UL 60947-4-1

STANDARD FOR SAFETY

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

UL Standard for Safety for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1

Fourth Edition, Dated May 31, 2022

Summary of Topics

Adoption of the Third Edition of IEC 60947-4-1, Standard for Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, as the Fourth Edition of ANSI/UL 60947-4-1.

This standard is an adoption of IEC 60947-4-1, Edition 3.0, issued 2009 and its amendment 1, issued (2012). Please note that the National Difference document incorporates all of the U.S. national differences for UL 60947-4-1.

The requirements are substantially in accordance with Proposal(s) on this subject dated May 8, 2020 and September 10, 2021.

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Third Edition
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Underwriters Laboratories Inc.
UL 60947-4-1
Fourth Edition

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

May 31, 2022

This standard is based on IEC 60947-4-1, edition 3 (2009) consolidated with amendment 1 (2012).

ANSI/UL 60947-4-1-2022

Commitment for Amendments

This standard is issued jointly by the Canadian Standards Association (operating as “CSA Group”) and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to CSA Group or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue.

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This Standard is subject to review within five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. The technical content of IEC and ISO publications is kept under constant review by IEC and ISO. To submit a proposal for change, please send the following information to inquiries@csagroup.org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Fourth Edition. The most recent designation of ANSI/UL 60947-4-1 as an American National Standard (ANSI) occurred on May 31, 2022. 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.

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PREFACE

This is the harmonized CSA Group and UL standard for Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters. It is the third edition of CSA C22.2 No. 60947-4-1, and the fourth edition of UL 60947-4-1. This edition of CSA C22.2 No. 60947-4-1 supersedes the previous edition published in 2014 as CAN/CSA-C22.2 No. 60947-4-1.

This harmonized standard is based on IEC publication 60947-4-1, Edition 3.1, Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, issued July 2012. IEC 60947-4-1 is copyrighted by the IEC.

This harmonized standard was prepared by CSA Group 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 Integrated Committee on Industrial Control, 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 developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of 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.

CSA C22.2 No. 60947-4-1 is to be used in conjunction with the third edition of CSA C22.2 No. 60947-1. Requirements of this Standard, where stated, amend the requirements of CSA C22.2 No. 60947-1.

UL Standard 60947-4-1 is to be used in conjunction with the sixth edition of UL 60947-1. Requirements of this Standard, where stated, amend the requirements of UL 60947-1.

Level of Harmonization

This standard adopts the IEC text with national differences.

This standard is published as an equivalent standard for CSA Group 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 CSA Group 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

National differences from the IEC are being added in order to address safety and regulatory situations present in the US and Canada.

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.

IEC Copyright

For CSA Group, the text, figures, and tables of International Electrotechnical Commission Publication 60947-4-1, Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters, copyright 2012, are used in this Standard with the consent of the International Electrotechnical Commission. The IEC Foreword and Introduction are not a part of the requirements of this Standard but are included for information purposes only.

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, copyright 2012, are indicated by notations (differences) and are presented in bold text. The national difference type is included in the body.

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.

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

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

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

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6) All users should ensure that they have the latest edition of this publication.

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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This consolidated version of IEC 60947-4-1 consists of the third edition (2009) [documents 17B/1674/FDIS and 17B/1677/RVD] and its amendment 1 (2012) [documents 17B/1769/FDIS and 17B/1780/RVD]. It bears the edition number 3.1.

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience. A vertical line in the margin shows where the base publication has been modified by amendment 1. Additions and deletions are displayed in red, with deletions being struck through.

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 edition includes the following significant technical changes with respect to the previous edition (2000) and its Amendments 1 (2002) and 2 (2005):

• deletion of the test at –5 °C and +20 °C for thermal overload relays that are not compensated for ambient air temperature;

• addition of conditions of the tests according to Annex Q of IEC 60947-1;

• EMC tests: clarification of acceptance criteria and alignment with IEC 60947-1 for fast transient severity level;

• Annex B, test for Icd: modification of the duration of the dielectric test voltage from 5 s to 60 s;

• Annex B, electrical durability: improvement of the statistical aspects;

• Annex H: clarification and introduction of new extended functions within electronic overload relays;

• Annex K, procedure to determine data for electromechanical contactors used in functional safety applications: creation of this new annex

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

A list of all parts of the IEC 60947 series can be found, under the general title *Low-voltage switchgear and controlgear*, on the IEC website.

This standard shall be read in conjunction with IEC 60947-1, *Low voltage switchgear and controlgear – Part 1: General rules*. The provisions of the general rules are applicable to this standard, where specifically called for.

The committee has decided that the contents of the base publication and its amendments 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.

IMPORTANT – The "colour inside" logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this publication using a colour printer.

DV.1 DE *Modification to replace the second paragraph following Item (9) of the IEC Foreword with the following:*

This Final version does not show where the technical content is modified by amendment 1. A separate redline version with all changes highlighted is not available in this publication.

DV.2 DE *Modification of the IEC Foreword by adding the following:*

The numbering system in the standard uses a space instead of a comma to indicate thousands and uses a comma instead of a period to indicate a decimal point. For example, 1 000 means 1,000 and 1,01 means 1.01.

DV.3 D2 *Modification of the IEC Foreword by adding the following:*

This standard shall be read in conjunction with Canadian and United States equivalent standards to the IEC 60947 series per Table DVA.2. Where specifically called for, any reference to IEC 60947-1 shall be to the applicable clause – either the national difference "DV" clause or IEC clause, or a reference to the applicable standard listed in the Annex. The provisions of the general rules are applicable to this standard, where specifically called for.

No Text on This Page

INTRODUCTION
(to amendment 1)

This amendment includes the following significant technical changes with respect to the previous edition 3 (2009):

• introduction of the motor management starter;

• definitions and measurement method of the power consumption of the control circuit during holding and pick-up operations;

• measurement method of the pole impedance;

• requirements for screwless terminals;

• performance requirements for latched contactors;

• alignments to Amendment 1 of IEC 60947-1:2007;

• harmonisation with IEC 60947-2 of the operation tests of under-voltage relays and shunt releases;

• short-circuit tests harmonisation with North America;

• test requirements for utilisation AC-6b capacitor load;

• polarity for DC contactors;

• dielectric test method in presence of built-in varistor;

• addition of an extended function for electronic overload relay: control functions.

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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

1.1 Scope

This part of IEC 60947 applies to the types of equipment listed in 1.1.1 and 1.1.2 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) forms 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 or protected starters are rated as units.

For circuit-breakers and fuse-combination units used as short-circuit protective devices in combination starters and in protected starters, the requirements of IEC 60947-2 and IEC 60947-3 respectively apply.

Equipment covered by this standard is as follows.

1.1DV.1 D2 ***Modification of 1.1 by adding the following:***

This equipment is intended for installation in accordance with CSA C22.1, Canadian Electrical Code (CE Code, Part I), and the US National Electrical Code (NEC), NFPA 70.

1.1.1 AC and DC contactors

AC and DC contactors intended for closing and opening electric circuits and, if combined with suitable relays (see 1.1.2), for protecting these circuits against operating overloads which may occur therein.

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

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

Contactors or starters with an electronically controlled electromagnet are also covered by this standard.

1.1.1DV.1 D2 ***Modification of 1.1.1 by adding the following:***

This standard also applies to manual controllers and combination motor controllers. See Annex DVC for specific requirements.

1.1.2 AC motor-starters

AC motor-starters (including motor management starter) 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.

For overload relays for starters, including those based on electronic technology with or without extended functions according to Annex H, the requirements of this standard apply.

1.1.2.1 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.

1.1.2.2 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).

1.1.2.2.1 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 starting 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.

1.1.2.2.2 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.

1.1.2.3 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.

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 are 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.

1.2 Exclusions

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.

1.3 Object

The object of this standard is to state:

a) the characteristics of contactors and starters and associated equipment;

b) the conditions applicable to contactors and starters 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1:2004, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60300-3-5:2001, *Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles*

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

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-2:2006, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-3:2008, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1 (2007)

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2005, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2008, *Electromagnetic compatibility (EMC) – Part 4-6:Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61051-2:1991, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61439-1:2009, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

IEC 61513:2001, *Nuclear power plants –Instrumentation and control for systems important to safety – General requirements for systems*

IEC 61649:2008, *Weibull analysis*

IEC 61810-1:2008, *Electromechanical elementary relays – Part 1: General requirements* (available in English only)

IEC 62061:2005, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

CISPR 11:2003, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*
Amendment 1 (2004)
Amendment 2 (2006)

ISO 13849-1:2006, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

2DV D2 *Modification of Clause 2 by adding the following:*

For a list of normative standards, see Table DVA.1 and Table DVA.2. See Table DVB.1 for component standards.

3 Terms, definitions, symbols and abbreviations

3.1 General

For the purposes of this document, the terms and definitions of Clause 2 of IEC 60947-1, as well as the following terms, definitions, symbol and abbreviations apply.

3.1DV D2 ***Add the following definition to 3.1:***

3.1DV.1
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.

3.2 Alphabetical index of terms

3.3 Terms and definitions concerning contactors

3.3.1
(mechanical) contactor
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 1 Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[IEV 441-14-33]

NOTE 2 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 3 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 4 A contactor is usually intended to operate frequently.

3.3.2
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

NOTE The electromagnet may be electronically controlled.

3.3.3
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

3.3.4
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

3.3.5
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]

3.3.6
vacuum contactor (or starter)
contactor (or starter) in which the main contacts open and close within a highly evacuated envelope

3.3.7
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]

3.3.8
electronically controlled electromagnet
electromagnet in which the coil is controlled by a circuit with active electronic elements

3.3.9
holding power (of a contactor)
power needed to maintain the operation of the electromagnet

3.3.10
pick-up power (of a contactor)
power needed to operate the contactor from the de-energized state to the energized state

3.4 Terms and definitions concerning starters

3.4.1
starter
combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

[IEV 441-14-38, modified]

3.4.2
direct-on-line starter
starter which connects the line voltage across the motor terminals in one step

[IEV 441-14-40]

3.4.3
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

3.4.4
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

3.4.5
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

3.4.5.1
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]

3.4.5.2
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 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."

3.4.6
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 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.

3.4.6.1
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

3.4.6.2
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]

3.4.7
protected starter
equipment consisting of a starter, a manually-operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

NOTE 1 The protected starter may or may not be enclosed.

NOTE 2 In the context of this standard, the term “manufacturer“ means any person, company or organization with ultimate responsibility as follows:

− to verify compliance with the appropriate standard;

− to provide the product information according to Clause 6.

NOTE 3 The manually operated switching device and the short-circuit protective device may be just one device and may also incorporate the starter overload protection.

3.4.8
combination starter (see Figure 3)
equipment consisting of a protected starter incorporating an isolating function

NOTE Also called "combination motor controller".

3.4.9
manual starter
starter in which the force for closing the main contacts is provided exclusively by manual energy

[IEV 441-14-39]

3.4.10
electromagnetic starter
starter in which the force for closing the main contacts is provided by an electromagnet

3.4.11
motor-operated starter
starter in which the force for closing the main contacts is provided by an electric motor

3.4.12
pneumatic starter
starter in which the force for closing the main contacts is provided by using compressed air, without the use of electrical means

3.4.13
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

3.4.14
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.

3.4.15
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.

3.4.16
***n*-step starter** (see Figure 4)
starter in which there are (*n*-1) intermediate accelerating positions between the OFF and ON positions

[IEV 441-14-41]

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

3.4.17
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

3.4.18
under-current relay or release
measuring relay or release which operates automatically when the current through it is reduced below a predetermined value

3.4.19
under-voltage relay or release
measuring relay or release which operates automatically when the voltage applied to it is reduced below a predetermined value

3.4.20
starting time (of a rheostatic starter)
period of time during which the starting resistors or parts of them carry current

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

3.4.21
starting time (of an auto-transformer starter)
period of time during which the auto-transformer carries current

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

3.4.22
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 as an additional step.

3.4.23
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 as an additional step.

3.4.24
inching (jogging)
energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.25
plugging
stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.4.26
protected switching device
equipment (for non motor loads) consisting of a contactor or a semiconductor controller, overload protection, a manually operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

NOTE 1 The protected switching device may or may not be enclosed.

NOTE 2 In the context of this standard, the term “manufacturer” means any person, company or organization with ultimate responsibility as follows:

– to verify compliance with the appropriate standard;

– to provide the product information according to Clause 6.

NOTE 3 The manually operated switching device and the short-circuit protective device may be just one device and may incorporate the overload protection as well.

3.4.27
combination switching device
equipment consisting of a protected switching device incorporating an isolating function

3.4.28
stall sensitive (electronic overload) relay
electronic overload relay which operates when the current has not decreased below a predetermined value for a specific period of time during start-up or when the relay receives the input indicating there is no rotation of the motor after a predetermined time in accordance with specified requirements

NOTE 1 Explanation of stall: rotor locked during start.

NOTE 2 With appropriate adjustment of the current and starting time settings, such relay can be used to detect overtime starts.

3.4.29
jam sensitive (electronic overload) relay
electronic overload relay which operates in the case of overload and also when the current has increased above a predetermined value for a specific period of time during operation, in accordance with specified requirements

NOTE Explanation of jam: high overload occurring after the completion of starting which causes the current to reach the locked rotor current value of the motor being controlled.

3.4.30
inhibit time
time-delay period during which the tripping function of the relay is inhibited (may be adjustable)

3.4.31
motor management starter
starter including extended functions with communication ability

NOTE Interoperable device profiles for motor management starter are defined by IEC 61915-2.

3.5 Terms and definitions concerning characteristic quantities

3.5.1
transient recovery voltage
TRV
recovery voltage during the time in which it has a significant transient character

NOTE In a vacuum contactor or starter, the highest transient recovery voltage may occur on an other pole than the first pole to clear.

[IEC 60947-1, 2.5.34, modified]

3.5.2
CO operation
breaking of the circuit by the SCPD resulting from closing the circuit by the equipment under test

3.5.3
O operation
breaking of the circuit by the SCPD resulting from closing the circuit on the equipment under test which is in the closed position

NOTE The SCPD is normally in the closed position prior closing the circuit; in some cases the SCPD has to close the circuit 9.3.4.2.2, item b).

3.6 Symbols and abbreviations

AQL	Acceptable quality level
EMC	Electromagnetic compatibility
SCPD	Short-circuit protective device
I_c	Current made and broken (Table 7)
I_e	Rated operational current (5.3.2.5)
I_{er}	Rated rotor operational current (5.3.2.7)
I_{es}	Rated stator operational current (5.3.2.6)
I_q	Maximum conditional short-circuit test current
I_{th}	Conventional free air thermal current (5.3.2.1)
I_{the}	Conventional enclosed thermal current (5.3.2.2)
I_{thr}	Conventional rotor thermal current (5.3.2.4)
I_{ths}	Conventional stator thermal current (5.3.2.3)
I_u	Rated uninterrupted current (5.3.2.8)
P_c	Nominal holding power of a d.c. controlled contactor
P_p	Pick-up power of a d.c. controlled contactor with separate pick-up and hold-on windings
"r"	Minimum short-circuit test current
S_h	Holding power of an a.c. controlled contactor
S_p	Pick-up power of an a.c. controlled contactor
T_p	Tripping time (Table 2)
U_c	Rated control circuit voltage (5.5)
U_d	Voltage drop of a contactor pole
U_e	Rated operational voltage (5.3.1.1)
U_{er}	Rated rotor operational voltage (5.3.1.1.2)
U_{es}	Rated stator operational voltage (5.3.1.1.1)
U_i	Rated insulation voltage (5.3.1.2)
U_{imp}	Rated impulse withstand voltage (5.3.1.3)
U_{ir}	Rated rotor insulation voltage (5.3.1.2.2)
U_{is}	Rated stator insulation voltage (5.3.1.2.1)

U_r	Power frequency or d.c. recovery voltage (Table 7)
U_s	Rated control supply voltage (5.5)
Z	Pole impedance of a contactor (5.3.7)

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);

– 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).

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 Figure 4 and Figure 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 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 IEC 60947-1 applies.

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 rotor 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 insulation voltage of the switching devices inserted in the rotor circuit shall be at least 50 % the highest voltage between open slip-rings.

NOTE Electrical stresses are lower and shorter in the rotor than in the stator.

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 IEC 60947-1 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 IEC 60947-1 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 IEC 60947-1 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1 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, precisely 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.