BS 7870-3.40:2011
Incorporating Corrigendum No. 1

BSI Standards Publication

LV and MV polymeric insulated cables for use by distribution and generation utilities

Part 3: Specification for distribution cables of rated voltage 0.6/1 kV

Section 3.40: XLPE insulated, copper wire waveform concentric cables with solid aluminium conductors

(Implementation of HD 603)

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 12, an inside back cover and a back cover.

Foreword

Publishing information

This section of BS 7870 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2011. It was prepared by Subcommittee GEL/20/16, *Medium/High voltage cables*, under the authority of Technical Committee GEL/20, *Electric cables*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This section of BS 7870 supersedes BS 7870-3.40:2001, which is withdrawn.

Relationship with other publications

BS 7870 implements the nationally applicable parts of Harmonization Documents HD 603, 605, 620, 626 and 627 published by the European Committee for Electrotechnical Standardization (CENELEC) in accordance with the decision of the CENELEC Technical Board.

BS 7870 applies to cables for fixed installations having a rated voltage U_0/U up to and including 19/33 kV, and is published as a series of separate parts and sections, as listed in the table in the foreword of BS 7870-1.

BS 7870-3.40 specifies a range of XLPE insulated, copper wire waveform concentric cables with solid aluminium conductors; it implements Part 5R of HD 603 S1 A2, and is to be read in conjunction with BS 7870-1 and BS 7870-2.

Information about this document

This is a full revision of the standard, and brings the standard up to date in accordance with current practice in the industry.

The start and finish of text introduced or altered by Corrigendum No. 1 is indicated in the text by tags ⟦C1⟩ and ⟨C1⟧.

A general guide to use for the types of cable specified in BS 7870 is given in BS 7870-1 and specific details for the types of cable specified in this section of BS 7870 are given in Annex A.

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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1 Scope

This section of BS 7870 specifies requirements for the construction, dimensions and mechanical and electrical properties of copper wire waveform cables with solid aluminium core conductors, XLPE insulation and PVC oversheath having a rated voltage of 0.6/1(1.2) kV.

It specifies requirements for the following types of cable:

a) 3-core, 3-phase, with a concentric neutral/earth conductor of copper wires bedded on a single rubber layer;

b) 4-core, 3-phase and a separate neutral, with a concentric earth conductor of copper wires bedded on a single rubber layer.

This section of BS 7870 is applicable to cables that are designed for a maximum continuous conductor operating temperature of 80 °C and for a maximum short circuit conductor temperature of 250 °C.

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.

BS 3988:1970+A3:1989, *Specification for wrought aluminium for electrical purposes – Solid conductors for insulated cables*

BS 7870-1, *LV and MV polymeric insulated cables for use by distribution and generation utilities – Part 1: General*

BS 7870-2, *LV and MV polymeric insulated cables for use by distribution and generation utilities – Part 2: Methods of test*

BS EN 60228, *Specification for conductors in insulated cables and cords*

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

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

3 Voltage designation

Cables shall be designated by the voltages U_0, U and U_m, expressed in the form U_0/U (U_m).

The voltage designation of cables in this standard shall be 0.6/1(1.2) kV.

The rated voltage of the cable shall be at least equal to the nominal voltage of the system for which it is intended.

4 Core conductors

The core conductors shall be circular or shaped solid aluminium in accordance with Table 1 or Table 2, as applicable, and shall conform to the requirements for solid conductors (class 1) as specified in BS EN 60228. The conductors shall also conform to the dimensional requirements specified in BS 3988:1970+A3, **2.4**.

The geometry of the core conductors shall conform to BS 3988:1970+A3.

Conformity shall be checked by visual examination and measurement as specified in **14.2**.

The d.c. resistance shall conform to the relevant value given in Table 1 or Table 2, as applicable.

Conformity shall be checked by the test method specified in **13.2**.

5 Insulation

The insulation of the core conductors specified in Clause **4** shall be XLPE type DIX 3, conforming to the requirements given in BS 7870-1, Annex B.

The insulation shall be applied by extrusion and shall form a compact and homogeneous layer.

The thickness of the insulation shall be in accordance with the relevant values specified in Table 1 or Table 2, as applicable.

Conformity shall be checked by the test methods specified in **14.4**.

The cores of all cables shall be identified by colours, as follows:

a) 3-core: brown, black, grey;

b) 4-core: brown, black, grey, blue.

6 Assembly of cores

The cores shall be laid up with a right-hand direction of lay, in the sequence specified in Clause **5**.

The minimum lay length of the cores shall be as specified in Table 1 or Table 2, as applicable.

NOTE Suitable binder tapes may be applied to form a compact assembly.

7 Concentric conductor

7.1 Material

The concentric conductor shall consist of plain annealed copper wires.

NOTE In order to maintain the waveform during manufacture, the copper wires typically need to be annealed to a level to achieve greater than 18% elongation at break.

7.2 Application

The wires shall be applied concentrically with a waveform lay. The lay length shall be as given in Table 1 or Table 2, as applicable.

The mean gap between adjacent wires shall not exceed 4 mm and at any point the gap shall not exceed 8 mm.

The developed length of each wire in the waveform wavelength shall be at least 106%.

Conformity shall be checked by visual examination and measurement as specified in **14.3**.

The d.c. resistance of the concentric conductor shall conform to the relevant value given in Table 1 or Table 2, as applicable.

Conformity shall be checked by the test method specified in **13.2**.

NOTE Examples of concentric conductor construction are given in Table 1 and Table 2.

7.3 Rubber layer

The copper wires shall be bedded on a layer of soft non-vulcanizable synthetic rubber material which is compatible with the core insulation and PVC oversheath.

Conformity shall be checked by testing in accordance with **15.6**.

The rubber layer shall fill the interstices between the cores of the cable where these are not covered by binder tapes.

The rubber layer shall be easily removable. Conformity shall be checked by the method specified in **14.5**.

8 Oversheath

The oversheath shall be an extruded layer of black PVC compound type DMV 23, conforming to the requirements given in BS 7870-1, Annex B.

The thickness of the oversheath shall conform to the relevant values specified in Table 1 or Table 2, as applicable.

Conformity shall be checked by the test methods specified in **14.6**.

9 Marking

9.1 External marking

The external surface of the cable shall be legibly marked with the following elements:

Element	Example of marking
a) Cable manufacturer	Manufacturer's name and their unique factory identifier
NOTE 1 A simplified version of the manufacturer's name, or trading name of the manufacturer, may be used in place of the full name.	
NOTE 2 Any suitable method may be used to unambiguously identify the manufacturer's factory.	
NOTE 3 The manufacturer's own trademark or equivalent may be added but this cannot be used instead of the manufacturer's name and identifier.	
b) Electric cable	ELECTRIC CABLE
c) Voltage designation	600/1 000 V
d) British Standard number	BS 7870-3.40 [1)]
e) Number of cores, type and nominal area of core conductors, e.g.:	
3-core cable with 70 mm^2 aluminium core conductors having a copper concentric neutral/earth conductor	3 × 70 AL

[1)] Marking BS 7870-3.40 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

4-core cable with 95 mm² aluminium core conductors having a copper concentric earth conductor	4 × 95 AL
f) Year of manufacture	YYYY

NOTE 4 The year of manufacture may take the form of the actual year (e.g. 2011) or a coded year identifier assigned by the manufacturer.

The marking of elements a) to f) shall be by embossing or by indenting on the oversheath. Elements b), c) and d) shall appear, in any sequence that is deemed neither to confuse nor to conflict, on two or more primary lines along the axis of the cable, approximately equally spaced around the circumference of the cable. Elements a), e) and f) shall appear, together or separately, in any sequence that is deemed neither to confuse nor to conflict, either on one of the primary lines, or on a secondary line or lines.

The letters and figures shall consist of upright block characters. The characters shall have a minimum height of 3 mm.

The distance between the end of one element of marking and the beginning of the next identical element shall be not greater than 550 mm for elements b), c) and d) and not greater than 1 100 mm for elements a), e) and f).

Conformity shall be checked by visual examination and measurement as specified in **13.5**.

9.2 Mark of an approval organizational

If the mark of an approval organization is used, it shall be provided throughout the length of the cable, either as an identification thread or by marking on the surface of the cable, as specified by the approval organization.

If the mark is on the external surface of the cable, it shall be in the form of the symbol(s) specified by the approval organization, and the distance between the end of one element of marking and the beginning of the next identical element shall be not greater than 1 100 mm.

Conformity shall be checked by visual examination and measurement as specified in **13.5**.

9.3 Additional marking

Where additional marking is made, it shall be throughout the length of the cable, and on the external surface of the cable, or by means of a tape or thread within the cable, or by a combination of these methods. If the additional marking is applied to the surface of the cable it shall not render illegible the marking specified in **9.1** and **9.2**.

The additional marking, however made, shall be repeated at intervals not exceeding 1 100 mm.

Conformity shall be checked by visual examination and measurement as specified in **13.5**.

10 End sealing

Before dispatch, the manufacturer shall cap the ends of the cables in order to form a seal to prevent the ingress of water during transportation and storage.

11 Dimensions

The thickness of each component layer shall be as specified in Table 1 or Table 2, as applicable.

NOTE Typical examples of concentric conductor construction and overall cable diameters are also given in Table 1 and Table 2.

Table 1 **3-core, 3-phase cables**

Parameter	**Nominal cross-sectional area of core conductor** mm²						
	35	**70**	**95**	**120**	**185**	**240**	**300**
Form of core conductor	Circular	Sector shaped					
Minimum average thickness of insulation (mm)	0.9	1.1	1.1	1.2	1.6	1.7	1.8
[C1] Minimum thickness of insulation at any point (mm)	0.71	0.89	0.89	0.98	1.34	1.43	1.52 [C1]
Minimum lay length of cores (mm)	600	700	800	1 000	1 200	1 400	1 600
Minimum average thickness of oversheath (mm)	1.8	1.9	2.1	2.2	2.5	2.7	2.8
Minimum thickness of oversheath at any point (mm)	1.43	1.51	1.68	1.77	2.02	2.19	2.28
Maximum d.c. resistance per km of cable at 20 °C:							
– core conductors (Ω)	0.868	0.443	0.320	0.253	0.164	0.125	0.100
– concentric neutral/earth conductor (Ω)	0.868	0.443	0.320	0.253	0.164	0.164	0.164
Typical waveform construction:							
Concentric neutral/earth conductor:							
– number of wires	26	16	22	28	41	41	41
– diameter of wires (mm)	1.04	1.85	1.85	1.85	1.85	1.85	1.85
– length of lay (mm)	220	220	250	270	300	375	440
Overall diameter of cable (mm)	26.3	30.5	33.4	35.9	45.3	51.2	53.4

Table 2 **4-core, 3-phase cables**

Parameter	**Nominal cross-sectional area of core conductor** mm²			
	95	**185**	**240**	**300**
Form of core conductor	Sector shaped			
Minimum average thickness of insulation (mm)	1.1	1.6	1.7	1.8
[C1] Minimum thickness of insulation at any point (mm)	0.89	1.34	1.43	1.52 [C1]
Minimum lay length of cores (mm)	800	1 200	1 400	1 600
Minimum average thickness of oversheath (mm)	2.2	2.6	2.8	3.1
Minimum thickness of oversheath at any point (mm)	1.77	2.11	2.28	2.88
Maximum d.c. resistance per km of cable at 20°C:				
– core conductors (Ω)	0.320	0.164	0.125	0.100
– concentric earth conductor (Ω)	0.320	0.164	0.164	0.164
Typical waveform construction:				
Concentric earth conductor:				
– number of wires	22	41	41	41
– diameter of wires (mm)	1.85	1.85	1.85	1.85
– length of lay (mm)	250	300	375	440
Overall diameter of cable (mm)	37.5	49.9	56.9	62.3

12 Tests

Tests shall be performed in accordance with the schedule of tests specified in Table 3.

Table 3 **Schedule of tests**

Test	Requirements given in clause	Test method Clause of BS 7870-2 unless otherwise specified
Routine tests		
Core conductor resistance	**13.2**	**3.1.1**
Concentric conductor resistance	**13.2**	**3.1.1**
Voltage test on complete cable	**13.3**	**3.2.1**
Spark test		
– insulation	**13.4**	**3.6.1**
– oversheath	**13.4**	**3.6.1**
Cable markings	Clause **9**	**13.5** this standard
Sample tests		
Core conductor material and construction	Clause **4**	**14.2** this standard, BS 3988
Insulation		
– application	Clause **5**	**14.4** this standard
– thickness	Clause **5**	**14.4** this standard
– colour	Clause **5**	**14.4** this standard
– durability of colour	**14.4**	**2.5.4**
Concentric conductor material, construction and application	Clause **7**	**14.3** this standard
Rubber layer		
– removal	**7.3**	**14.5** this standard
Oversheath		
– application	Clause **8**	**14.6** this standard
– thickness	Clause **8**	**14.6** this standard
Type tests		
Insulation	**15.2**	BS 7870-1, Annex B
Shrinkage of insulation	**15.3**	BS EN 60811-1-3
Bend test	**15.4**	**2.4.1.1**
Oversheath	**15.5**	BS 7870-1, Annex B
Compatibility	Table 4	**15.6** this standard

13 Routine tests

13.1 General

Routine tests shall be as specified in Table 3.

13.2 Conductor resistance

The d.c. resistance of the core and concentric conductors shall be measured in accordance with BS 7870-2, **3.1.1**, and shall be as given in Table 1 or Table 2, as applicable.

13.3 Voltage test on complete cable

When a voltage test is carried out in accordance with BS 7870-2, **3.2.1**, using a test voltage of 3.5 kV r.m.s. for a duration of 5 min, no breakdown of the insulation shall occur.

13.4 Spark test

Spark testing of the insulation and the oversheath shall be carried out in accordance with BS 7870-2, **3.6.1**. No failures shall occur.

13.5 Cable markings

The cable markings shall be checked by visual examination and measurement and shall conform to the requirements of Clause **9**.

14 Sample tests

14.1 General

Sample tests shall be as specified in Table 3.

14.2 Core conductor material and construction

The core conductor material and construction shall be checked by visual examination and by measurement in accordance with BS 3988:1970+A.3, and shall conform to the requirements of Clause **4**.

14.3 Concentric conductor material, construction and application

The concentric conductor material, construction and application shall be checked by visual examination and measurement and shall conform to the requirements of **7.1** and **7.2**.

14.4 Insulation

The application of the insulation shall be checked by visual examination and shall conform to the requirements of Clause **5**.

A cable sample shall be taken from one end of each drum length of cable selected for the test, and any portion that may have suffered damage shall be discarded. The thickness of the insulation of each of the samples shall be measured in accordance with the procedure given in BS 7870-2, **2.1.1** with the measurement being made in one place only.

If any of the thicknesses measured does not conform to the requirements specified in Table 1 or Table 2, as applicable, two further samples shall be checked for the non-conforming parameter. If both the further samples meet the specified requirements, the cable shall be deemed to conform to the standard, but if either does not meet the specified requirements, the cable shall be deemed not to conform to the standard.

When tested in accordance with BS 7870-2, **2.5.4**, the colour shall remain identifiable.

14.5 Rubber layer removal

On a sample of cable approximately 200 mm in length, a jointer's plastic knife shall be used to cut longitudinally through the rubber layer and lift it away from the cores. Using the raised edge, the rubber layer shall then be unwrapped from the cores.

The majority of the rubber shall lift easily and cleanly away. Any remaining residue shall be readily removable using the jointer's plastic knife.

14.6 Oversheath

The application of the oversheath shall be checked by visual examination and shall conform to the requirements of Clause **8**.

A cable sample shall be taken from one end of each drum length of cable selected for the test, and any portion that may have suffered damage shall be discarded. The thickness of the oversheath of each of the samples shall be measured in accordance with the procedure given in BS 7870-2, **2.1.2** with the measurement being made in one place only.

If any of the thicknesses measured does not conform to the requirements specified in Table 1 or Table 2, as applicable, two further samples shall be checked for the non-conforming parameter. If both the further samples meet the specified requirements, the cable shall be deemed to conform to the standard, but if either does not meet the specified requirements, the cable shall be deemed not to conform to the standard.

15 Type tests

15.1 General

Type tests shall be as specified in Table 3.

15.2 Insulation

The insulation shall be tested in accordance with BS 7870-1, Annex B and shall conform to the requirements for type DIX 3.

15.3 Shrinkage of insulation

When a 200 mm sample of core is tested at (130 ±2) °C for 1 h, in accordance with BS EN 60811-1-3, Clause **10**, the shrinkage of the insulation shall not exceed 4%.

15.4 Bend test

The cable shall be tested in accordance with BS 7870-2, **2.4.1.1**, at ambient temperature, using a cylinder diameter of 20*D*, where *D* is the overall diameter of the cable given in Table 1 or Table 2, as applicable. The wires shall remain in a waveform and there shall be no visible damage to the insulation or oversheath.

15.5 Oversheath

The oversheath shall be tested in accordance with BS 7870-1, Annex B and shall conform to the requirements for type DMV 23.

15.6 Compatibility test

A sample of completed cable shall be tested in accordance with BS EN 60811-1-2, **8.1.4** for 7 days at (90 ±2) °C. The materials shall conform to the requirements specified in Table 4.

Table 4 **Requirements for compatibility of insulation, oversheath and rubber layer**

Parameter	Requirement	
	Insulation DIX 3	Oversheath DMV 23
Minimum tensile strength (N/mm^2)	12.5	12.5
Minimum elongation at break (%)	200	150
Maximum variation of tensile strength (%) [A)]	25	25
Maximum variation of elongation at break (%) [A)]	25	25

[A)] The variation is the difference between the respective values obtained prior to and after heat treatment expressed as a percentage of the former.

Annex A (informative)

Guide to selection and use of cables

The object of this annex is to provide specific recommendations for the selection (taking into account the cable system), storage, transportation and installation of cables specified in this section of BS 7870.

The general recommendations given in BS 7870-1, Annex A apply except where amended in Table A.1.

Table A.1 **Guide to use**

BS 7870-1, Annex A Clause	**Recommendations for this section of BS 7870**
A.2.2 System categories	Category A or B
A.3.1.2 Drum barrel diameter	Minimum barrel diameter 25*D* (where *D* is the overall diameter of the cable as given in Table 1 or Table 2, as applicable)
A.3.2.5 Cable coils	Minimum coil diameter 25*D* (where *D* is the overall diameter of the cable as given in Table 1 or Table 2, as applicable)
A.4.6 Bending radii during installation	Minimum bending radius 8*D* (where *D* is the overall diameter of the cable as given in Table 1 or Table 2, as applicable)
A.4.10 Lowest temperature of cable prior to and during installation	Minimum temperature 0 °C for 24 h prior to installation
A.4.11 Cable fixing	No recommendations given for the maximum horizontal distance and the maximum vertical distance between cleats but care should be taken when deciding these distances to avoid the risk of damage or hazardous conditions under normal or fault conditions
A.4.12 Pulling force, *P*	For Al conductors σ = 30 N/mm^2 Maximum value of *P*: 20 kN
A.4.14 Testing after installation	A voltage test after installation is not a recommendation of this section of BS 7870, but if a test is made then a d.c. voltage should be applied and gradually increased to 3 500 V and maintained at this value for 15 min. No breakdown should occur

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

HD 603 S1, *Distribution cables of rated voltage 0.6/1 kV*

HD 605 S2, *Electric cables – Additional test methods*

HD 620 S2, *Distribution cables with extruded insulation for rated voltages from 3.6/6 (7.2) kV up to and including 20.8/36 (42) kV*

HD 626 S1, *Overhead distribution cables of rated voltage $U_o/U(U_m)$: 0.6/1(1.2) kV*

HD 627 S1, *Multicore and multipair cable for installation above and below ground*

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