



UL 60947-4-1A

Underwriters Laboratories Inc. Standard for Safety

Low-Voltage Switchgear and
Controlgear – Part 4-1:
Contactors and motor-starters
– Electromechanical contactors
and motor-starters



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UL Standard for Safety for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, UL 60947-4-1A

Second edition, Dated January 26, 2007

Summary of Topics

The revisions dated April 29, 2011 were issued to incorporate the following changes:

- 1. Harmonization of IEC utilization categories with the UL ratings for control of external loads.*
- 2. Deletion of Table 5.5DV.1 and associated references to standard VA ratings based on size of contactor.*
- 3. Deletion of Clause 6.2DV.3.3 requiring marking for separately provided, poly-phase overload relays.*
- 4. Reduction of the number of marking locations in Table 6.2DV.1 to three.*
- 5. Modification of Clause 6.2DV.3.5 marking requirements for overload relays with removable current elements.*
- 6. Deletion of Clause 8.1DV.2.1 requiring a stop on an instantaneous trip circuit breaker.*
- 7. Deletion of Clause 8.1.5.1DV and all subclauses requiring handle position marking.*
- 8. Deletion of Clause 8.2.5DV.1.2 allowing testing of contactor to be waived when tested as a starter.*
- 9. Deletion of Clause 8.2.5DV.1.4 requiring testing of self-protected manual combination motor controller with a separate remote controlled motor controller.*
- 10. Deletion of Clause 9.1.5DV.1 as this testing is optional.*
- 11. Deletion of Clause 9.3.3.2.2DV.1 requiring calibration testing of devices with overload relay to be tested with largest wire that will fit into terminal.*
- 12. Deletion of Clause 9.3.3.2.2DV.2 addressing the sizing of wire for calibration testing.*
- 13. Deletion of Clause 9.3.3.2.2DV.3 relating sizing of wire for calibration testing to trip marking on relay.*
- 14. Deletion of Clause 9.3.3.2.2DV.4 regarding selection of samples for calibration testing.*
- 15. Revision of Table 8.2.2DV.1 to reference K (Kelvin) instead of C (Celsius) for temperature rises.*
- 16. Revision of Clause 9.3.4.2.3DV.4.1 part (d) to eliminate need for reconducting short circuit testing on overload relays where there has been current element burnout.*
- 17. Clarification of marking for reduced voltage autotransformer controllers.*

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UL 60947-4-1A is an adoption of IEC 60947-4-1, Second Edition, issued by the IEC in 2000, as revised by the corrigendum (July 2001). Please note that the National Difference document incorporates all of the U.S. national differences for UL 60947-4-1A. These revisions involve the revision and deletion of national differences as noted above.

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated May 16, 2008, February 27, 2009 and September 3, 2010.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the preface. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.



Association of Standardization and Certification
NMX-J-290-ANCE
Second Edition



Canadian Standards Association
CAN/CSA C22.2 No. 60947-4-1-07
First Edition (IEC 60947-4-1:2000, MOD)



Underwriters Laboratories Inc.
UL 60947-4-1A
Second Edition

Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

January 26, 2007

(Title Page Reprinted: April 29, 2011)



ANSI/UL 60947-4-1-2011

Approved
by
Standards Council
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Commitment for Amendments

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This ANSI/UL Standard for Safety consists of the Second Edition including revisions through April 29, 2011. The most recent designation of ANSI/UL 60947-4-1A as an American National Standard (ANSI) occurred on April 29, 2011. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

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Preface

This is the common ANCE, CSA, and UL standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters. It is the second edition of NMX-J-290-ANCE, the first edition of CAN/CSA C22.2 No. 60947-4-1, and the second edition of UL 60947-4-1A. This edition of UL 60947-4-1A supersedes the previous edition of UL 60947-4-1 published on April 20, 2004.

This standard is based on IEC Publication 60947-4-1: Edition 2 (2000), Low-voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, as revised by the corrigendum (July 2001). IEC publication 60947-4-1 is copyrighted by the IEC.

This second edition of UL 60947-4-1A is being issued as a tri-national standard. A suffix “A” has been added to the existing standard number to identify it as such from the previously published UL/IEC-based edition. This edition of UL 60947-4-1A is the same standard edition number as the corresponding IEC standard with which this standard is harmonized.

This UL Standard, 60947-4-1A, Standard for Safety for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, is to be used in conjunction with the third edition of UL 60947-1. The requirements for contactors and motor-starters are contained in this part 2 Standard and UL 60947-1.

Requirements of this part 2 Standard, where stated, amend the requirements of UL 60947-1.

This common standard was prepared by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (CSA), and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Industrial Control Equipment, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

This standard was reviewed by the CSA Subcommittee on 60947-4-1, under the jurisdiction of the CSA Technical Committee on Industrial Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

This standard has been approved as a National Standard of Canada by the Standards Council of Canada.

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of harmonization

This standard adopts the IEC text with national differences.

This standard is published as an equivalent standard for ANCE, CSA, and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

All national differences from the IEC text are included in the ANCE, CSA, and UL versions of the standard. While the technical content is the same in each organization's version, the format and presentation may differ.

Reasons for differences from IEC

This standard adopts the IEC text with national differences. Where applicable, national differences have been identified throughout the standard for the countries involved.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

ANCE Effective Date

The effective date for ANCE will be announced through the Diario Oficial de la Federación (Official Gazette) and is indicated on the cover page.

CSA Effective Date

The effective date for CSA International will be announced through *CSA Informs* or a CSA Certification Notice.

UL Effective Date

As of January 26, 2017, all products Listed or Recognized by UL must comply with the requirements in this standard.

Between January 26, 2012 and January 26, 2017, all new product submittals will be evaluated to this standard. Revisions to existing UL 508 products will be evaluated to this standard unless the manufacturer specifically requests that the products be evaluated to the superseded requirements of UL 508.

Between January 26, 2007 and January 26, 2012, new product submittals to UL may be evaluated under this standard or, if requested in writing, evaluated under UL 508.

A UL effective date is one established by Underwriters Laboratories Inc. and is not part of the ANSI approved standard.

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National Differences

National Differences from the text of International Electrotechnical Commission (IEC) Publication 60947-4-1, Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, edition 2 (2000), are indicated by notations (differences) and are presented in bold text.

There are five types of National Differences as noted below. The difference type is noted on the first line of the National Difference in the standard. The standard may not include all types of these National Differences.

DR – These are National Differences based on the **national regulatory requirements**.

D1 – These are National Differences which are based on **basic safety principles and requirements**, elimination of which would compromise safety for consumers and users of products.

D2 – These are national differences from IEC requirements based on existing **safety practices**. These requirements reflect national safety practices, where empirical substantiation (for the IEC or national requirement) is not available or the text has not been included in the IEC standard.

DC – These are National Differences based on the **component standards** and will not be deleted until a particular component standard is harmonized with the IEC component standard.

DE – These are National Differences based on **editorial comments or corrections**.

Each national difference contains a description of what the national difference entails. Typically one of the following words is used to explain how the text of the national difference is to be applied to the base IEC text:

Addition / Add - An addition entails adding a complete new numbered clause, subclause, table, figure, or annex. Addition is not meant to include adding select words to the base IEC text.

Modification / Modify - A modification is an altering of the existing base IEC text such as the addition, replacement or deletion of certain words or the replacement of an entire clause, subclause, table, figure, or annex of the base IEC text.

Deletion / Delete - A deletion entails complete deletion of an entire numbered clause, subclause, table, figure, or annex without any replacement text.

INTERNATIONAL ELECTROTECHNICAL COMMISSION**LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 4-1: Contactors and motor-starters –
Electromechanical contactors and motor-starters****FOREWORD**

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.

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International Standard IEC 60947-4-1 has been prepared by subcommittee 17B: Low-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This standard should be used in conjunction with IEC 60947-1.

This second edition cancels and replaces the first edition published in 1990, the corrigendum (1991), amendment 1 (1994), amendment 2 (1996) and amendment 3 (2000).

The text of this standard is based on first edition, amendment 1, amendment 2 and the following documents:

FDIS	Report on voting
17B/1049/FDIS	17B/1083/RVD

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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 3.

The committee has decided that the contents of this publication will remain unchanged until 2003. At this date, the publication will be

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

The provisions of the general rules dealt with in part 1 (IEC 60947-1) are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to part 1, e.g. 1.2.3 of part 1, table 4 of part 1 or annex A of part 1.

DV.1 D2 Modification: Replace the paragraph referencing IEC 60947-1 with the following:

The provisions of the general rules dealt with in Annex DVB, Table 101.DVB.3, Ref. No. 10, are applicable to this standard. Where specifically called for, any references to Part 1 shall be to the applicable clause, either to the national difference, "DV", or to an IEC clause.

Annexes A and B form an integral part of this standard.

Annexes C and D are for information only.

DV.2 DE Modification: Replace the two statements referencing Annexes with the following:

Annexes C, 101.DVA, and DVB form an integral part of this standard.

Annexes A, B, D, and DVC are informative.

DV.3 DE Modification: Add the following to the Foreword:

In Canada, manufacturers designing products for use in Canada can find a helpful summary of the equipment related references of the Canadian Electrical Code, Part I, in the CSA publication entitled, "Guide for the Design of Electrical Equipment for Installation and Use in Canada." In Mexico and United States, this does not apply.

In Canada, the Canadian Electrical Code, Part I, requires that the disconnecting means disconnect all ungrounded conductors of the circuit simultaneously. In Mexico and United States, this does not apply.

In Canada, the requirements of Annex DVB, Table 101.DVB.3, Ref. No. 14, are applicable.

In Mexico and United States, this does not apply.

The contents of the corrigendum of July 2001 have been included in this copy.

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Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters

1 Scope and object

This part of IEC 60947 applies to the types of equipment listed in 1.1 and 1.2 whose main contacts are intended to be connected to circuits the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

Starters and/or contactors dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 9.3.4) shall form part of the installation but not necessarily of the contactor or the starter.

In this context, this standard gives requirements for:

- contactors associated with overload and/or short-circuit protective devices;
- starters associated with separate short-circuit protective devices and/or with separate short-circuit and integrated overload protective devices;
- contactors or starters combined, under specified conditions, with their own short-circuit protective devices. Such combinations, e.g. combination starters (see 3.2.7) or protected starters (see 3.2.8) are rated as units.

Circuit-breakers and fuse-combination units used as short-circuit protective devices in combination starters and in protected starters shall comply with the requirements of IEC 60947-2 and IEC 60947-3, as the case may be.

1DV DC Modification to Clause 1:

1DV.1 Circuit breakers used as short-circuit protective devices in combination starters and protected starters shall comply with the requirements of Annex DVB, Table 101.DVB.3, Ref. No. 3. IEC 60947-2 Part 2: Circuit-breakers does not apply.

1DV.2 Disconnect switches shall comply with the requirements of Annex DVB, Table 101.DVB.3, Ref. No 1. IEC 60947-3 Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units does not apply.

1DV.3 Fuses used as short-circuit protective devices in combination and protected starters shall comply with the requirements of Annex DVB, Table 101.DVB.3, Ref. No. 2.

1DV.4 Molded case switches in combination with fuses used as short-circuit protective devices in combination starters shall comply with the requirements of Annex DVB, Table 101.DVB.3, Ref. No. 3, and Annex DVB, Table 101.DVB.3, Ref. No. 2.

Equipment covered by this standard is as follows.

1.1 AC and d.c. contactors

AC and d.c. contactors intended for closing and opening electric circuits and, if combined with suitable relays (see 1.2), for protecting these circuits against operating overloads which may occur therein.

NOTE Contactors combined with suitable relays and which are intended to provide short-circuit protection shall additionally satisfy the relevant conditions specified for circuit-breakers (IEC 60947-2).

1.1DV DC Modify note in 1.1 by replacing with the following:

The note reference to IEC 60947-2 does not apply.

This standard applies also to the actuators of contactor relays and to the contacts dedicated exclusively to the coil circuit of a contactor.

1.1DV.2 D2 Modification: Add the following to 1.1:

1.1DV.2.1 This standard also applies to manual controllers.

1.2 AC motor-starters

AC motor-starters intended to start and accelerate motors to normal speed, to ensure continuous operation of motors, to switch off the supply from the motor and to provide means for the protection of motors and associated circuits against operating overloads.

Starters the operation of which depends on thermal electrical relays for motor protection complying with IEC 60255-8, or motor-incorporated thermal protective devices dealt with in IEC 60034-11 do not necessarily meet all the relevant requirements of this standard.

Overload relays for starters, including those based on solid state technology, shall meet the requirements of this standard.

1.2.1 Direct-on-line (full voltage) a.c. starters

Direct-on-line starters intended to start and accelerate a motor to normal speed, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

This standard applies also to reversing starters.

1.2.1DV D2 Modification: Add the following to 1.2.1:

Self-protected combination motor controller – Self-protected combination motor controller intended to start and accelerate a motor to normal speed, to provide means for the protection of the motor and its associated circuits against operating overloads and short circuits, and to switch off the supply from the motor. A disconnecting means is also provided.

1.2.2 Reduced voltage a.c. starters

Reduced voltage a.c. starters intended to start and accelerate a motor to normal speed by connecting the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

Automatic change-over devices may be used to control the successive switching operations from one step to the others. Such automatic change-over devices are, for example, time-delay contactor relays or specified time all-or-nothing relays, under-current devices and automatic acceleration control devices (see 5.10).

1.2.2.1 Star-delta starters

Star-delta starters intended to start a three-phase motor in the star connection, to ensure continuous operation in the delta connection, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

The star-delta starters dealt with in this standard are not intended for reversing motors rapidly and, therefore, utilization category AC-4 does not apply.

NOTE In the star connection, the current in the line and the torque of the motor are about one-third of the corresponding values for delta connection. Therefore, star-delta starters are used when the inrush current due to the starting is to be limited, or when the driven machine requires a limited torque for starting. Figure 1 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.

1.2.2.2 Two-step auto-transformer starters

Two-step auto-transformer starters, intended to start and accelerate an a.c. induction motor from rest with reduced torque to normal speed and to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

This standard applies to auto-transformers which are part of the starter or which constitute a unit specially designed to be associated with the starter.

Auto-transformer starters with more than two steps are not covered by this standard.

The auto-transformer starters dealt with in this standard are not intended for inching duty or reversing motors rapidly and, therefore, utilization category AC-4 does not apply.

NOTE In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage):(rated voltage). Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited or when the driven machine requires a limited torque for starting. Figure 2 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.

1.2.3 Rheostatic rotor starters

Starters intended to start an a.c. induction motor having a wound rotor by cutting out resistors previously inserted in the rotor circuit, to provide means for the protection of the motor against operating overloads and to switch off the supply from the motor.

In the case of asynchronous slip-ring motors (wound-rotors), the highest voltage between open slip-rings shall be not greater than twice the rated insulation voltage of the switching devices inserted in the rotor circuit (see 5.3.1.1.2).

NOTE This requirement is based on the fact that the electric stresses are less severe in the rotor than in the stator and are of short duration.

This standard applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped (see 5.3.5.5). Operations including inching and plugging necessitate additional requirements and shall be subject to agreement between manufacturer and user.

This standard applies to resistors which are part of the starter or constitute a unit specially designed to be associated with the starter.

1.3 This standard does not apply to:

- d.c. starters;
- star-delta starters, rheostatic rotor starters, two-step auto-transformer starters intended for special applications and designed for continuous operation in the starting position;
- unbalanced rheostatic rotor starters, i.e. where the resistances do not have the same value in all phases;
- equipment designed not only for starting, but also for adjustment of speed;
- liquid starters and those of the "liquid-vapour" type;
- semiconductor contactors and starters making use of semiconductor contactors in the main circuit;
- rheostatic stator starters;
- contactors or starters designed for special applications;
 - auxiliary contacts of contactors and contacts of contactor relays. These are dealt with in IEC 60947-5-1.

1.3DV D2 Modify 1.3 by adding the following:

1.3DV.1 This standard does not apply to controllers for hermetic compressor applications.

1.4 The object of this standard is to state:

- a) the characteristics of contactors and starters and associated equipment;
- b) the conditions with which contactors or starters shall comply with reference to:
 - 1) their operation and behaviour,
 - 2) their dielectric properties,
 - 3) the degrees of protection provided by their enclosures, where applicable,
 - 4) their construction;
- c) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
- d) the information to be given with the equipment or in the manufacturer's literature.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60947. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60947 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60034-1: 1996,
Rotating electrical machines – Part 1: Rating and performance

IEC 60034-11: 1978,
Rotating electrical machines – Part 11: Built-in thermal protection – Chapter 1: Rules for protection of rotating electrical machines

IEC 60050(441): 1984,
International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses

IEC 60076-1: 1993,
Power transformers – Part 1: General

IEC 60085: 1984,
Thermal evaluation and classification of electrical insulation

IEC 60112: 1979,
Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions

IEC 60255-8: 1990,
Electrical relays – Part 8: Thermal electrical relays

IEC 60269-1: 1998,
Low-voltage fuses – Part 1: General requirements

IEC 60269-2: 1986,
Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)

IEC 60269-2-1: 1998,
Low-voltage fuses – Part 2-1: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Sections I to V: Examples of types of standardized fuses

IEC 60410: 1973,
Sampling plans and procedures for inspection by attributes

IEC 60947-1:1999,
Low-voltage switchgear and controlgear – Part 1: General rules

IEC 60947-2: 1995,
*Low-voltage switchgear and controlgear – Part 2: Circuit-breakers**

IEC 60947-3: 1999,
Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units

IEC 60947-5-1: 1997,
*Low-voltage switchgear and controlgear - Part 5: Control circuit devices and switching elements - Section 1: Electromechanical control circuit devices***

IEC 61000-4-2: 1995,
*Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC publication****

IEC 61000-4-3:1995,
*Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated radio-frequency electromagnetic field immunity test*****

IEC 61000-4-4:1995,
Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test – Basic EMC publication

IEC 61000-4-5:1995,
Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test

IEC 61095: 1992,
Electromechanical contactors for household and similar purposes

IEC 61810-1: 1998,
Electromechanical all-or-nothing relays – Part 1: General requirements

CISPR 11: 1997,
Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics – Limits and methods of measurement

*There is a consolidated edition 2.1 (1998) that includes IEC 60947-2 (1995) and its amendment 1 (1997).

**There is a consolidated edition 2.1 (1999) that includes IEC 60947-5-1 (1997) and its amendment 1 (1999).

***There is a consolidated edition 1.1 (1999) that includes IEC 61000-4-2 (1995) and its amendment 1 (1998).

****There is a consolidated edition 1.1 (1998) that includes IEC 61000-4-3 (1995) and its amendment 1 (1998).

2DV D2 Modification: Add the following to Clause 2:

2DV.1 For a list of normative standards, see Annex DVB, Table 101.DVB.1 and Table 101.DVB.2, for normative references. See informative Annex DVC, Table 101.DVC.1, for component standards.

3 Definitions

For the purpose of this part of IEC 60947, the definitions of clause 2 of IEC 60947-1 together with the following additional definitions apply.

3DV D2 Addition: Add the following to Clause 3:

3.101DV "CO" operation – An operation of closing the test device on the circuit.

3.102DV "O" operation – An operation of closing the circuit on the test device. The test device is placed in the closed position before the start of the test.

3.103DV Group installation – A motor branch circuit for two or more motors, or one or more motors with other loads and protected by a circuit breaker or a single set of fuses.

3.104DV Self-protected – A qualifying term applied to a controller that contains coordinated overload and short circuit protection. A self-protected controller is evaluated as a complete unit whether comprised of a single or multiple components. Coordinated protection may be inherent or obtained by correct selection of components or accessory parts in accordance with the manufacturer's instructions.

3.1 Definitions concerning contactors

3.1.1 contactor (mechanical) mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

NOTE Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[IEV 441-14-33]

The followings notes are not included in IEV 441-14-33:

NOTE 1 The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies.

NOTE 2 In French, a contactor the main contacts of which are closed in the position of rest is usually called a "rupteur". The word "rupteur" has no equivalent in the English language.

NOTE 3 A contactor is usually intended to operate frequently.

3.1.2 electromagnetic contactor contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

3.1.3 pneumatic contactor contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air, without the use of electrical means

3.1.4 electro-pneumatic contactor contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air under the control of electrically operated valves

3.1.5 latched contactor contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

NOTE 1 The latching, and the release of the latching, may be mechanical, electromagnetic, pneumatic, etc.

NOTE 2 Because of the latching, the latched contactor actually acquires a second position of rest and, according to the definition of a contactor, it is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[IEV 441-14-34]

3.1.6 vacuum contactor (or starter) contactor (or starter) in which the main contacts open and close within a highly evacuated envelope

3.1.7 position of rest (of a contactor) position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized [IEV 441-16-24]

3.2 Definitions concerning starters

3.2.1 **starter** combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection [IEV 441-14-38]

3.2.2 **direct-on-line starter** starter which connects the line voltage across the motor terminals in one step [IEV 441-14-40]

3.2.3 **reversing starter** starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections while the motor may be running

3.2.4 **two-direction starter** starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections only when the motor is not running

3.2.5 **reduced voltage starter** starter which connects the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals

3.2.5.1 **star-delta starter** starter for a three-phase induction motor such that in the starting position the stator windings are connected in star and in the final running position they are connected in delta [IEV 441-14-44]

3.2.5.2 **auto-transformer starter** starter for an induction motor which uses for starting one or more reduced voltages derived from an auto-transformer [IEV 441-14-45]

NOTE (not included in IEV 441-14-45) An auto-transformer is defined as follows in 3.1.2 of IEC 60076-1:

“A transformer in which at least two windings have a common part.”

3.2.6 **rheostatic starter** starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and for limiting the current [IEV 441-14-42]

NOTE (not included in IEV 441-14-42) A rheostatic starter generally consists of three basic parts which may be supplied either as a composite unit or as separate units to be connected at the place of utilization:

- the mechanical switching devices for supplying the stator (generally associated with an overload protective device);
- the resistor(s) inserted in the stator or rotor circuit;
- the mechanical switching devices for cutting out the resistor(s) successively.

3.2.6.1 **rheostatic stator starter** rheostatic starter for a squirrel cage motor which, during the starting period, cuts out successively one or several resistors previously provided in the stator circuit

3.2.6.2 **rheostatic rotor starter** rheostatic starter for an asynchronous wound-rotor motor which, during the starting period, cuts out successively one or several resistors previously provided in the rotor circuit [IEV 441-14-43]

3.2.7 **combination starter** (see figure 3) equipment consisting of a starter, a manual externally operated switching device and a short-circuit protective device, mounted and wired in a dedicated enclosure. The switching and short-circuit protective devices may be a fuse combination unit, a switch with fuses or a circuit-breaker with or without an isolating function

NOTE 1 A dedicated enclosure is an enclosure specifically designed and dimensioned for its application in which all tests are conducted.

NOTE 2 The manually operated switching device and the short-circuit protective device may be just one device and may incorporate the overload protection as well.

3.2.8 protected starter equipment consisting of a starter, a manually operated switching device and a short-circuit protective device, mounted and wired, enclosed or unenclosed according to the instructions of the starter manufacturer

NOTE The manually operated switching device and the short-circuit protective device may be one single device and may incorporate the overload protection as well.

3.2.9 manual starter starter in which the force for closing the main contacts is provided exclusively by manual energy [IEV 441-14-39]

3.2.10 electromagnetic starter starter in which the force for closing the main contacts is provided by an electromagnet

3.2.11 motor-operated starter starter in which the force for closing the main contacts is provided by an electric motor

3.2.12 pneumatic starter starter in which the force for closing the main contacts is provided by using compressed air, without the use of electrical means

3.2.13 electro-pneumatic starter starter in which the force for closing the main contacts is provided by using compressed air under the control of electrically operated valves

3.2.14 single-step starter starter in which there is no intermediate accelerating position between the OFF and ON positions

NOTE This starter is a direct-on-line starter (see 3.2.2).

3.2.15 two-step starter starter in which there is only one intermediate accelerating position between the OFF and ON positions

Example: A star-delta starter is a two-step starter.

3.2.16 n-step starter (see figure 4) starter in which there are (n-1) intermediate accelerating positions between the OFF and ON positions

Example: A three-step rheostatic starter has two sections of resistors used for starting.

[IEV 441-14-41]

3.2.17 phase loss sensitive thermal overload relay or release multipole thermal overload relay or release which operates in the case of overload and also in case of loss of phase in accordance with specified requirements

3.2.18 under-current (under-voltage) relay or release measuring relay or release which operates automatically when the current through it (or the voltage applied to it) is reduced below a pre-determined value

3.2.19 **starting time (of a rheostatic starter)** period of time during which the starting resistors or parts of them carry current

3.2.20 **starting time (of an auto-transformer starter)** period of time during which the auto-transformer carries current

NOTE to 3.2.19 and 3.2.20 The starting time of a starter is shorter than the total starting time of the motor which takes into account the last period of acceleration following the switching operation ON position.

3.2.21 **open transition (with an auto-transformer starter or star-delta starter)** circuit arrangement such that the supply to the motor is interrupted and reconnected when changing over from one step to another

NOTE The transition stage is not considered an additional step.

3.2.22 **closed transition (with an auto-transformer starter or star-delta starter)** circuit arrangement such that the supply to the motor is not interrupted (even momentarily) when changing over from one step to another

NOTE The transition stage is not considered an additional step.

3.2.23 **inching (jogging)** energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.2.24 **plugging** stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.2DV D2 Addition: Add the following to 3.2:

3.2DV.1 Combination controller – An open or enclosed device containing a magnetic controller and a disconnecting means. The controller is not required to contain overload protection or short circuit protection. An enclosed combination controller includes an external means for operating the disconnecting means.

3.2DV.2 Combination motor controller – A controller intended for motor service that provides a disconnecting means, branch circuit (short-circuit and ground fault) protection, motor controller, and motor overload protection. In addition, where an individual controller is enclosed, it includes means for locking the disconnecting device in the "OFF" position.

3.2DV.3 Motor controller – A device or group of devices that serve to govern in some predetermined manner the electric power delivered to the motor. A motor controller is rated in horsepower, kilowatts, or locked-rotor and full-load amperes.

3.2DV.4 Manual controller – A hand-operated switching device whose contacts are controlled by the position of a mechanical actuator. A manual controller may be provided with an instantaneous trip element for short circuit protection only and optionally provided with an overload relay.

3.3 Characteristic quantities

3.3.1 Transient recovery voltage (abbreviation: TRV) [IEV 441-17-26]

Subclause 2.5.34 of part 1 applies with the following addition.

NOTE 3 (*not included in IEC 441-17-26*) In a vacuum contactor or starter, the highest transient recovery voltage may occur on an other pole than the first pole to clear.

4 Classification

Subclause 5.2 gives all the data which may be used as criteria for classification.

5 Characteristics of contactors and starters

5.1 Summary of characteristics

The characteristics of a contactor or starter shall be stated in the following terms, where such terms are applicable:

- type of equipment (5.2);
- rated and limiting values for main circuits (5.3);
- utilization category (5.4);
- control circuits (5.5);
- auxiliary circuits (5.6);
- types and characteristics of relays and releases (5.7);
- co-ordination with short-circuit protective devices (5.8);
- switching overvoltages (5.9);
- types and characteristics of automatic change-over devices and automatic acceleration control devices (5.10);
- types and characteristics of auto-transformers for two-step auto-transformer starters (5.11);
- types and characteristics of starting resistors for rheostatic rotor starters (5.12).

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5.2 Type of equipment

The following shall be stated (see also clause 6).

5.2.1 Kind of equipment

- contactor;
- direct-on-line a.c. starter;
- star-delta starter;
- two-step auto-transformer starter;
- rheostatic rotor starter;
- combination or protected starter.

5.2.2 Number of poles

5.2.3 Kind of current (a.c. or d.c.)

5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)

5.2.5 Operating conditions of the equipment

5.2.5.1 Method of operation

For example: manual, electromagnetic, motor-operated, pneumatic, electro-pneumatic.

5.2.5.2 Method of control

For example:

- automatic (by pilot switch or sequence control);
- non-automatic (such as by hand operation or by push-buttons);
- semi-automatic (i.e. partly automatic, partly non-automatic).

5.2.5.3 Method of change-over for particular types of starters

The change-over for star-delta starters, rheostatic rotor starters or auto-transformer starters may be automatic, non-automatic or semi-automatic (see figures 4 and 5).

5.2.5.4 Method of connecting for particular types of starters

For example: open transition starter, closed transition starter (see figure 5).

5.3 Rated and limiting values for main circuits

The rated values established for a contactor or starter shall be stated in accordance with subclauses 5.3.1 to 5.4, and 5.8 and 5.9, but it may not be necessary to specify all the values listed.

NOTE The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.2, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.5 but it is not necessary to specify all the values listed.

5.3.1 Rated voltages

A contactor or starter is defined by the following rated voltages.

5.3.1.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of part 1 applies.

5.3.1.1DV D2 Modification: Add the following to 5.3.1.1:

5.3.1.1DV.1 The rating of a.c. equipment shall include the number of phases except that the rating of equipment obviously intended for single-phase use only is not required to include the number of phases.

5.3.1.1.1 Rated stator operational voltage (U_{es})

For rheostatic rotor starters, a rated stator operational voltage is a value of voltage which, when combined with a rated stator operational current, determines the application of the stator circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics. In no case shall the maximum rated operational voltage exceed the corresponding rated insulation voltage.

NOTE The rated stator operational voltage is expressed as the voltage between phases.

5.3.1.1.2 Rated rotor operational voltage (U_{er})

For rheostatic rotor starters, the value of rated operational voltage is that of the voltage which, when combined with a rated rotor operational current, determines the application of the rotor circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

This voltage is taken as equal to the voltage measured between slip-rings, with the motor stopped and the rotor open-circuited, when the stator is supplied at its rated voltage.

The rated rotor operational voltage is only applied for a short duration during the starting period. For this reason, it is permissible that the rated rotor operational voltage exceed the rated rotor insulation voltage by 100 %.

The maximum voltage between the different live parts (e.g. switching devices, resistors, connecting parts, etc.) of the rotor circuit of the starter will vary and account may be taken of this fact in choosing the equipment and its disposition.

5.3.1.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of part 1 applies.

5.3.1.2.1 Rated stator insulation voltage (U_{is})

For rheostatic rotor starters, the rated stator insulation voltage is the value of voltage which is designated for the devices inserted in the stator supply as well as the unit they are part of, and to which dielectric tests and creepage distances are referred.

Unless otherwise stated, the rated stator insulation voltage is the value of the maximum rated stator operational voltage of the starter.

5.3.1.2.2 Rated rotor insulation voltage (U_{ir})

For rheostatic rotor starters, the rated rotor insulation voltage is the value of voltage which is designated to the devices inserted in the rotor circuit as well as the unit they are part of (connecting links, resistors, enclosure), and to which dielectric tests and creepage distances are referred.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of part 1 applies.

5.3.1.4 Rated starting voltage of an auto-transformer starter

The rated starting voltage of an auto-transformer starter is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage are 50 %, 65 % or 80 % of the rated operational voltage.

5.3.2 Currents or powers

A contactor or a starter is defined by the following currents.

NOTE In the case of a star-delta starter, these currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.

5.3.2.1 Conventional free air thermal current (I_{th})

Subclause 4.3.2.1 of part 1 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of part 1 applies.

5.3.2.3 Conventional stator thermal current (I_{ths})

The conventional stator thermal current of a starter may be either free air current I_{ths} or enclosed current I_{thes} , in line with 5.3.2.1 and 5.3.2.2.

For a rheostatic rotor starter, the stator thermal current is the maximum current it can carry on eight-hour duty (see 5.3.4.1) without the temperature rise of its several parts exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

5.3.2.4 Conventional rotor thermal current (I_{thr})

The conventional rotor thermal current of a starter may be either free air current I_{thr} or enclosed current I_{ther} , in line with 5.3.2.1 and 5.3.2.2.

For rheostatic rotor starters, the rotor thermal current is the maximum current that those parts of the starter through which the rotor current flows in the ON position, viz. after cutting out resistors, can carry on eight-hour duty (see 5.3.4.1) without their temperature rise exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

NOTE 1 For those elements (switching devices, connecting links, resistors) through which a current of practically no value flows in the ON position, it should be verified that, for the rated duties (see 5.3.4) stated by the manufacturer, the value of integral

$$\int_0^t i^2 dt$$

does not lead to temperature rises higher than those appearing in 8.2.2.

NOTE 2 When resistors are built-in into the starter, the temperature rise should be taken into account.

5.3.2.5 Rated operational currents (I_e) or rated operational powers

A rated operational current of a contactor or a starter is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.1.1), the conventional free air or enclosed thermal current, the rated current of the overload relay, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the current and the power.

For starters, the rated operational current (I_e) is the current in the ON position of the starter.

5.3.2.5DV D2 Modification: Add the following to 5.3.2.5:

5.3.2.5DV.1 For kW/horsepower rated devices, see Annex 101.DVA. In Canada and the United States, only horsepower rated devices apply. In Mexico, only kW ratings rated devices apply.

5.3.2.6 Rated stator operational current (I_{es}) or rated stator operational power

For rheostatic rotor starters, a rated stator operational current is stated by the manufacturer and takes into account the rated current of the overload relay installed in this starter, the rated stator operational voltage (see 5.3.1.1.1), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.5) and the type of protective enclosure.

The indication of a rated stator operational current may be replaced by the indication of the maximum rated power output, at the rated stator operational voltage considered, of the motor for which the stator elements of the starter are intended. The manufacturer shall be prepared to state the relationship assumed between the motor power and the stator current.

5.3.2.7 Rated rotor operational current (I_{er})

For rheostatic rotor starters, a rated rotor operational current is stated by the manufacturer and takes into account the rated rotor operational voltage (see 5.3.1.1.2), the conventional free air or enclosed rotor thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.5) and the type of protective enclosure.

It is taken as equal to the current flowing in the connections to the rotor when the latter is short-circuited and the motor is running at full load and the stator is supplied at its rated voltage and rated frequency.

When the rotor part of a rheostatic rotor starter is rated separately, the indication of a rated rotor operational current may be supplemented by the maximum rated power output, for motors having the rated rotor operational voltage considered, of the motor for which that part of the starter (switching devices, connecting links, relays, resistors) is intended. This power varies in particular with the breakaway torque foreseen and consequently takes into account the starting characteristics (see 5.3.5.5).

5.3.2.8 Rated uninterrupted current (I_u)

Subclause 4.3.2.4 of part 1 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of part 1 applies.

5.3.4 Rated duties

Subclause 4.3.4 of part 1 applies.

5.3.4.1 Eight-hour duty (continuous duty)

Subclause 4.3.4.1 of part 1 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor-starter, the continuous duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed while each of them carries a steady current long enough for the starter to reach thermal equilibrium, but not for more than 8 h without interruption.

5.3.4.2 Uninterrupted duty

Subclause 4.3.4.2 of part 1 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor starter, the uninterrupted duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed without interruption while each of them carries a steady current for periods of more than 8 h (weeks, months or even years).

5.3.4.3 Intermittent periodic duty or intermittent duty

Subclause 4.3.4.3 of part 1 applies with the following addition.

For a reduced voltage starter, the intermittent duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the starter to reach thermal equilibrium.

Preferred classes of intermittent duty are:

- for contactors: 1, 3, 12, 30, 120, 300 and 1 200 (operating cycles per hour);
- for starters: 1, 3, 12 and 30 (operating cycles per hour).

It is recalled that an operating cycle is a complete working cycle comprising one closing operation and one opening operation.

For starters, an operating cycle comprises starting, running to full speed and switching off the supply from the motor.

NOTE In the case of starters for intermittent duty, the difference between the thermal time-constant of the overload relay and that of the motor may render a thermal relay unsuited for overload protection. It is recommended that, for installations intended for intermittent duty, the question of overload protection be subject to agreement between manufacturer and user.

5.3.4.4 Temporary duty

Subclause 4.3.4.4 of part 1 applies.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of part 1 applies.

5.3.5 Normal load and overload characteristics

Subclause 4.3.5 of part 1 applies with the following additions.

5.3.5.1 Ability to withstand motor switching overload currents

Requirements to meet these conditions are given for contactors in 8.2.4.4.

5.3.5.2 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.3 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.4 Conventional operational performance

This performance is specified as a series of making and breaking operations in 8.2.4.2.

5.3.5.5 Starting and stopping characteristics of starters (see figure 6)

Typical service conditions for starters are:

- a) one direction of rotation with the motor being switched off during running in normal service conditions (utilization categories AC-2 and AC-3);
- b) two directions of rotation, but the running in the second direction is realized after the starter has been switched off and the motor has completely stopped (utilization categories AC-2 and AC-3);
- c) one direction of rotation, or two directions of rotation as in item b), but with the possibility of infrequent inching (jogging). For this service condition, direct-on-line starters are usually employed (utilization category AC-3);
- d) one direction of rotation with frequent inching (jogging). Usually direct-on-line starters (utilization category AC-4) are used for this duty;

e) one or two directions of rotation, but with the possibility of infrequent plugging for stopping the motor, plugging being associated, if so provided, with rotor resistor braking (reversing starter with braking). Usually a rheostatic rotor starter is used for this duty condition (utilization category AC-2);

f) two directions of rotation, but with the possibility of reversing the supply connections to the motor while it is running in the first direction (plugging), in order to obtain its rotation in the other direction, with switching off the motor running in normal service conditions. Usually a direct-on-line reversing starter is used for this duty condition (utilization category AC-4).

Unless otherwise stated, starters are designed on the basis of the starting characteristics of the motors compatible with the making capacities of table 7. These making capacities cover both the transient and steady-state starting currents of the great majority of standard motors. However, the starting currents for some large motors may attain peak values corresponding to power factors considerably lower than those specified for the test circuit in table 7. In these cases, the operational current of the contactor or starter should be decreased to a value lower than its rated value such that the making capacity of the contactor or starter is not exceeded.

5.3.5.5.1 Starting characteristics of rheostatic rotor starters

A distinction shall be drawn between the currents and voltages in the stator and rotor circuits of slip-ring motors. However, the changes of the current values in stator and rotor circuits, caused by the various steps of the starting process, are nearly proportional under normal operating conditions.

The following definitions deal mainly with the characteristics of the rotor circuit:

U_{er} = rated rotor operational voltage;

I_{er} = rated rotor operational current;

Z_r = characteristic impedance of the rotor of an a.c. slip-ring induction motor;

where

$$Z_r = \frac{U_{er}}{\sqrt{3} \cdot I_{er}} ;$$

I_1 is the current in the rotor circuit immediately before shorting out a resistor section;

I_2 is the current in the rotor circuit immediately after shorting out a resistor section;

$I_m = 1/2 (I_1 + I_2)$;

T_e is the rated motor operational torque;

t_s is the starting time (see 3.2.19);

k is the severity of start = I_m / I_{er} .

It is recognized that many rheostatic rotor starter applications have very specific starting requirements which may result not only in a different number of starting steps and different values of I_1 and I_2 , but also in the values of I_1 and I_2 being different for individual resistor sections. Therefore, no attempt has been made to lay down standard parameters, but the following factors should be taken into consideration:

- for most applications, between two and six starting steps are adequate depending upon load torque, inertia and the severity of start required;
- the resistor sections should be designed to have adequate thermal ratings bearing in mind the starting time of the drive, which will be dependent upon load torque and load inertia.

5.3.5.5.2 Standard conditions for making and breaking corresponding to the starting characteristics for rheostatic rotor starters

These conditions are given in table 7 and apply to starting with high torque. (For the designation of the mechanical switching devices, see figure 4.)

NOTE Conditions for starting with full torque and half torque are under consideration.

The conditions for making and breaking as given in table 7 for AC-2 utilization category are considered as standard.

The starter circuit shall be designed to open all rotor resistor switching devices before or approximately simultaneously with the opening of the stator switching device. Otherwise, the stator switching device shall comply with AC-3 requirements.

5.3.5.5.3 Starting characteristics for two-step auto-transformer starters

Unless otherwise stated, the auto-transformer starters and specifically the auto-transformers are designed on the condition that the starting time (see 3.2.20) for all classes of duty (see 5.3.4) shall not exceed 15 s. The number of starting cycles per hour assumes equal periods between starts except that, in the event of two operating cycles being made in rapid succession, the starter and the auto-transformer shall be allowed to cool to ambient air temperature before a further start is made.

When a starting time in excess of 15 s is required, this shall be the subject of agreement between manufacturer and user.

5.3.5.5.3DV D2 Modification: Add the following to 5.3.5.5.3:

5.3.5.5.3DV.1 Intermittent duty ratings for reduced voltage motor starting – Ratings for heavy and medium duty controllers shall be based on the duty cycles and the load conditions specified in Table 9.3.3.6DV.4.

5.3.6 Rated conditional short-circuit current

Subclause 4.3.6.4 of part 1 applies.

5.4 Utilization category

Subclause 4.4 of part 1 applies with the following additions.

For contactors and starters, the utilization categories as given in table 1 are considered standard. Any other type of utilization shall be based on agreement between manufacturer and user, but information given in the manufacturer's catalogue or tender may constitute such an agreement.

Each utilization category is characterized by the values of the currents, voltages, power-factors or time-constants and other data of tables 7 and 8, and by the test conditions specified in this standard.

For contactors or starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in table 7.

The voltage for all utilization categories is the rated operational voltage of a contactor or a starter other than a rheostatic rotor starter, and the rated stator operational voltage for a rheostatic rotor starter.

All direct-on-line starters belong to one or more of the following utilization categories: AC-3, AC-4, AC-7b, AC-8a and AC-8b.

All star-delta and two-step auto-transformer starters belong to utilization category AC-3.

Rheostatic rotor starters belong to utilization category AC-2.

5.4DV D2 Addition to 5.4:

5.4DV.1 The equipment rating and required load designation shall be in accordance with Table 5.4DV.1. In addition, utilization categories and/or additional load designations may be marked.

Table 5.4DV.1 – Ratings of a device controlling an external load

Load type	Equivalent utilization category (2)	Equipment rating	Required Load Marking	Additional load designations (2)
General purpose; Non-inductive or slightly inductive	AC-1	Amperes	None	General Use; AC-1
General purpose; Non-inductive or slightly inductive	DC-1	Amperes	None	General Use; DC-1
AC Resistance (not air heating)	–	Amperes	Resistive	Res.
DC Resistance (not air heating)	–	Amperes	Resistive	Res.
AC Electric Heating Control (3)	–	Amperes	None	None
Resistance air heating, AC	–	Amperes	Resistance	Resistance air heating
Resistance air heating, DC	–	Amperes	Resistance	Resistance air heating
Incandescent lamp, AC	AC-5b	Amperes or watts	Tungsten	AC-5b
Incandescent lamp, DC	DC-6	Amperes or watts	Tungsten	DC-6
Ballast (electric discharge lamp)	AC-5a	Amperes	Ballast	AC-5a
Motor (Hermetic Compressor Rating)	AC-8a	FLA and LRA	"hermetic refrigeration compressor"	"herm. refrig. comp."; AC-8a
Motor (Hermetic Compressor, Recycle Rating)	AC-8b	LRA	None	AC-8b
Motor (Hermetic Compressor, Part-Winding Endurance Rating)	–	FLA and LRA	None	None
Motor (non-standard rating)	–	FLA and LRA	None	None
Controller (standard rating)	–	Watts/Horsepower (1)	None	See Annex 101.DVA
Manual motor controller suitable for motor disconnecting means	–	Watts/Horsepower (1) or FLA and LRA	"Suitable as Motor Disconnect"	None
Motor for elevator control	–	Watts/Horsepower (1) or FLA and LRA	Elevator duty	None
Motor and tap conductor protection	–	Watts/Horsepower (1) or FLA and LRA	"Suitable for Tap Conductor Protection in Group Installations"	None
Capacitive switching	–	kVar and FLA	None	None

(1) Horsepower rated devices apply in Canada and USA only. kW ratings rated devices apply in Mexico only.

(2) When the marked ratings are the utilization category code designations in the table, the information concerning the load characteristics for each code designation shall be published in a catalog, be contained on a marking sheet packed with the product, or be otherwise readily available to the user.

(3) Electric Heating Control rating applies in Canada only.

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5.4.1 Assignment of utilization categories based on the results of tests

a) A contactor or starter which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned other utilization categories without testing provided that the test currents, voltages, power-factors or time-constants, number of operating cycles, on and off times given in tables 7 and 8, and the test circuit for the assigned utilization categories are not more severe than those at which the contactor or starter has been tested and the temperature rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

For example, when tested for utilization category AC-4, a contactor may be assigned utilization category AC-3 provided I_e for AC-3 is not higher than 1,2 I_e for AC-4 at the same rated operational voltage.

b) DC-3 and DC-5 contactors are assumed to be capable of opening and closing loads other than those on which they have been tested provided that:

- the voltage and current do not exceed the specified values of U_e and I_e ;
- the energy J stored in the actual load is equal to or less than the energy J_c stored in the load with which they were tested.

The values of the energy stored in the test circuit are as follows:

Utilization category	Stored energy J_c
DC-3	$0,00525 \times U_e \times I_e$
DC-5	$0,0315 \times U_e \times I_e$

The values of the constants 0,00525 and 0,0315 are derived from:

$$J_c = 1/2 L I^2$$

where the time-constant has been replaced by:

$2,5 \times 10^{-3}$ s (DC-3) and:

15×10^{-3} s (DC-5)

and where $U = 1,05 U_e$, $I = 4 I_e$ and L is the inductance of the test circuit.

(See table 7 of this standard.)

Table 1 – Utilization categories

Kind of current	Utilization categories	Typical applications
AC	AC-1	Non-inductive or slightly inductive loads, resistance furnaces
	AC-2	Slip-ring motors: starting, switching off
	AC-3	Squirrel-cage motors: starting, switching off motors during running ¹⁾
	AC-4	Squirrel-cage motors: starting, plugging, inching
	AC-5a	Switching of electric discharge lamp controls
	AC-5b	Switching of incandescent lamps
	AC-6a	Switching of transformers
	AC-6b	Switching of capacitor banks
	AC-7a ³⁾	Slightly inductive loads in household appliances and similar applications
	AC-7b ³⁾	Motor-loads for household applications
	AC-8a	Hermetic refrigerant compressor motor ²⁾ control with manual resetting of overload releases
	AC-8b	Hermetic refrigerant compressor motor ²⁾ control with automatic resetting of overload releases
DC	DC-1	Non-inductive or slightly inductive loads, resistance furnaces
	DC-3	Shunt-motors: starting, plugging, inching
		Dynamic breaking of d.c. motors
	DC-5	Series-motors: starting, plugging, inching
		Dynamic breaking of d.c. motors
	DC-6	Switching of incandescent lamps
¹⁾ AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period. ²⁾ A hermetic refrigerant compressor motor is a combination consisting of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant. ³⁾ For AC-7a and AC-7b, see IEC 61095.		

5.5 Control circuits

Subclause 4.5 of part 1 applies.

5.5DV D2 National Difference Deleted

5.6 Auxiliary circuits

Subclause 4.6 of part 1 applies.

5.7 Characteristics of relays and releases (overload relays)

NOTE In the remainder of this standard, the words "overload relay" will be taken to apply equally to an overload relay or an overload release, as appropriate

5.7.1 Summary of characteristics

The characteristics of relays and releases shall be stated in the following terms, whenever applicable:

- types of relay or release (see 5.7.2);
- characteristic values (see 5.7.3);
- designation and current settings of overload relays (see 5.7.4);
- time-current characteristics of overload relays (see 5.7.5);
- influence of ambient air temperature (see 5.7.6).

5.7.2 Types of relay or release

- a) Release with shunt coil (shunt trip).
- b) Under-voltage and under-current opening relay or release.
- c) Overload time-delay relay the time-lag of which is:
 - 1) substantially independent of previous load (e.g. time-delay magnetic overload relay);
 - 2) dependent on previous load (e.g. thermal overload relay);
 - 3) dependent on previous load (e.g. thermal overload relay) and also sensitive to phase loss (see 3.2.17).
- d) Instantaneous over-current relay or release (when applicable).
- e) Other relays or releases (e.g. phase loss sensitive relay, control relay associated with devices for the thermal protection of the starter).

NOTE Types referred to in items d) and e) require consultation between manufacturer and user according to the particular application.

5.7.3 Characteristic values

a) Release with shunt coil, under-voltage (under-current) opening relay or release:

- rated voltage (current);
- rated frequency;
- operating voltage (current).

b) Overload relay:

- designation and current settings (see 5.7.4);
- rated frequency, when necessary (for example in the case of a current transformer operated overload relay);
- time-current characteristics (or range of characteristics), when necessary;
- trip class according to classification in table 2, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1, table 3, column D, when this time exceeds 30 s;
- number of poles;
- nature of the relay: thermal, magnetic or solid state.

Table 2 – Trip classes of thermal, time-delay magnetic or solid state overload relays

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1, table 3, column D s
10A	$2 < T_p \leq 10$
10	$4 < T_p \leq 10$
20	$6 < T_p \leq 20$
30	$9 < T_p \leq 30$

NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5.

NOTE 2 In the case of a rheostatic rotor starter, the overload relay is commonly inserted in the stator circuit. As a result, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty start); protection of the rotor circuit should be the subject of a specific agreement between manufacturer and user (see, inter alia, 8.2.1.1.3).

NOTE 3 In the case of a two-step auto-transformer starter, the starting auto-transformer is normally designed for use during the starting period only: as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer should be the subject of specific agreement between manufacturer and user (see 8.2.1.1.4).

NOTE 4 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.

Table 2DV D2 Modify Note 4 of Table 2 by replacing with the following:

The lower limiting values do not apply.

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5.7.4 Designation and current settings of overload relays

Overload relays are designated by their current setting (or the upper and lower limits of the current setting range, if adjustable) and their trip class.

The current setting (or current setting range) shall be marked on the relays.

However, if the current setting is influenced by the conditions of use or other factors which cannot readily be marked on the relay, then the relay or any interchangeable parts thereof (e.g. heaters, operating coils or current transformers) shall carry a number or an identifying mark which makes it possible to obtain the relevant information from the manufacturer or his catalogue or, preferably, from data furnished with the starter.

In the case of current transformer operated overload relays, the marking may refer either to the primary current of the current transformer through which they are supplied or to the current setting of the overload relays. In either case, the ratio of the current transformer shall be stated.

5.7.5 Time-current characteristics of overload relays

Typical time-current characteristics shall be given in the form of curves supplied by the manufacturer. These curves shall indicate how the tripping time, starting from the cold state (see 5.7.6), varies with the current up to a value of at least eight times the full-load current of the motor with which it is intended that the relay be used. The manufacturer shall be prepared to indicate, by suitable means, the general tolerances applicable to these curves and the conductor cross-sections used for establishing these curves (see 9.3.3.2.2, item c)).

NOTE It is recommended that the current be plotted as abscissae and the time as ordinates, using logarithmic scales. It is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheet detailed in 5.6.1 of IEC 60269-1, in IEC 60269-2 (figure 1) and in figures 4(I), 3(II) and 4(II) of IEC 60269-2-1.

5.7.6 Influence of ambient air temperature

The time-current characteristics (see 5.7.5) refer to a stated value of ambient air temperature, and are based on no previous loading of the overload relay (viz. from an initial cold state). This value of the ambient air temperature shall be clearly given on the time curves; the preferred values are +20 °C or +40 °C.

The overload relays shall be able to operate within the ambient air temperature range of -5 °C to +40 °C, and the manufacturer shall be prepared to state the effect of variation in ambient air temperature on the characteristics of overload relays.

5.8 Co-ordination with short-circuit protective devices

Contactors and starters are characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) to be used to provide over-current protection beyond the crossover current between the starter and the SCPD and adequate protection of the contactor and starter against short-circuit currents. Requirements are given in 8.2.5.1, in 8.2.5.2, in clause B.4 of this standard, and in 4.8 of part 1.

5.9 Switching overvoltages

Subclause 4.9 of part 1 applies.

Requirements are given in 8.2.6.

5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices

5.10.1 Types

a) Time-delay devices, e.g. time-delay contactor relays (see IEC 60947-5-1) applicable to control-circuit devices or specified-time all-or-nothing relays (see IEC 61810-1).

b) Undercurrent devices (undercurrent relays).

c) Other devices for automatic acceleration control:

- devices dependent on voltage;
- devices dependent on power;
- devices dependent on speed.

5.10.2 Characteristics

a) The characteristics of time-delay devices are:

- the rated time-delay or its range, if adjustable;
- for time-delay devices fitted with a coil, the rated voltage, when it differs from the starter line voltage.

b) The characteristics of the undercurrent devices are:

- the rated current (thermal current and/or rated short-time withstand current, according to the indications given by the manufacturer);
- the current setting or its range, if adjustable.

c) The characteristics of the other devices shall be determined by agreement between manufacturer and user.

5.11 Types and characteristics of auto-transformers for two-step auto-transformer starters

Account being taken of the starting characteristics (see 5.3.5.5.3), starting auto-transformers shall be characterized by:

- the rated voltage of the auto-transformer;
- the number of taps available for adjusting the starting torque and current;
- the starting voltage, i.e. the voltage at the tapping terminals, as a percentage of the rated voltage of the auto-transformer;
- the current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling
 - air-cooling;
 - oil-cooling.

The auto-transformer can be:

- either built-in into the starter, in which case the resulting temperature rise has to be taken into account in determining the ratings of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the transformer and the manufacturer of the starter.

5.12 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 5.3.5.5.1), the starting resistors shall be characterized by:

- the rated rotor insulation voltage (U_{ir});
- their resistance value;
- the mean thermal current, defined by the value of steady current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling
 - free air;
 - forced air;
 - oil-immersion.

They can be:

- either built-in into the starter, in which case the resulting temperature rise has to be limited in order not to cause any damage to the other parts of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the resistors and the manufacturer of the starter.

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer.

6.1.1 Identification

- a) manufacturer's name or trade mark;
- b) type designation or serial number;
- c) number of this standard, if the manufacturer claims compliance.

6.1.2 Characteristics, basic rated values and utilization

Characteristics:

- d) rated operational voltages (see 5.3.1.1);
- e) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the equipment (see 5.3.2.5 and 5.4);
- f) either the value of the rated frequency/frequencies, e.g. 50 Hz or 50 Hz/60 Hz, or the indication "d.c." (or the symbol $\overline{\text{=}}$);
- g) rated duty with the indication of the class of intermittent duty, if any (see 5.3.4).

Associated values:

- h) rated making and breaking capacities. These indications may be replaced, where applicable, by the indication of the utilization category (see table 7).

Safety and installation:

- i) rated insulation voltage (see 5.3.1.2);
- j) rated impulse withstand voltage (see 5.3.1.3), when determined;
- k) IP code, in case of an enclosed equipment (see 8.1.11);
- l) pollution degree (see 7.1.3.2);

m) rated conditional short-circuit current (see 5.3.6) and type of co-ordination of the contactor or starter (see 8.2.5.1) and the type, current rating and characteristics of the associated SCPD;

rated conditional short-circuit current (see 5.3.6) of the combination starter or protected starter and type of co-ordination (see 8.2.5.1);

n) switching overvoltages (see 5.9).

Control circuits:

The following information concerning control circuits shall be placed either on the coil or on the equipment:

o) rated control circuit voltage (U_c), nature of current and rated frequency;

p) if necessary, nature of current, rated frequency and rated control supply voltage (U_s).

Air supply systems for starters or contactors operated by compressed air:

q) rated supply pressure of the compressed air and limits of variation of this pressure, if they are different from those specified in 8.2.1.2.

Auxiliary circuits:

r) ratings of auxiliary circuits (see 5.6).

Overload relays and releases:

s) characteristics according to 5.7.

Additional information for certain types of contactor and starter:

Rheostatic rotor starters:

t) circuit diagram;

u) severity of start (see 5.3.5.5.1);

v) starting time (see 5.3.5.5.1).

Auto-transformer starters:

w) rated starting voltage(s), i.e. voltage(s) at the tapping terminals.

NOTE This value may be expressed as a percentage of the rated operational voltage of the starter.

Vacuum contactors and starters:

x) maximum permissible altitude of the site of installation, if less than 2 000 m.

EMC:

y) environment 1 or 2: see 7.3.1 of part 1;

z) special requirements, if applicable, for example shielded or twisted conductors.

NOTE Unshielded or untwisted conductors are considered as normal installation conditions.

6.2 Marking

Subclause 5.2 of part 1 applies to contactors, starters and overload relays with the following additions.

Data under items d) to x) in 6.1.2 shall be included on the nameplate or on the equipment or in the manufacturer's published literature.

Data under items c) and k) in 6.1.2 shall preferably be marked on the equipment.

6.2DV D2 Additions to 6.2:

6.2DV.1 Markings – Locations of required markings shall be as shown in Table 6.2DV.1.

Table 6.2DV.1 – D2 Markings (6.2DV.1)

Clause reference	Required marking ^a	Location ^b	
		Enclosed	Open
Motor controllers			
6.2DV.2.1	Motor controller short circuit current rating / protective device / Group installation	A	B
6.2DV.2.2	Short circuit marking for tap conductor protection in group installations (see also 6.2DV.4.5 and 6.2DV.4.7)	A	B
8.2.5DV.1	Motor controller for use with specific overload relay	B	B
Cautionary markings for motor controllers ^c			
6.2DV.2.3	Marking for motor controllers having high available fault current rating	A	B
6.2DV.2.4	Control with limited terminal size for a direct current motor rating	B	B
Overload relays			
6.2DV.3.1	Combination of manual and automatic reset position	A	A
6.2DV.3.2	Automatic restart of motor	A	B
6.2DV.3.3	Overload relay with two or more current elements	B	B
6.2DV.3.4	Current transformer for use with electronic overload relays	A	B
6.2DV.3.6	Relay trip class designation and tripping current	A	B
6.2DV.3.7	Ambient temperature rating for non-ambient compensated overload relays	A	B
Cautionary markings for overload relays ^c			
6.2DV.3.5	Marking for overload relay with replaceable type thermal elements having calibrated current sensing element	A	B