheathing materials of electric and optical cables – Common test methods. Part 1-4: General application. Tests at low temperature. (IEC 60811-1-4)*

EN 60811-2-1, *Insulating and sheathing materials of electric and optical cables – Common test methods – Part 2-1: Methods specific to elastomeric compounds – Ozone resistance, hot set and mineral oil immersion tests (IEC 60811-2-1)*

EN 60811-3-1*, Insulating and sheathing materials of electric cables – Common test methods Part 3-1: Methods specific to PVC compounds – Pressure test at high temperature, test for resistance to cracking (IEC 60811-3-1)*

EN 50525-3-21, *Rubber insulated cables of rated voltages up to and including 450/750 V Part 13: Single and multicore flexible cables, insulated and sheathed with crosslinked polymer and having low emission of smoke and corrosive gases;*

HD 605*, Power cables – Part 605: Additional test methods*

HD 60364-5-52, *Erection of low voltage installations –Part 5: Selection and erection of electrical equipment –Chapter 52: Wiring systems (IEC 60364-5-52, modified)*

HD 60364-7-712 *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems (IEC 60364-7-712, modified)*

3 Terms and definitions

For the purposes of this document, following definitions apply.

3.1
Type test (symbol T)
Tests required to be made before supplying a type of cable covered by this standard on a general commercial basis, in order to demonstrate satisfactory performance characteristics to meet the intended application.

NOTE: These 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 or design or manufacturing process which might change the performance characteristics.

3.2
sample tests (symbol S)
Tests made on samples of completed cable or components taken from a completed cable, at a specified frequency, so as to verify that the finished product meets the specified requirements.

3.3
Routine tests (symbol R)
Tests made by the manufacturer on each manufactured length of cable to check that each length meets the specified requirements

3.4 halogen free material
material complying with the requirements of IEC 62821-1, Annex B

4 Rated voltage

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

5 Requirements for the construction of cables

5.1 General

The cable shall exist of a conductor (class 1 or class 2), of an insulation layer, and of an outer sheath. In case of direct burial installation an inner sheath and protection layer against migration of humidity are required, the insulation and inner sheath can be combined as reinforced insulation.

In any case the maximum temperature at conductor is 90 °C

A temperature index of 90°C applies to the insulation and the sheath, based on EN 60216-1 (20.000h).

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

Cables for direct buried installations shall have a metal barrier as protection against migration of humidity

5.2 Conductors

5.2.1 Material

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

The single aluminium wires can be copper-cladded.

5.2.2 Construction

The class of the conductor shall be Class 2 or Class 1 in accordance with IEC 60228.

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

5.2.3 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.

5.2.4 Check of construction

Compliance with the requirements of 5.2.1, 5.2.2 and 5.2.3, including the requirements of IEC 60228, shall be checked by inspection and by measurement.

5.3 Insulation

5.3.1 Material

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

5.3.2 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 or to the conductor. 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.

Compliance shall be checked by inspection and by manual test.

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 90 % of the specified value by more than 0,1 mm, i.e.:

$t_m > 0{,}9t_s - 0{,}1$
where:
t_m is the minimum insulation thickness at any point in millimeters t_s is the specified insulation thickness, in millimeters

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

5.4 Sheath

Cables for direct burying covered in this standard shall have a metallic layer for humidity protection and as screen. This requires an insulation and inner sheath below the metallic layer. Therefore this specification differs between inner (below the metallic layer) and outer (over the metallic layer) sheath. For cables without metallic layer, e.g. in case that the cable is installed in metallic cable ducts, only requirements of 5.4.2 are applicable.
An optional bedding is not considered as a part of insulation.

5.4.1 Inner sheath (only applicable for cables with metallic humidity protection)

5.4.1.1 Material

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

5.4.1.2 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.

5.4.1.3 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.:

$t_m > 0{,}85t_s - 0{,}1$
where:
t_m is the minimum sheath thickness at any point in millimeters
t_s is the specified sheath thickness, in millimeters

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

5.4.2 Outer sheath see page 9, 5.5

5.4.2.1 Material

The sheath material shall be a cross-linked compound (in case that the cable has got an crosslinked inner sheath below metallic layer the outer sheath need not to be mandatorily crosslinked) and fulfil the requirements as specified in Table B.1 in Annex B. Cross-linked material is not required over an existing metallic layer.

5.4.2.2 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.

5.4.2.3 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 85 % of the specified value by more than 0,1 mm, i.e.:

$t_m > 0{,}85t_s - 0{,}1$

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.

5.4.2.4 Color

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

5.4.3 Humidity protection

The humidity protection barrier shall consist of a single layer of metallic tape. The tensile strength of aluminium shall be not less than 50 N/mm2.

The metal barrier shall be self-contained as humidity protection.

The manufacturer shall, where necessary, apply a suitable binder tape over the metallic layer.

The layer of the humidity barrier shall have a min. thickness of 0,3 – 0,01mm.

NOTE: The mentioned humidity barrier can be considered as rodent protection.and as basic mechanical protection.

5.4.4 Bedding

5.4.4.1 General

The bedding shall consist of an extruded layer of polymeric material compatible with the operating temperature of the cable. When tested in accordance with EN 60811-501 it shall have a tensile strength of not less than 4 N/mm2 and elongation at break not less than 50 %.
It shall be possible to remove the bedding without damaging the insulation. This shall be checked by visual examination.

An optional bedding is not considered as a part of insulation.

5.4.4.2 Thickness of bedding

When measured in accordance with EN 50396, 4.2, the smallest value, tm, of the radial thickness of bedding shall not fall below 80% of the relevant nominal value given in Table 1, as applicable, by more than 0.2 mm, i.e.:

$tm \geq 0.8\ tn - 0.2$
where:

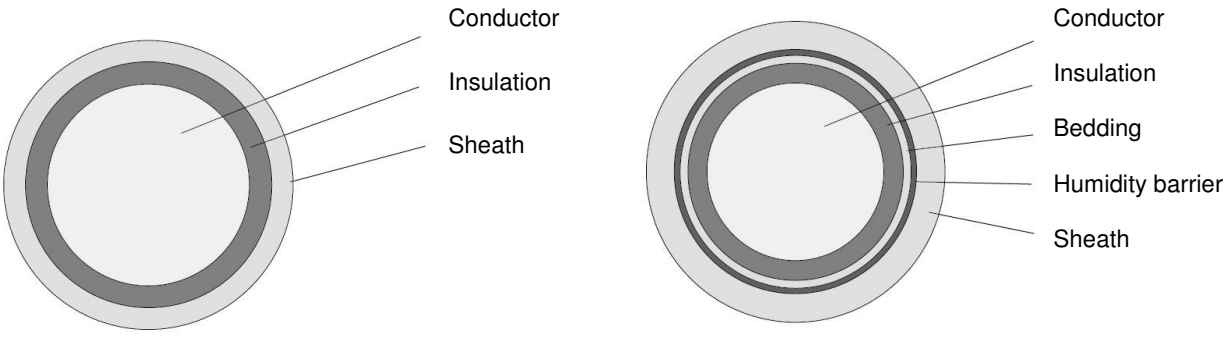
tm is the smallest value measured, in millimetres (mm);
tn is the nominal thickness, given in Table 1, in millimetres (mm).

5.4.5 Additional Elements

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

5.5 Overall diameters and ovality

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 %.



Without humidty protection layer

With humidity protection layer

Figure 1: Construction

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.

6.3 Nominal cross-sectional area of conductor

Cables shall be marked with the nominal cross-sectional area, for example ‘25 mm²’.

6.4 Code designation

PV1500DC-AL

6.5 Additional Marking

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

Direct burial cables shall be marked with “DB”

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 standard.
NOTE 2 Other marking, such as that required under recognized voluntary 3rd party approval schemes, may also follow the requirements of this subclause.

The diagram below shows an example of the marking as used on the outer sheath of the cable.

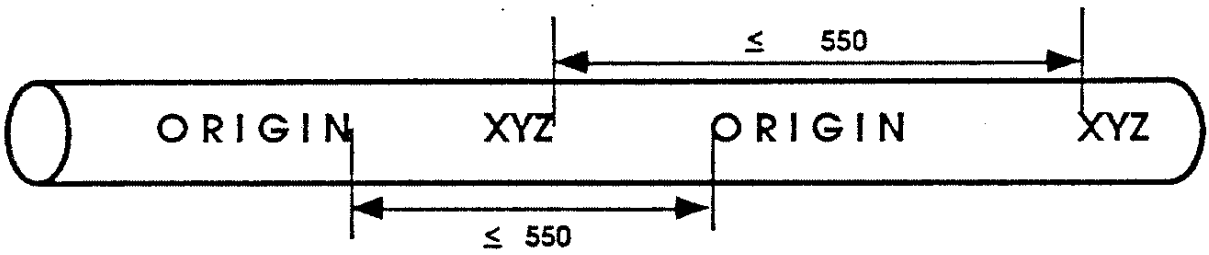


Figure 2 - Example of the marking as used on the outer sheath of the cable

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.

6.7.2 Legibility

All markings shall be legible.

7 Requirements for complete cables

7.1 General

The tests to be carried out on cables specified in this standard shall be as scheduled in Table 2, 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).

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

7.2 Electrical tests

7.2.1 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, following maximum voltages:

AC 15kV
DC 25kV
HF 16kV (>3 kHz)

In case checking of the insulation only is impossible, testing shall be performed on the complete cable in case of no humidity barrier. Cables having a metallic humidity barrier shall be tested before application of the metallic layer.

No fault shall be detected.

7.3 Non electrical tests

7.3.1 Dimensions

Following values, given in Tab, 1 are applicable.

Table 1: Dimensional and insulation resistance values for class aluminium conductor cables

1	2	3	4	5	6
Nominal cross-sectional area of conductors **mm²**	**Thickness of insulation or inner sheath specified value** **mm**	**Thickness of sheath specified value** **mm**	**Thickness of bedding specified value** **mm**	**Minimum insulation resistance at 20°C** **MΩ x km**	**Minimum insulation resistance at 90°C** **MΩ x km**
10	0,8	0,8	0,8	489	0,489
16	0,9	0,9	0,8	395	0,395
25	1,0	1,0	0,8	393	0,393
35	1,1	1,1	0,8	335	0,335
50	1,2	1,2	0,8	314	0,314
70	1,2	1,2	0.8	291	0,291
95	1,3	1,3	0,8	258	0,258
120	1,3	1,3	0,8	249	0,249
150	1,4	1,4	1,0	268	0,268
185	1,6	1,6	1,0	260	0,260
240	1,7	1,7	1,0	249	0,249
300	1,8	1,8	1,0	237	0,237
400	2,0	2,0	1,2	230	0,230

Table 2 – Tests for Aluminium PV-cable

1	2	3	3	4	5	6
Ref. No.	Test	Units	Requirements	Category of test	Test method described in	
					standard	clause
1	**Electrical tests**					
1.1	Resistance of conductors			T,S	IEC 60228	Annex A
1.2	Voltage test on completed cable with AC or DC			T,S	IEC 60245-2	2.2
1.2.1	Conditions Length of sample Temperature of the water Min. period of immersion in water	 m °C h	 20 20 ± 5 1			
1.2.2	Voltage applied AC or Voltage applied DC	kV kV	6,5 15			
1.2.3	Duration of application of voltage	min	5			
1.2.4	Result to be obtained:		No breakdown			
1.3	Check for absence of faults on insulation (or on complete cable) kV	see 7.2.1		R	IEC 62230	10
1.3.1	Voltage applied AC HF OR DC					
1.3.2	Result to be obtained:		No fault shall be detected			
1.4	Measurements of insulation resistance					
1.4.1	Cables at 20°C			T		
1.4.1.1	Test conditions length of cable Min. period of immersion in water temperature of the water	 m h °C	 5 2h 20 ± 2		IEC 60245-2	2.4
1.4.1.2	values to be obtained	MΩ x km	minimum as stated in table 1			
1.4.2	Cables at 90°C			T	IEC 60245-2	2.4
1.4.2.1	Test conditions length of cable Min. period of immersion in water temperature of the water	 m h °C	 5 2h 90 ± 2			
1.4.2.2	values to be obtained	MΩ x km	minimum as stated in table 1			
1.5	Long term resistance of insulation to d.c. on completed cables without metallic layer and on cables with metallic layer and outer sheath			T	IEC 62821-2	5.1.1
1.5.1	Test conditions: length of sample Duration of tests temperature of the water DC-voltage applied	 m h °C kV	 5 240 85± 5 1,8			
1.5.2	Result to be obtained:		No breakdown and no signs of damage			

1	2	3	3	4	5	6
Ref. No.	**Test**	**Units**	**Requirements**	**Category of test**	**Test method described in**	
					standard	**clause**
2	**Constructional and dimensional tests**					
2.1	Checking of compliance with constructional provisions			T,S		Inspection and manual tests
2.2	Measurement of insulation thickness a	mm	see 5.3.3	T,S	EN 50396	4.1
2.2.1	Measurement of thickness of inner sheath	mm	see 5.4.1.3			
2.2.2	Measurement of bedding thickness	mm	see 5.4.4.2			
2.3	Measurement of sheath thickness	mm	see 5.4.2.3	T,S	EN 50396	4.2
2.4	Measurement of metallic layer thickness	mm	see 5.4.3			
2.5	Measurement of overall dimensions					
2.5.1	– Mean value r	mm	see 5.5	T,S	EN 50396	4.4
2.5.2	– Ovality	%	≤ 15	T,S	EN 50396	4.4
3	**Damp heat test** . on completed cables without metallic layer			T	EN 60068-2-78	
3.1	Test conditions:					
	– temperature	°C	90			
	– duration	h	1000			
	– relative humidity min. %	%	85			
3.2	Results to be obtained:					
	– variation of tensile strength max.	%	– 30			
	– variation of elongation at break max.	%	– 30			
4	**Compatibility test**[a]			T		60811-401
4.1	Test conditions:					
	– temperature	°C	105 ± 2			
	– duration of test	h	168			
4.2	Results to be obtained		As stated in table 3 of this standard			
5	**Cold impact test**			T	EN 60811-1-4	8.5
5.1	Test conditions:					
	– temperature	°C	–40 ± 2			
	– duration of conditioning	h	5			
	– mass of hammer		See Annex E			
	– mass of gauge		See Annex E			
	– height		See Annex E			
5.2	Results to be obtained:					
	– visual check		Absence of cracks			
	– Voltage test					Table 2, 1.2

1	2	3	3	4	5	6
Ref. No.	**Test**	**Units**	**Requirements**	**Category of test**	**Test method described in**	
					standard	**clause**
6	Ozone resistance on completed cables without metallic layer and on cables with metallic layer and outer sheath			T		
6.1	Method B				EN 50396	8.1.3
	– temperature	°C	40 ± 2			
	– relative humidity	%	55 ± 5			
	– duration	h	72			
	– Ozone concentration(by volume)	%	(200 ± 50) $\times 10^{-6}$			
6.2	Result to be obtained		.			
	– visual check		Absence of cracks			
	– Voltage test					Table 2, 1.2
7	**Weathering/UV-resistance (only on outer sheath)**			T	EN 50289-4-17	4.1.1
7.1	Conditions:					
	– duration	h	720			
	– temperature during drying (Black-Standard-temperature)	°C	60 ± 3			
	– relative humidity	%	55±10			
	– min. power at wavelength 300-400 nm	W	60 ± (15 %)			
	– duration spraying/drying	Min.	18/102			
	Results to be obtained		.			
	– variation of tensile strength max.	%	30			
	– variation of elongation at break max.	%	30			Table 3, 1.2
8	**Assessment of halogens for all non-metallic materials**			T, S	50525-1	
8.1	Result to be obtained		Comply with requirements of Annex B of EN 50525-1:2011		50525-1	Annex B

[a] This test may be performed on test samples of insulation and sheath compound.

Table 3 – Requirements for insulation (and inner sheath) and sheath compounds

1	2	3	4	5	6	7
Ref. No.	Test	Unit	Test method described in		Type of compound	
			standard	clause	insulation and inner sheath	sheath (only cross-linked compound)
1	**Mechanical characteristics**					
1.1	**Properties before ageing**		EN 60811-1-1	9.2		
1.1.1	Values to be obtained for the tensile strength: [c]					
	– median, min.	N/mm^2			6,5	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**		EN 60811-1-2	8.1		
1.2.1	Ageing conditions:					
	– temperature	°C			120 ± 2	120 ± 2
	– duration of treatment	h			7 × 24	7 × 24
1.2.2	Values to be obtained for the tensile strength:[c]					
	– median, min.	N/mm^2			–	–
	– variation, max.	%			–30[a]	–30[a]
1.2.3	Values to be obtained for the elongation at break:[c]					
	– median, min.	%			–	–
	– variation, max.	%			– 30[a]	– 30[a]
1.3	**Hot set test**		EN 60811-2-1	9		
1.3.1	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.	%	HD 603 S1		175	175
	– permanent elongation after cooling, max.	%			25	25
1.4	**Thermal endurance properties**		EN 60216-2			
1.4.1	Conditions					
	Either test of elongation at break or bending test shall be performed.					
	– Temperature index				90	90
	– elongation at break [c]	%			50	50
1.5	**Sheath-resistance against acid and alkaline solution (also on sheath of cables having a metallic layer)**		EN 60811-2-1	10		
1.5.1	Conditions:					
	Chemical stress:					
	acid: N-Oxal-acid					

	alkaline solution: N-sodium hydroxide solution					
	temperature	°C				23± 3[d]
	duration	h				168[d]
1.5.2	Values to be obtained for tensile strength:					
	– median, min.	N/mm^2				–
	– variation, max.	%				± 30[d]
1.5.3	Values to be obtained for the elongation at break:					
	– median, min.	%				100[d]
	– variation, max.	%				–
1.6	**Compatibility test**		EN 60811-401	4.2.3.4		
1.6.1	Test conditions:					
	– temperature	°C			105 ± 2	105 ± 2
	– duration of treatment	h			7x24	7x24
1.6.2	Values to be obtained for tensile strength					
	– variation, maximum				± 30[d]	- 30[a]
	Values to be obtained for the elongation at break					
	– variation, maximum				± 30	- 30[a]

a No positive value for variation fixed.

b See test method in column 4 and 5.

c This test may be performed at test samples of insulation and sheath compound.

d These values are also applicable for not cross-linked material compounds

8 Guide for use (normative)

General guidance information given in IEC 62440 (Guide to Use for low voltage cables) must be used, excepting the requirement concerning direct burial installation (clause 4.1). Cables according to this standard are intended for use in PV-systems according to IEC 60364-7-712 and IEC 62548. They are intended for fixed installation in ground. They are also intended for installation in conduits and trunkings.

They are suitable for the application in/at equipment with protective insulation (class II)

They are inherently short-circuit and earth fault proof acc. to IEC 60364-5-52.

Only cables with metallic layer as humidity protection are applicable to be direct buried. Cables without metallic layer for humidity protection shall be installed in metallic conduits if intended to be installed in ground.

The metallic layer might be considered as a screen and shall be grounded.

8.1 Use of cables for PV systems

In addition, the following specific information shall be taken into account for the products specified in this standard.
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 standard 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 (k)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

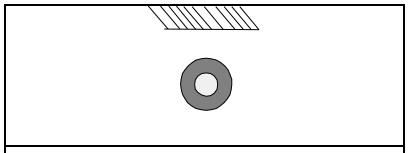
Table 8.1 - Intended use of cables for PV systems (environmental conditions)	
Shape of cable	Round
Conductor construction	Class 1 or Class 2
1 DUTY [a]	
1.4 Heavy	+
2 PRESENCE OF WATER	
2.1 Cables without metal layer: Condition AD 7[b]	+
2.2 Cables with metal layer: Condition AD 8[b]	+
3 CORROSIVE OR 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 1 - Class 2 -
6 FLORA	
6.1 Condition AK 2 [b]	+
7 FAUNA	
7.1 Condition AL 2 [b]	Metallic layer+ -
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 for definitions. b see Annex A of IEC 62440 for definitions. c see Annex B of IEC 62440 for definitions.	

8.2 Current carrying capacity

Ambient temperature: 20°C

Max. temperature at conductor: 90 °C

Table 8.2 – Current carrying capacity of PV-cables



in soil
(max 20°C depth 1m)

Conductor (mm²)	Temp. 90 °C Load Factor 1.00	Temp. 90 °C Load Factor 0.70
1x10	115	125
1x16	150	163
1x25	192	210
1x35	230	253
1x50	271	300
1x70	333	370
1x95	398	444
1x120	454	507
1 x 150	501	558
1 x 185	569	639
1 x 240	660	741
1 x 300	745	844
1 x 400	853	973

Groups

For groups reduction factors according to IEC 60364-5-52, Table A.52-17 shall apply.

Annex A

(normative)

Compatibility test

A.1 Conditions

Test samples must be aged for 7 days at (105 ± 2) °C at conditions according to table 4.

A.2 Requirements

After ageing the insulation and the sheath shall pass the requirements of table A.1.

Table A.1 – Requirements

Tests		units	insulation	sheath
Tensile strength	– median, min.	N/mm^2	–	–
	– variation [a], max.	%	± 30	–30 [b]
Elongation at break	– median, min.	%	–	–
	– variation [a], max.	%	± 30	± 30

[a] Variation: difference between the median value obtained after ageing and the median value obtained without ageing expressed as a percentage of the latter.

[b] Positive tolerances are not limited.

Annex B

(normative)

Test of absence of halogen

B.1 Requirements

Insulation, sheath and separation layers (if applicable) shall pass the requirements as follows:

a) Type test

The material must be tested as described in table B.1.

Table B.1 – Test method, measurement, requirements

	Test method	Measurement	requirements
1	EN 50267-2-2	pH and conductivity	pH ≥ 4,3 und conductivity ≤ 10 µS/mm[a]
2	EN 50267-2-1	Chlorine- and Bromine content, expressed in HCl	≤ 0,5 %
3a	EN 50525-1 Annex C	Halogen: Fluorine	If negative: Stop test. No further test needed. Accept material.
			If positive, do test according to 3b
3b	EN 60684-2	Fluorine content	≤ 0,1 %
a If discrepancies regarding conductivity appear, e.g. the recommended value is exceeded even if there is compliance with the recommended ph-value, other test method may be applied after agreement with all participants.			

b) Sample test

The material shall be tested according to test sequence of Table B.2.

Table B.2 – Sequential test programme

	Test method	Measurement	Value	Result
Stage 0	EN 50525-1, Annex C	Halogen: Fluorine, Chlorine and Bromine		If negative: Stop test. No further testing needed. Accept material.
				If positive continue with stage 1.
Stage 1	EN 50267-2-2	pH	< 4,3	Reject material.
			≥ 4,3	Evaluate conductivity.
		conductivity	≤ 2,5 µS/mm	Accept material. No further testing needed.
		conductivity	> 10 µS/mm	Reject material.
		conductivity	> 2,5 µS/mm but ≤ 10 µS/mm	Test according to EN 50267-2-1
Stage 2	EN 50267-2-1	Chlorine- and Bromine content, expressed in HCl	> 0,5 %	Reject material..
			≤ 0,5 %	Test according to EN 60684-2.
Stage 3	EN 60684-2	Fluorine content	> 0,1 %	Reject material..
			≤ 0,1 %	Accept material..

Annex C

(normative)

Determination of halogens – Elemental analysis

Warning

Owing to its potentially hazardous nature, the fusion operation should be carried out in a fume cupboard, using a safety screen.

C.1 Equipment

Bunsen burner
3 small/medium soda glass test tubes (approximately 50 mm x 10 mm)
Test tube holder
Evaporating basin/mortar
Wire gauze;
Funnel
Filter paper

C.2 Materials

Unknown sample
Sodium metal
Dilute nitric acid (5 %)
Aqueous silver nitrate (5 %)
Dilute ammonia (10 %)
Freshly made up zirconium-alizarin red S reagent
Glacial acetic acid
Acid/pH indicator papers

C.3 Procedure

C.3.1 Sodium fusion

Place 200 mg – 250 mg of the sample into the bottom of a small soda glass test tube. Add 10 ml of distilled/de-ionized water to the evaporating basin and place this in the fume cupboard behind the safety screen. Whilst holding the test tube firmly with the test tube holder at an angle of 45° - 60° to the vertical, introduce a piece of freshly cut, clean sodium (about the size of a small pea) (200 mg – 250 mg) into the mouth of the test tube without allowing it to come into contact with the sample. With the safety screen in place, heat the sodium gently until it melts and runs down on to the sample (there may be a vigorous reaction when the molten sodium reaches the sample if halogens are present). Heat the tube gently for about 1 min, then more strongly until the lower 20 mm of the tube glows red hot. Plunge the red hot tube into the water in the evaporating basin, immediately placing the gauze on top. (The gauze prevents any loss of material when the tube shatters on contact with the water.) Allow any non reacted sodium to react before grinding up the solution and glass. Filter, and separate the filtrate into two equal portions.

C.3.2 Chlorine and bromine

To the first portion of the filtrate, add sufficient nitric acid to make the solution acidic. Boil this solution until its total volume has been reduced by half (this is to remove any HCN or H_2S, if present, which would interfere with the test). Add 1 ml silver nitrate solution; a white or yellowish-white precipitate indicates the presence of halogen (Cl, Br) in the original sample. (If the liquor is decanted, and the precipitate is white and readily soluble in dilute ammonia, then chloride is present.)

C.3.3 Fluorine

To the second portion of the filtrate, acidify with glacial acetic acid. Boil this solution until its total volume has been reduced by half. Add 2 to 3 drops freshly prepared zirconium lake reagent (equal volumes of: a) Alizarin solution: 0,05 g Alizarin Red-S in 50 ml distilled water, b) Zirconium solution: 0,05 g zirconium nitrate in 10 ml concentrated HCl diluted with 50 ml distilled water). Heat at 40 °C for 1 h. The presence of fluoride is indicated by the red/pink colouration being bleached to yellow.

Annex D

(normative)

Test of long term resistance to D.C. for cables without metallic layer.

A test sample having a cross section not bigger than 16mm² with a length of 1m shall be immersed into water containing 1 % NaCl. Further on minimum 300mm of the sample shall stick out of the water. The water-bath shall be retained for (240 ± 2) h at a high temperature of (85 ± 2) °C and a D.C.-voltage 1,8kV shall be applied between conductor and water whereby the conductor shall be connected to the negative potential.

The current of this circuit shall be measured with a period of not more than 24h. If possible a continuous measurement shall be preferred.

The measured values shall be recorded in a time-current-curve which identifies a stable progress.

NOTE A stable progress is e.g. an increase of less than 10% of leakage current on the average for a time of 24h (This is part of the inspection based on practical experiences)

After storing the samples shall be taken out of the salt-water-solution and a voltage test according to Ref.-No. 1.2 of table 3 shall be performed.

Annex E

(normative)

Cold impact test

The cold impact test shall be performed at –40°C according to clause 8.5 of EN 60811-1-4, but the mass of hammer, the mass of test probe and the height shall comply with table E.1.

Table E.1 – Parameter for cold impact test

Diameter of cable (D)	Mass of hammer	Mass of gauge	height
mm	g	g	mm
$D \leq 15$	1 000	200	100
$15 < D \leq 25$	1 500	200	150
$D > 25$	2 000	200	200

The inner and outer surface of sheath shall be inspected with normal or corrective visual faculty without magnification. Only the outer surface of the insulation shall be inspected. No cracks shall be determined

The sample shall be allowed to return to ambient temperature and then subjected to the voltage test given in no. 1.2 of Table 1.

Annex F

(normative)

Dynamic penetration test

A test apparatus for pull test (or a 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 (see figure F.1b) through the insulation or sheath of a completed cable. A circuit with low voltage which finish the test at the moment when the needle penetrates the insulation or the sheath and makes contact with the conductor shall be added.

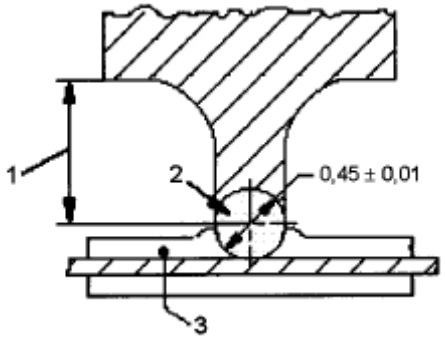
The test shall be performed at room temperature. The force applying to the needle shall be increased continuously with 1 N/s until contact with the conductor has been made. Four tests at each sample shall be performed and the force at the moment of contact shall be recorded. After each test the sample shall be moved forward for min. 25mm and shall be turned clockwise for 90°.

The mean value of the 4 test results must not be less than the minimum value F determined with following formula

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

d_L diameter of conductor according to table 2 of IEC 60719, in mm

Dimensions in mm



Key

1 Shoulder with sufficient depth for testing the insulation
2 Needle of spring steel
3 Sample

Figure F.1 – Arrangement for penetration test