Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2 \text{ kV}$) up to 30 kV ($U_m = 36 \text{ kV}$) –

Part 2: Cables for rated voltages from 6 kV ($U_m = 7,2 \text{ kV}$) up to 30 kV ($U_m = 36 \text{ kV}$)

This English-language version is derived from the original bilingual publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

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Part 2:
Cables for rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV)
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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60502-2 has been prepared by IEC technical committee 20: Electric cables.


Significant technical changes with respect to the first edition have been made. The changes relate to possible water ingress, large conductor sizes, partial discharge requirements, insulation and oversheath thickness requirements, range of type approval, electrical tests after installation and tabulated current ratings.
IEC 60502 consists of the following parts, under the general title *Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1.2$ kV) up to 30 kV ($U_m = 36$ kV):

- **Part 1:** Cables for rated voltages of 1 kV ($U_m = 1.2$ kV) and 3 kV ($U_m = 3.6$ kV);
- **Part 2:** Cables for rated voltages from 6 kV ($U_m = 7.2$ kV) up to 30 kV ($U_m = 36$ kV);
- **Part 3:** Reserved;
- **Part 4:** Test requirements on accessories for cables with rated voltages from 6 kV ($U_m = 7.2$ kV) up to 30 kV ($U_m = 36$ kV).

The text of this standard is based on the following documents:

<table>
<thead>
<tr>
<th>FDIS</th>
<th>Report on voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/749/FDIS</td>
<td>20/763/RVD</td>
</tr>
</tbody>
</table>

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.
1 Scope

This part of IEC 60502 specifies the construction, dimensions and test requirements of power cables with extruded solid insulation from 6 kV up to 30 kV for fixed installations such as distribution networks or industrial installations.

When determining applications, it is recommended that the possible risk of radial water ingress is considered. Cable designs with barriers claimed to prevent longitudinal water penetration and an associated test are included in this part of IEC 60502.

Cables for special installation and service conditions are not included, for example cables for overhead networks, the mining industry, nuclear power plants (in and around the containment area) nor for submarine use or shipboard application.

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 60038, IEC standard voltages
IEC 60060-1, High-voltage test techniques – Part 1: General definitions and test requirements
IEC 60183, Guide to the selection of high-voltage cables
IEC 60228, Conductors of insulated cables
IEC 60229, Tests on cable oversheaths which have a special protective function and are applied by extrusion
IEC 60230, Impulse tests on cables and their accessories
IEC 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 premixed flame
IEC 60811-1-1, Common test methods for insulating and sheathing materials of electric cables and optical cables – Part 1-1: Methods for general application – Measurement of thickness and overall dimensions – Tests for determining the mechanical properties
IEC 60811-1-2, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 2: Thermal ageing methods

IEC 60811-1-3, Common test methods for insulating and sheathing materials of electric and optical cables – Part 1-3: General application – Methods for determining the density – Water absorption tests – Shrinkage test

IEC 60811-1-4, Common test methods for insulating and sheathing materials of electric cables – Part 1: Methods for general application – Section 4: Test at low temperature

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

IEC 60811-3-1, Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section 1: Pressure test at high temperature – Tests for resistance to cracking

IEC 60811-3-2, Common test methods for insulating and sheathing materials of electric cables – Part 3: Methods specific to PVC compounds – Section 2: Loss of mass test – Thermal stability test

IEC 60811-4-1, Insulating and sheathing materials of electric and optical cables – Common test methods – Part 4-1: Methods specific to polyethylene and polypropylene compounds – Resistance to environmental stress cracking – Measurement of the melt flow index – Carbon black and/or mineral filler content measurement in polyethylene by direct combustion – Measurement of carbon black content by thermogravimetric analysis (TGA) – Assessment of carbon black dispersion in polyethylene using a microscope

IEC 60885-3, Electrical test methods for electric cables – Part 3: Test methods for partial discharge measurements on lengths of extruded power cables

IEC 60986, Short-circuit temperature limits of electric cables with rated voltages from 6 kV (U_{m} 7,2 kV) up to 30 kV (U_{m} =36 kV)

ISO 48, Rubber, vulcanized or thermoplastic – Determination of hardness (hardness between 10 IRHD and 100 IRHD)

3 Terms and definitions

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

3.1 Definitions of dimensional values (thicknesses, cross-sections, etc.)

3.1.1 nominal value
value by which a quantity is designated and which is often used in tables

NOTE Usually, in this standard, nominal values give rise to values to be checked by measurements taking into account specified tolerances.

3.1.2 approximate value
value which is neither guaranteed nor checked; it is used, for example, for the calculation of other dimensional values
3.1.3 median value
when several test results have been obtained and ordered in an increasing (or decreasing) succession, the median value is the middle value if the number of available values is odd, and the mean of the two middle values if the number is even.

3.1.4 fictitious value
value calculated according to the "fictitious method" described in Annex A.

3.2 Definitions concerning the tests

3.2.1 routine tests
tests made by the manufacturer on each manufactured length of cable to check that each length meets the specified requirements.

3.2.2 sample tests
tests made by the manufacturer 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.

3.2.3 type tests
tests made before supplying, on a general commercial basis, a type of cable covered by this standard, 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.

3.2.4 electrical tests after installation
tests made to demonstrate the integrity of the cable and its accessories as installed.

4 Voltage designations and materials

4.1 Rated voltages
The rated voltages $U_0/U(U_m)$ of the cables considered in this standard are as follows:

$$U_0/U(U_m) = 3,6/6 (7,2) – 6/10 (12) – 8,7/15 (17,5) – 12/20 (24) – 18/30 (36) \text{ kV.}$$

NOTE 1 The voltages given above are the correct designations although in some countries other designations are used, e.g. $3,5/6 – 5,8/10 – 11,5/20 – 17,3/30 \text{ kV.}$

In the voltage designation of cables $U_0/U(U_m)$:

$U_0$ is the rated power frequency voltage between conductor and earth or metallic screen for which the cable is designed;

$U$ is the rated power frequency voltage between conductors for which the cable is designed;

$U_m$ is the maximum value of the "highest system voltage" for which the equipment may be used (see IEC 60038).
The rated voltage of the cable for a given application shall be suitable for the operating conditions in the system in which the cable is used. To facilitate the selection of the cable, systems are divided into three categories:

- **category A**: this category comprises those systems in which any phase conductor that comes in contact with earth or an earth conductor is disconnected from the system within 1 min;
- **category B**: this category comprises those systems which, under fault conditions, are operated for a short time with one phase earthed. This period, according to IEC 60183, should not exceed 1 h. For cables covered by this standard, a longer period, not exceeding 8 h on any occasion, can be tolerated. The total duration of earth faults in any year should not exceed 125 h;
- **category C**: this category comprises all systems which do not fall into category A or B.

NOTE 2 It should be realized that in a system where an earth fault is not automatically and promptly isolated, the extra stresses on the insulation of cables during the earth fault reduce the life of the cables to a certain degree. If the system is expected to be operated fairly often with a permanent earth fault, it may be advisable to classify the system in category C.

The values of $U_0$ recommended for cables to be used in three-phase systems are listed in Table 1.

### Table 1 – Recommended rated voltages $U_0$

<table>
<thead>
<tr>
<th>Highest system voltage $(U_m)$ (kV)</th>
<th>Rated voltage $(U_0)$ (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Categories A and B</td>
</tr>
<tr>
<td>7,2</td>
<td>3,6</td>
</tr>
<tr>
<td>12,0</td>
<td>6,0</td>
</tr>
<tr>
<td>17,5</td>
<td>8,7</td>
</tr>
<tr>
<td>24,0</td>
<td>12,0</td>
</tr>
<tr>
<td>36,0</td>
<td>18,0</td>
</tr>
</tbody>
</table>

#### 4.2 Insulating compounds

The types of insulating compound covered by this standard are listed in Table 2, together with their abbreviated designations.
Table 2 – Insulating compounds

<table>
<thead>
<tr>
<th>Insulating compound</th>
<th>Abbreviated designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) <strong>Thermoplastic</strong></td>
<td></td>
</tr>
<tr>
<td>- polyvinyl chloride intended for cables with rated voltages $U_0/U = 3.6/6 \text{kV}$</td>
<td>PVC/B*</td>
</tr>
<tr>
<td>b) <strong>Thermosetting</strong></td>
<td></td>
</tr>
<tr>
<td>- ethylene propylene rubber or similar (EPM or EPDM)</td>
<td>EPR</td>
</tr>
<tr>
<td>- high modulus or hard grade ethylene propylene rubber</td>
<td>HEPR</td>
</tr>
<tr>
<td>- cross-linked polyethylene</td>
<td>XLPE</td>
</tr>
</tbody>
</table>

* Insulating compound based on polyvinyl chloride intended for cables with rated voltages $U_0/U \leq 1.8/3 \text{kV}$ is designated PVC/A in IEC 60502-1.

The maximum conductor temperatures for different types of insulating compound covered by this standard are given in Table 3.

Table 3 – Maximum conductor temperatures for different types of insulating compound

<table>
<thead>
<tr>
<th>Insulating compound</th>
<th>Maximum conductor temperature $^\circ \text{C}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal operation</td>
</tr>
<tr>
<td>Polyvinyl chloride</td>
<td>(PVC/B)</td>
</tr>
<tr>
<td>- Conductor cross-section $\leq 300 \text{ mm}^2$</td>
<td>70</td>
</tr>
<tr>
<td>- Conductor cross-section $&gt;300 \text{ mm}^2$</td>
<td>70</td>
</tr>
<tr>
<td>Cross-linked polyethylene (XLPE)</td>
<td>90</td>
</tr>
<tr>
<td>Ethylene propylene rubber (EPR and HEPR)</td>
<td>90</td>
</tr>
</tbody>
</table>

The temperatures in Table 3 are based on the intrinsic properties of the insulating materials. It is important to take into account other factors when using these values for the calculation of current ratings.

For example, in normal operation, if a cable directly buried in the ground is operated under continuous load (100% load factor) at the maximum conductor temperature shown in the table, the thermal resistivity of the soil surrounding the cable may, in the course of time, increase from its original value as a result of drying-out processes. As a consequence, the conductor temperature may greatly exceed the maximum value. If such operating conditions are foreseen, adequate provisions shall be made.

For guidance on continuous current ratings, reference should be made to Annex B.

For guidance on the short-circuit temperatures, reference should be made to IEC 60986.

4.3 Sheathing compounds

The maximum conductor temperatures for the different types of sheathing compound covered by this standard are given in Table 4.
Table 4 – Maximum conductor temperatures for different types of sheathing compound

<table>
<thead>
<tr>
<th>Sheathing compound</th>
<th>Abbreviated designation</th>
<th>Maximum conductor temperature in normal operation °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Thermoplastic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>polyvinyl chloride (PVC)</td>
<td>ST₁</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>polyethylene</td>
<td>ST₂</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ST₃</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ST₇</td>
<td>90</td>
</tr>
<tr>
<td>b) Elastomeric:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>polychloroprene, chlorosulfonated polyethylene or similar polymers</td>
<td>SE₁</td>
<td>85</td>
</tr>
</tbody>
</table>

5 Conductors

The conductors shall be either of class 1 or class 2 of plain or metal-coated annealed copper or of plain aluminium or aluminium alloy in accordance with IEC 60228. For class 2 conductors measures may be taken to achieve longitudinal watertightness.

6 Insulation

6.1 Material

Insulation shall be extruded dielectric of one of the types listed in Table 2.

6.2 Insulation thickness

The nominal insulation thicknesses are specified in Tables 5 to 7.

The thickness of any separator or semi-conducting screen on the conductor or over the insulation shall not be included in the thickness of the insulation.

Table 5 – Nominal thickness of PVC/B insulation

<table>
<thead>
<tr>
<th>Nominal cross-sectional area of conductor mm²</th>
<th>Nominal thickness of insulation at rated voltage 3,6/6 (7,2) kV mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 to 1 600</td>
<td>3,4</td>
</tr>
</tbody>
</table>

NOTE 1 Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen (see 7.1), or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

NOTE 2 For conductor cross-sections larger than 1 000 mm², the insulation thickness may be increased to avoid any mechanical damage during installation and service.
Table 6 – Nominal thickness of cross-linked polyethylene (XLPE) insulation

<table>
<thead>
<tr>
<th>Nominal cross-sectional area of conductor mm²</th>
<th>Nominal thickness of insulation at rated voltage $U_0/U$ ($U_m$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,6/6 (7,2) kV mm</td>
</tr>
<tr>
<td></td>
<td>6/10 (12) kV mm</td>
</tr>
<tr>
<td></td>
<td>8,7/15 (17,5) kV mm</td>
</tr>
<tr>
<td></td>
<td>12/20 (24) kV mm</td>
</tr>
<tr>
<td></td>
<td>18/30 (36) kV mm</td>
</tr>
<tr>
<td>10</td>
<td>2.5</td>
</tr>
<tr>
<td>16</td>
<td>2.5</td>
</tr>
<tr>
<td>25</td>
<td>2.5</td>
</tr>
<tr>
<td>35</td>
<td>2.5</td>
</tr>
<tr>
<td>50 to 185</td>
<td>2.5</td>
</tr>
<tr>
<td>240</td>
<td>2.6</td>
</tr>
<tr>
<td>300</td>
<td>2.8</td>
</tr>
<tr>
<td>400</td>
<td>3.0</td>
</tr>
<tr>
<td>500 to 1 600</td>
<td>3.2</td>
</tr>
</tbody>
</table>

NOTE 1 Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen (see 7.1), or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

NOTE 2 For conductor cross-sections larger than 1,000 mm², the insulation thickness may be increased to avoid any mechanical damage during installation and service.

Table 7 – Nominal thickness of ethylene propylene rubber (EPR) and hard ethylene propylene rubber (HEPR) insulation

<table>
<thead>
<tr>
<th>Nominal cross-sectional area of conductor mm²</th>
<th>Nominal thickness of insulation at rated voltage $U_0/U$ ($U_m$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,6/6 (7,2) kV mm</td>
</tr>
<tr>
<td></td>
<td>6/10 (12) kV mm</td>
</tr>
<tr>
<td></td>
<td>8,7/15 (17,5) kV mm</td>
</tr>
<tr>
<td></td>
<td>12/20 (24) kV mm</td>
</tr>
<tr>
<td></td>
<td>18/30 (36) kV mm</td>
</tr>
<tr>
<td>10</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>16</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>25</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>35</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>50 to 185</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>240</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>300</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>400</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
<tr>
<td>500 to 1 600</td>
<td>Unscreened: 3.0 mm, Screened: 2.5 mm</td>
</tr>
</tbody>
</table>

NOTE 1 Any smaller conductor cross-section than those given in this table is not recommended. However, if a smaller cross-section is needed, either the diameter of the conductor may be increased by a conductor screen (see 7.1), or the insulation thickness may be increased in order to limit, at the values calculated with the smallest conductor size given in this table, the maximum electrical stresses applied to the insulation under test voltage.

NOTE 2 For conductor cross-sections larger than 1,000 mm², the insulation thickness may be increased to avoid any mechanical damage during installation and service.

7 Screening

All cables shall have a metallic layer surrounding the cores, either individually or collectively.
Screening of individual cores in single or three-core cables, when required, shall consist of a conductor screen and an insulation screen. These shall be employed in all cables with the following exceptions:

a) at rated voltage 3,6/6 (7,2) kV cables insulated with EPR and HEPR may be unscreened, provided the larger insulation thickness in Table 7 is used;
b) at rated voltage 3,6/6 (7,2) kV cables insulated with PVC shall be unscreened.

7.1 Conductor screen

The conductor screen shall be non-metallic and shall consist of an extruded semi-conducting compound, which may be applied on top of a semi-conducting tape. The extruded semi-conducting compound shall be firmly bonded to the insulation.

7.2 Insulation screen

The insulation screen shall consist of a non-metallic, semi-conducting layer in combination with a metallic layer.

The non-metallic layer shall be extruded directly upon the insulation of each core and consist of either a bonded or strippable semi-conducting compound.

A layer of semi-conducting tape or compound may then be applied over the individual cores or the core assembly.

The metallic layer shall be applied over either the individual cores or the core assembly collectively and shall comply with the requirements of Clause 10.

8 Assembly of three-core cables, inner coverings and fillers

The assembly of three-core cables depends on the rated voltage and whether a metallic screen is applied to each core.

Subclauses 8.1 to 8.3 do not apply to assemblies of sheathed single-core cables.

8.1 Inner coverings and fillers

8.1.1 Construction

The inner coverings may be extruded or lapped.

For cables with circular cores, a lapped inner covering shall be permitted only if the interstices between the cores are substantially filled.

A suitable binder is permitted before application of an extruded inner covering.

8.1.2 Material

The materials used for inner coverings and fillers shall be suitable for the operating temperature of the cable and compatible with the insulating material.
8.1.3 Thickness of extruded inner covering

The approximate thickness of extruded inner coverings shall be derived from Table 8.

<table>
<thead>
<tr>
<th>Fictitious diameter over laid-up cores</th>
<th>Thickness of extruded inner covering (approximate values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to and including mm</td>
<td>mm</td>
</tr>
<tr>
<td>-</td>
<td>1.0</td>
</tr>
<tr>
<td>25</td>
<td>1.2</td>
</tr>
<tr>
<td>35</td>
<td>1.4</td>
</tr>
<tr>
<td>45</td>
<td>1.6</td>
</tr>
<tr>
<td>60</td>
<td>1.8</td>
</tr>
<tr>
<td>80</td>
<td>2.0</td>
</tr>
</tbody>
</table>

8.1.4 Thickness of lapped inner covering

The approximate thickness of lapped inner coverings shall be 0.4 mm for fictitious diameters over laid-up cores up to and including 40 mm and 0.6 mm for larger diameters.

8.2 Cables having a collective metallic layer (see Clause 9)

Cables shall have an inner covering over the laid-up cores. The inner covering and fillers shall comply with 8.1 and shall be non-hygroscopic except if the cable is claimed to be longitudinally watertight.

For cables having a semi-conducting screen over each individual core and a collective metallic layer, the inner covering shall be semi-conducting; the fillers may be semi-conducting.

8.3 Cables having a metallic layer over each individual core (see Clause 10)

The metallic layers of the individual cores shall be in contact with each other.

Cables with an additional collective metallic layer (see Clause 9) of the same material as the underlying individual metallic layers shall have an inner covering over the laid-up cores. The inner covering and fillers shall comply with 8.1 and shall be non-hygroscopic except if the cable is claimed to be longitudinally watertight. The inner covering and fillers may be semi-conducting.

When the underlying individual metallic layers and the collective metallic layer are of different materials, they shall be separated by an extruded sheath of one of the materials specified in 14.2. For lead sheathed cables, the separation from the underlying individual metallic layers may be obtained by an inner covering according to 8.1.

For cables without a collective metallic layer (see Clause 9), the inner covering may be omitted provided the outer shape of the cable remains practically circular.