SRI LANKA STANDARD 1187: 2021
(IEC 60183:2015)
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GUIDANCE FOR THE SELECTION OF HIGH-VOLTAGE A.C. CABLES SYSTEMS
(First Revision)

SRI LANKA STANDARDS INSTITUTION

Sri Lanka Standard
GUIDANCE FOR THE SELECTION OF HIGH-VOLTAGE A.C. CABLES SYSTEMS
(First Revision)

SLS 1187: 2021
(IEC 60183:2015)

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SRI LANKA

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This Standard does not purport to include all the necessary provisions of a contract

Sri Lanka Standard
GUIDANCE FOR THE SELECTION OF HIGH-VOLTAGE A.C. CABLES SYSTEMS
(Fist Revision)

NATIONAL FOREWORD

This standard was approved by the Sectoral Committee on Electrical Cables and Conductors and was authorized for adoption and publication as Sri Lanka Standard by the Council of the Sri Lanka Standards Institution on 2021-12-22.

This is the first revision of SLS 1187 and identical with IEC 60183: 2015 Guidance for the selection of high-voltage AC cables system published by the International Electrotechnical Commission (IEC).

In this revision following significant technical changes with respect to the previous version:

- the scope has been changed to a.c. high-voltage cables and cable systems;
- guidance relates to cables with extruded insulation;
- submarine cables are not covered but cables laid in water are covered;
- operation of systems with special bounding of the screen is covered;
- there is guidance on accessories;
- environmental aspects are addressed.

TERMINOLOGY AND CONVENTIONS

The text of the International Standard has been accepted as suitable for publication, without deviation, as a Sri Lanka Standard. However, certain terminology and conventions are not identical with those used in Sri Lanka Standards. Attention is therefore drawn to the following;

a) Wherever the word “International Standard” appear referring to this standard should be interpreted as “Sri Lanka Standard”.

b) The comma has been used throughout as a decimal marker. In Sri Lanka standard it is the current practice to use the full point at the basic as the decimal marker.

c) Wherever page numbers are quoted, they are IEC page numbers.

d) Whenever standard value of rated frequency appears it shall be taken as 50 Hz.

CROSS REFERENCES

International Standards	Corresponding Sri Lanka Standards
ISO 14001: Environment Management System	SLS ISO 14001: Environment Management System

Corresponding Sri Lanka Standards for the other international standards listed under references in IEC 60183: 2015 are not available.

SLS 1187: 2021

IEC 60183

Edition 3.0 2015-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Guidance for the selection of high-voltage A.C. cable systems

Lignes directrices pour le choix de systèmes de câbles à haute tension en courant alternatif

IEC 60183:2015-01(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

GUIDANCE FOR THE SELECTION OF HIGH-VOLTAGE A.C. CABLE SYSTEMS

FOREWORD

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International Standard IEC 60183 has been prepared by IEC technical committee 20: Electric cables.

This third edition cancels and replaces the second edition, published in 1984, and its Amendment 1 (1990) and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– the scope has been changed to a.c. high-voltage cables and cable systems;
– guidance relates to cables with extruded insulation;
– submarine cables are not covered but cables laid in water are covered;
– operation of systems with special bonding of the screen is covered;
– there is guidance on accessories;
– environmental aspects are addressed.

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

FDIS	Report on voting
20/1530/FDIS	20/1558/RVD

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 stability 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.

GUIDANCE FOR THE SELECTION OF HIGH-VOLTAGE A.C. CABLE SYSTEMS

1 Scope

This International Standard is intended to give guidance in the selection of a.c. high-voltage cables and cable systems with extruded insulation and mainly to be used on three-phase alternating systems operating at voltages exceeding U = 1 kV (in this standard the term 'high voltage' is used to cover any cable above 1 kV). Submarine cables are not included in the scope.

Guidance is given in the selection of the conductor size, insulation level and constructional requirements of cable to be used. In addition, information necessary to enable the appropriate selection to be made is summarized.

Paper insulated power cables are not considered in this standard for their selection into cable systems. However, when selecting cables with extruded insulation to be connected together with existing paper insulated cables, particular consideration for their proper compatibility, accessories and operational characteristics should be made.

Environmental aspects are mentioned at the level at which they may influence the selection of high-voltage cables and their application.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60071-1:2006, *Insulation co-ordination – Part 1: Definitions, principles and rules* Amendment 1:2010

IEC 60228, *Conductors of insulated cables*

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60287-1-1:2006, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*

IEC 60287-3-1, *Electric cables – Calculation of the current rating – Part 3-1: Sections on operating conditions – Reference operating conditions and selection of cable type*

IEC 60287-3-2, *Electric cables – Calculation of the current rating – Part 3-2: Sections on operating conditions – Economic optimization of power cable size*

IEC 60502, *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)*

IEC 60840, *Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m = 170 kV) – Test methods and requirements*

IEC 62067, *Power cables with extruded insulation and their accessories for rated voltages above 150 kV (U_m = 170 kV) up to 500 kV (U_m = 550 kV) – Test methods and requirements*

IEC TS 60815-1, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC 62271-209, *High-voltage switchgear and controlgear – Part 209: Cable connections for gas-insulated metal-enclosed switchgear for rated voltages above 52 kV – Fluid-filled and extruded insulation cables – Fluid-filled and dry-type cable terminations*

ISO 14000, *Environmental management*

3 Terms and definitions

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

3.1 Voltages pertaining to the cable and its accessories

NOTE Cables will henceforth be designated by U_0/U (U_m) to provide guidance on compatibility with switchgear and transformers. Table 1 gives this information.

3.1.1
rated voltage
U_0
rated r.m.s. power-frequency voltage between each conductor and screen or sheath for which cables and accessories are designed

3.1.2
rated voltage between conductors
U
rated r.m.s. power-frequency voltage between any two conductors for which cables and accessories are designed

Note 1 to entry: This quantity only affects the design of non-radial field cables and accessories.

3.1.3
highest system voltage
U_m
maximum r.m.s. power-frequency voltage between any two conductors for which cables and accessories are designed

Note 1 to entry: It is the highest voltage that can be sustained under normal operating conditions at any time and at any point in a system and excludes temporary voltage variations due to fault conditions and the sudden disconnection of large loads.

3.1.4
peak impulse voltage
U_p
peak value of the lightning impulse withstand voltage (and switching, where applicable) between each conductor and screen or sheath for which cables and accessories are designed

3.2 Voltages pertaining to the system on which cables and accessories are to be used

3.2.1
nominal voltage of system
r.m.s. phase-to-phase voltage by which the system is designated and to which certain operating characteristics of the system are related

3.2.2
highest voltage of three-phase system
highest r.m.s. phase-to-phase voltage which occurs under normal operating conditions at any time and at any point in the system

Note 1 to entry: It excludes voltage transients (such as those due to system switching) and temporary voltage variation due to abnormal system conditions (such as those due to fault conditions or sudden disconnection of large loads).

3.2.3
lightning overvoltage
phase-to-earth or phase-to-phase overvoltage at a given location in a system due to a lightning discharge or other cause, the wave-shape of which can be regarded, for insulation co-ordination purposes, as similar to the standard impulse

Note 1 to entry: See 3.18.3 of IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010 used for lightning impulse withstand tests.

Note 2 to entry: Such overvoltages are usually unidirectional and of very short duration.

3.2.4
switching overvoltage
phase-to-earth or phase-to-phase overvoltage at a given location in a system due to a switching operation in a system, the wave-shape of which can be regarded, for insulation co-ordination purpose, as similar to the standard impulse

Note 1 to entry: See 3.18.2 of IEC 60071-1:2006 and IEC 60071-1:2006/AMD1:2010 used for switching impulse withstand tests.

4 Service conditions

4.1 General

To determine the appropriate design of cable system for a particular project, the following information with regard to service conditions is required. Reference should be made to the relevant IEC publications which deal with many of the following service conditions.

4.2 Operating conditions

The following operation conditions apply:

a) Nominal voltage of the system.

b) Highest voltage of the three-phase system.

c) Lightning overvoltage and switching overvoltage for higher (U_m ≥300 kV) voltage systems (see Table 1).

d) System frequency.

e) Type of earthing and, where the neutral is not effectively earthed, the maximum permitted duration of earth fault conditions on any one occasion and the total duration per year.

f) Screen bonding.

   For single-core cables, the current-carrying capability depends largely on the screen bonding technique.

   Special bonding (single point bonding or cross-bonding) is generally used where bulk transmission has to be achieved, since the amount of losses in metal screens is significantly reduced, compared to solid bonding (see 2.3 of IEC 60287-1-1:2006). However they require special equipments such as surge voltage limiters (to protect cable sheaths and accessories from transient overvoltages) or earth continuity conductor to be laid along the cable route.

g) Where terminals are specified, the environmental conditions shall be given, for example:

- the altitude above sea level, if above 1 000 m;
- indoor or outdoor installation;
- whether excessive atmospheric pollution is expected; according to IEC TS 60815-1;
- termination in SF_6 switchgear; transformer or metal-clad system, with orientation; following IEC 62271-209;
- design clearance and insulation used in the method for connecting cable to equipment, for example transformers, switchgear, motors, etc. For example, clearance and surrounding insulation should be specified.

h) Maximum rated current:
   - for continuous operation;
   - for cyclic operation;
   - for emergency or overload operation, if any, without exceeding maximum allowed cable temperature.

   A load curve is essential if cyclic loading or emergency or overload operation is considered when determining conductor size.

i) The expected symmetrical and asymmetrical short-circuit currents which may flow in case of short-circuits, both between phases and to earth.

j) Maximum time for which short-circuit currents may flow.

k) Possible operation with forced cooling.

4.3 Installation data

4.3.1 General

The following details apply:

a) Length and profile of route.

b) Details of laying arrangements (e.g. flat or trefoil arrangement) and how the metallic coverings are connected to each other and to earth.

c) Special laying conditions, for example cables in water. Individual installations require special consideration.

4.3.2 Underground cables

The following details apply:

a) Typical ambient temperatures over the year (see IEC 60287-3-1).

b) Details of installation conditions (e.g. direct burial, in ducts, mechanical laying, etc.) to enable decisions to be taken on composition of metallic screen or sheath, type of armour (if required) and type of serving, for example anti-corrosion or anti-termite.

c) Depth of laying.

d) Thermal resistivities and kinds of soil along the route (e.g. sand, clay, made-up ground, special backfill), and whether this information is based on measurement and inspection or only assumed. Meteorological data to evaluate risk of soil drying (see IEC 60287 series).

e) Minimum, maximum and average ground temperature at the depth of burial.

f) Proximity of other load-carrying cables (especially where the link involves several parallel circuits) or of other heat sources, with details.

g) Lengths of troughs, ducts or pipe lines, with spacing of manholes, if any.

h) Details of ductbanks, if any: number of ducts or pipes. Internal diameter of ducts and pipes. Spacing between individual ducts and pipes, if more than one. Material of ducts or pipes.

i) Risk for water ingress and corrosion (the right cable design shall be chosen).

4.3.3 Cables in air

The following details apply:

a) Minimum, maximum and average ambient air temperature to be assumed.
b) Type of installation (e.g. direct laying on walls, racks, on poles, boxes, possibly water filled, etc. grouping of cables, dimensions of the tunnels, ducts, vertical shafts etc.).
c) Details of ventilation (for cables indoors, in tunnels or ducts).
d) Whether exposed to direct sunlight or having sun shield.
e) Special conditions, for example fire risk or flame spread, harmful gases and smoke.

4.3.4 Cables in water

The following details apply:

a) Water depth and currents.
b) Installation and laying technique.
c) Risk for mechanical damage during service from fishing equipment, ice, abrasion etc. (need for armouring, fastening and trenching).
d) How to fasten, protect and install the cable where it comes ashore (clamping, trenching, tubing, need for armouring etc.).
e) Risk for water ingress and corrosion (the right cable design must be chosen).

5 Cable insulation levels

5.1 Introductory remark

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 according to the duration of time the system can be operated under earth fault conditions.

5.2 System categories

The following details apply:

– 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 only with one phase earthed. This period should, in general, not exceed 1 h, but a longer period can be tolerated as specified in the relevant cable standard.

– Category C

  This category comprises all systems which do not fall into category A or B.

Reference should be made to the relevant cable standards choosing, for example, between those listed in Clause 2.

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 is advisable to classify the system in category C.

5.3 Selection of U_m

U_m should be chosen not less than the highest voltage of the three-phase system as defined in 3.2.2

5.4 Selection of U_p

The value of U_p chosen should not be less than the lightning impulse withstand voltage (and switching, where applicable) selected from IEC 60071-1 in accordance with the line insulation levels, the system protective levels, the surge impedance of the overhead lines and the cables, the length of cables and the distance of the flashover point from terminal.

6 Selection of the conductor size

The conductor size should be chosen from one of the standard sizes given in the relevant standard for cable construction. Where a standard does not exist for the type of cable to be used, the conductor size should be selected from one of the standard sizes for class 2 conductors given in IEC 60228.

In the selection of conductor size, the following factors should be taken into account:

a) The maximum allowed temperature in the cable under the normal operation (see 4.2 h) and short-circuit conditions.

   NOTE The IEC 60287 and IEC 60853 series give details of calculation procedures for different load conditions.

b) Mechanical loads imposed on the cable during installation and in service.

c) The electrical stress at the surface of the insulation (especially for accessories). A small diameter conductor arising from the use of a small cross-sectional area or a thin insulation may result in unacceptably high electric stress in the insulation.

d) Economical optimization of the cable taking into consideration the initial investment costs and the future costs of energy losses during the life of the cable (see IEC 60287-3-2).

e) For cables with very large conductor cross sections ($S > 1\ 600\ mm^2$) used for bulk power transmission, the most appropriate conductor shall be selected by taking into consideration suitable values of skin and proximity effects. Furthermore, appropriate a.c. measurements should be performed to confirm calculated resistance values.

7 Accessories

7.1 General

The design of accessories depends upon the values of the required power-frequency and impulse withstand voltages (which may be different from those required for the cable). Insulation levels for power frequency and impulse voltages will be chosen after consideration of the factors given in Clause 5 and 7.2.2.

The accessories shall withstand all mechanical and electrodynamic forces that can occur during normal operation and short-circuit currents. Special attention shall be taken for connectors, clamping and systems to restrain thermo mechanical stresses.

Accessories designed for U_m above 1 kV and up to 36 kV shall be tested in accordance with the requirements in IEC 60502.

Accessories designed for U_m above 36 kV shall be tested in accordance with the requirements in IEC 60840 and IEC 62067 as appropriate for the voltage level of the cable system.

The quality and performance of any new link or replaced joints and terminations are highly dependent on the skills, competence and workmanship of the jointers who ensure the proper installation of these accessories under field conditions.

Systematic and compulsory training is required by all high-voltage jointers to acquire and confirm the necessary skills.

7.2 Terminations

7.2.1 General

The design of terminations depends upon the degree of exposure to atmospheric pollution (see IEC TS 60815-1) and the altitude at the position of the termination.

7.2.2 Atmospheric pollution

The degree of exposure to atmospheric pollution determines the minimum creepage distances and the type of insulators to be used for cable sealing ends.

7.2.3 Altitude

The air density at high altitude is lower than at sea level. The electric strength of the air is thus reduced, and air clearances which are adequate at sea level may be insufficient at higher altitudes. The puncture strength and oil flashover values of terminations are not affected by altitude. Terminations capable of complying with the required impulse withstand test under standard atmospheric conditions are suitable for use at any altitude below 1 000 m. In order to ensure that the requirement is met at higher altitudes, the air clearances normally specified should be increased by a suitable amount.

7.3 Joints

The design of the joint determines the type of conductor joint that will be used. Which type of joint, pre-molded, pre-fabricated, taped or field molded, shall be used depends on the laying conditions, time for installation, mechanical/electrical/economical properties and material compatibility.

Special designs are used for cross bonding systems.

8 Environmental aspects

Consideration of environmental aspects related to execution of a planned high-voltage cable connection should be made at early stage of system definition. Defined particular requirements should then be made available for designers from the initial phase of both system and product design to promote appropriate selections to be made.

Environmental aspects may cover, but are not limited to, the following items:

– choice of a high-voltage system general design principle in relation to the system location in environment, like its effects to the landscape and population in the vicinity, to operational safety (normal/fault condition), security against atmospheric influences and also in relation to acceptable fault localization and reparation time in case of a fault and impact during installation;
– information about international, regional or national regulated substances so that those for which restrictions apply, can be avoided or reduced to a minimum within all parts and components of cable;
– avoidance of hazardous raw materials in production (e.g. use of lead), or in constructional parts where alternative technical solutions already exist or where they are not needed in order to achieve the required product performance;

- optimization of material consumption in product and system design by avoiding pure mechanical over sizing related to operation environment conditions (e.g. need of an armour is decided in relation to real risk of an external failure instead of tradition);
- product information availability related to option to recycle used materials after their completed life time, either for further re-use or for energy waste processing without hazardous substances;
- option to use recyclable delivery materials, like returnable or recyclable cable drums and accessory packages;
- reference to an environmental management system, e.g. ISO 14000, in component and system production requirements.

Table 1 – Relationship between U_0/U and (U_m) and impulse voltages

Rated voltage of cables and accessories	Nominal system voltage	Highest voltage for equipment	Lightning impulse voltage for equipment	Switching impulse voltage for equipment
U_0 kV	U kV	U_m kV	U_p kV	U_p kV
1,8	3	3,6	40	
3	3	3,6	40	
3,6	6	7,2	60	
6	6	7,2	60	
6	10	12	75	
8,7	10	12	75	
8,7	15	17,5	95	
12	20	24	125	
18	30 33	36	170	
26	45 47	52	250	
36	60 66 69	72,5	325	
64	110 115	123	550	
76	132 138	145	650	
87	150 161	170	750	
127	220 230	245	1 050	
160	275 287	300	1 050	850
190	330 345	362	1 175	950
220	380 400	420	1 425	1 050
290	500	550	1 550	1 175
430	700 750	800	2 100	1 550

Other voltage levels may be used. For such systems, the values of U, U_0, U_m together with impulse voltages should be clearly given, for instance 52/90 (100) – lightning impulse 450 kV.

Annex A
(informative)

System monitoring

A high-voltage cable line may be monitored mainly for two purposes:

– for optimal or maximum applicable current-carrying capacity by measuring cable temperature along cable route;

– for cable system insulation condition investigation by PD measurements.

Cable temperature measurement may be executed by an optical fibre situated inside a cable construction, for example in the cable metallic screen area and by using a monitoring computer with applicable software to read cable line temperature profile. The requirement for a cable temperature monitoring facility, if an optical fibre is integrated into the cable construction, shall be particularly specified in the technical requirements for the cable type to be ordered. Decision about taking such an integrated temperature measurement optical fibre in actual operational use may be made at the initial stage, or it may be delayed for future needs.

The cable and cable system insulation condition may be monitored by using partial discharge (PD) measurement technology to reveal a local defect. For cable system monitoring purposes, results of an initial PD measurement is needed for a basic point. Results of further measurements should be compared to initial results to see if essential changes have occurred. An initial system PD measurement made directly after installation may not only give a basic value for further measurements, but also give an indication of the level of completed installation.

Need for a system monitoring either for the most optimal current-carrying capacity or for cable system condition investigations by system PD measurements should be defined from the point of importance of the cable line.

Bibliography

IEC 60853 (all parts), *Calculation of the cyclic and emergency current rating of cables*

IEC TR 62602, *Conductors of insulated cables – Data for AWG and KCMIL sizes*

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Further particulars of the terms and conditions of the permit may be obtained from the Sri *Lanka Standards Institution, 17, Victoria Place, Elvitigala Mawatha, Colombo 08.*

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SRI LANKA STANDARDS INSTITUTION

The Sri Lanka Standards Institution (SLSI) is the National Standards Organization of Sri Lanka established under the Sri Lanka Standards Institution Act No. 6 of 1984 which repealed and replaced the Bureau of Ceylon Standards Act No. 38 of 1964. The Institution functions under the Ministry of Technology.

The principal objects of the Institution as set out in the Act are to prepare standards and promote their adoption, to provide facilities for examination and testing of products, to operate a Certification Marks Scheme, to certify the quality of products meant for local consumption or exports and to promote standardization and quality control by educational, consultancy and research activity.

The Institution is financed by Government grants, and by the income from the sale of its publications and other services offered for Industry and Business Sector. Financial and administrative control is vested in a Council appointed in accordance with the provisions of the Act.

The development and formulation of National Standards is carried out by Technical Experts and representatives of other interest groups, assisted by the permanent officers of the Institution. These Technical Committees are appointed under the purview of the Sectoral Committees which in turn are appointed by the Council. The Sectoral Committees give the final Technical approval for the Draft National Standards prior to the approval by the Council of the SLSI.

All members of the Technical and Sectoral Committees render their services in an honorary capacity. In this process the Institution endeavours to ensure adequate representation of all view points.

In the International field the Institution represents Sri Lanka in the International Organization for Standardization (ISO), and participates in such fields of standardization as are of special interest to Sri Lanka.

Printed at the Sri Lanka Standards Institution, 17, Victoria Place, Elvitigala Mawatha, Colombo 08.