



UL 60947-4-2

STANDARD FOR SAFETY

Low-Voltage Switchgear and
Controlgear – Part 4-2: Contactors and
Motor-Starters – AC Semiconductor
Motor Controllers and Starters

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UL Standard for Safety for Low-Voltage Switchgear and Controlgear – Part 4-2: Contactors and Motor-Starters – AC Semiconductor Motor Controllers and Starters, UL 60947-4-2

Second Edition, Dated May 31, 2022

Summary of Topics

Adoption of the Third Edition of IEC 60947-4-2, Standard for Low-Voltage Switchgear and Controlgear – Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters, as the Second Edition of ANSI/UL 60947-4-2.

This standard is an adoption of IEC 60947-4-2, Edition 3.0, issued May 2011 and corrigendum 1, issued July, 2012. Please note that the National Difference document incorporates all of the U.S. national differences for UL 60947-4-2.

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

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CSA Group
CSA C22.2 No. 60947-4-2:22
Second Edition
(IEC 60947-4-2:2011, MOD)



Underwriters Laboratories Inc.
UL 60947-4-2
Second Edition

Low-Voltage Switchgear and Controlgear – Part 4-2: Contactors and Motor-Starters – AC Semiconductor Motor Controllers and Starters

May 31, 2022

This national standard is based on IEC 60947-4-2, edition 3.0 (2011) and corrigendum 1 (2012).

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ANSI/UL 60947-4-2-2022



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This ANSI/UL Standard for Safety consists of the Second Edition. The most recent designation of ANSI/UL 60947-4-2 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 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters. It is the second edition of CSA C22.2 No. 60947-4-2 and the second edition of UL 60947-4-2. This edition of CSA C22.2 No. 60947-4-2 supersedes the previous edition published in 2014 as CAN/CSA-C22.2 No. 60947-4-2 (adopted IEC 60947-4-2:1999+A1:2001+A2:2006).

This harmonized standard is based on IEC publication 60947-4-2, third edition, Low-voltage switchgear and controlgear – Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters, issued May 2011 as revised by corrigendum 1 issued July 2012. IEC 60947-4-2 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 Controls, 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. 60947-4-2 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 60947-4-2 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.

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NATIONAL DIFFERENCES

National Differences from the text of International Electrotechnical Commission (IEC) Publication 60947-4-2, Low-voltage switchgear and controlgear – Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters, copyright 2011, 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:

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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.

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FOREWORD

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and 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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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.

International Standard IEC 60947-4-2 has been prepared by subcommittee 17B: Low-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This third edition replaces the second edition published in 1999 and its Amendments 1 (2001) and 2 (2006). It is a technical revision.

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

- updated EMC normative references and associated requirements,
- new references to IEC 60947-1,
- marking of electronic relays without thermal memory,

- marking of tripping time at 0 °C ambient or below,
- new test requirements for limits of operation of time-delay overload relays,
- new classes of overload current withstand time,
- damp heat, salt mist, vibration and shock tests,
- short-circuit test in the smallest enclosure,
- update of the routine and sampling tests.

This standard shall be read in conjunction with IEC 60947-1:2007, *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 text of this standard is based on the following documents:

| | |
|---------------|------------------|
| FDIS | Report on voting |
| 17B/1734/FDIS | 17B/1741/RVD |

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

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

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

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

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

The contents of the corrigendum of July 2012 have been included in this copy.

DV.1 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.2 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 60947-4-1 or 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.

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INTRODUCTION

This standard covers low-voltage a.c. semiconductor motor controllers and starters that have many capabilities and features beyond the simple starting and stopping of an induction motor, such as controlled starting and stopping, manoeuvring and controlled running.

The generic term “controller” is used in this standard wherever the unique features of the power semiconductor switching elements are the most significant points of interest. The generic term “starter” is used wherever the consequences of operating the power semi-conductor switching elements, together with suitable overload protective means, are the most significant points of interest. Specific designations (for example form 1, form HxB, etc.) are used wherever the unique features of various configurations comprise significant points of interest.

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR – Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters

1 Scope

This standard applies to a.c. semiconductor motor controllers and starters, which may include a series mechanical switching device, intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c.

This standard characterizes a.c. semiconductor motor controllers and starters with and without bypass means.

AC semiconductor motor controllers and starters dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see [8.2.4](#)) should form part of the installation, but not necessarily of the a.c. semiconductor motor controller or starter.

In this context, this standard gives requirements for a.c. semiconductor motor controllers and starters associated with separate short-circuit protective devices.

This standard does not apply to

- continuous operation of a.c. motors at motor speeds other than the normal speed;
- semiconductor equipment, including semiconductor contactors (see 2.2.13 of IEC 60947-1:2007) controlling non-motor loads;
- electronic a.c. power controllers covered by IEC 60146 series.

Contactors, overload relays and control circuit devices used in a.c. semiconductor motor controllers and starters should comply with the requirements of their relevant product standard. Where mechanical switching devices are used, they should meet the requirements of their own IEC product standard, and the additional requirements of this standard.

The object of this standard is to state as follows:

- the characteristics of a.c. semiconductor motor controllers and starters and associated equipment;
- the conditions with which a.c. semiconductor motor controllers and starters comply with reference to
 - a) their operation and behaviour;
 - b) their dielectric properties;
 - c) the degrees of protection provided by their enclosures where applicable;
 - d) their construction;
- the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;

– the information to be given with the equipment, or in the manufacturer's literature.

NOTE For the purpose of this standard, the term "controller" may be used instead of "a.c. semiconductor motor controller".

1DV D2 Modification of Clause 1 by adding the following:

1DV.1 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.

1DV.2 This standard also applies to combination motor controllers incorporating semiconductor motor controllers and starters. See Annex [DVC](#) for specific requirements.

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 60034-1:2010, *Rotating electrical machines – Part 1: Rating and performance*

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

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*; Amendment 1 (2009)

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

IEC 60664 (all parts), *Insulation coordination for equipment within low-voltage systems*

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

IEC 61000-4 (all parts), *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques*

CISPR 11:2009, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*; Amendment 1 (2010)

2DV DC 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 60947-1:2007, as well as the following terms, definitions, symbol and abbreviations apply.

3.2 Alphabetical index of terms

| | Reference |
|--|------------------------|
| | A |
| a.c. semiconductor motor controller | 3.3.2 |
| | B |
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| bypassed controller | 3.4.31 |
| | C |
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| electromagnetic emission | 3.5.2 |
| | F |
| FULL-ON (state of controllers) | 3.4.12 |
| | H |
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| hybrid motor controller or starter, form HxB | 3.4.2 |
| | I |
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| | J |
| jam sensitive electronic overload relay | 3.4.27 |
| | M |
| manoeuvre | 3.4.5 |
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| | O |
| O operation | 3.4.33 |
| OFF-state | 3.4.14 |
| OFF-state leakage current [I_L] | 3.4.15 |
| OFF-time | 3.4.30 |
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| ON-time | 3.4.29 |
| OPEN position | 3.4.3 |
| operating capability | 3.4.18 |
| operating cycle (of a controller) | 3.4.17 |

| | | |
|---|---|------------------------|
| operation (of a controller) | | 3.4.16 |
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| | P | |
| phase loss sensitive overload relay or release | | 3.4.23 |
| prospective current (of a circuit and with respect to a switching device or a fuse) | | 3.4.9 |
| prospective locked rotor current [I_{LRP}] | | 3.4.10 |
| | R | |
| radio (frequency) disturbance | | 3.5.4 |
| radio frequency interference [RFI] | | 3.5.5 |
| rating index | | 3.4.20 |
| | S | |
| semiconductor direct on line (DOL) motor controller (form 3) | | 3.3.5 |
| semiconductor motor controller (form 1) | | 3.3.3 |
| semiconductor motor starter (form 1, form 2, form 3) | | 3.3.6 |
| semiconductor soft-start motor controller (form 2) | | 3.3.4 |
| semiconductor switching device | | 3.3.1 |
| stall sensitive electronic overload relay | | 3.4.26 |
| | T | |
| transient (adjective and noun) | | 3.5.6 |
| trip-free controller or starter | | 3.4.22 |
| tripping operation (of a controller or starter) | | 3.4.21 |
| | U | |
| under-current relay or release | | 3.4.24 |
| under-voltage relay or release | | 3.4.25 |
| | V | |
| voltage surge | | 3.5.8 |

3.3 Terms and definitions concerning a.c. semiconductor motor controllers and starters

3.3.1

semiconductor switching device

switching device designed to make and/or break the current in an electric circuit by means of the controlled conductivity of a semiconductor

NOTE This definition differs from IEC 60050-441:1984, 441-14-03 since a semiconductor switching device is also designed for breaking the current.

[IEC 60947-1:2007, 2.2.3]

3.3.2

a.c. semiconductor motor controller

semiconductor switching device that provides the starting function for an a.c. motor and an OFF-state

NOTE 1 Because dangerous levels of leakage currents can exist in a semiconductor motor controller in the OFF-state, the load terminals should be considered as live parts at all times.

NOTE 2 In a circuit where the current passes through zero (alternately or otherwise), the effect of "not making" the current following such a zero value is equivalent to breaking the current.

3.3.3

semiconductor motor controller (form 1)

a.c. semiconductor motor controller, in which the starting function may comprise any starting method specified by the manufacturer, and that provides control functions which may include any combination of manoeuvring, controlled acceleration, running or controlled deceleration of an a.c. motor. A FULL-ON state may also be provided

NOTE See [Figure 1](#) and [Table 1](#).

3.3.4

semiconductor soft-start motor controller (form 2)

special form of a.c. semiconductor motor controller, in which the starting function is limited to a voltage and/or current ramp which may include controlled acceleration, and where the additional control function is limited to providing FULL-ON

NOTE See [Figure 1](#) and [Table 1](#).

3.3.5

semiconductor direct on line (DOL) motor controller (form 3)

special form of a.c. semiconductor motor controller, in which the starting function is limited to a full-voltage, unramped starting method only, and where the additional control function is limited to providing FULL-ON

NOTE See [Figure 1](#) and [Table 1](#).

3.3.6

semiconductor motor starter (form 1, form 2, form 3)

a.c. semiconductor motor controller with suitable overload protection, rated as a unit

NOTE See [Figure 1](#) and [Table 1](#).

| | | | |
|--|---|---|---|
| Device | | | |
| Semiconductor motor controller (forms 1, 2, 3) | | | |
| Semiconductor motor starter (forms 1, 2, 3) | | | |
| Hybrid motor controller HxA ^a where x = 1, 2, or 3 | | | |
| Hybrid motor controller HxB ^b | | | |
| Bypassed controller | | | |
| Bypassed hybrid motor controller ^c | | | |
| Hybrid motor starter | Form H1A or H1B with motor overload protection | Form H2A or H2B with motor overload protection | Form H3A or H3B with motor overload protection |
| ^a Two separate controls for the controller and the series mechanical switching device. ^b One control only for the series mechanical switching device. ^c For other configurations, tests may be suitably adapted by agreement between the user and the manufacturer. | | | |

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Figure 1
Semiconductor motor control devices

Table 1
Functional possibilities of semiconductor motor control devices

| Device | Form 1 | Form 2 | Form 3 |
|---|--|---|--|
| Semiconductor motor controller | <ul style="list-style-type: none"> – OFF – Starting function – Manoeuvring – Controlled acceleration – Running – FULL ON – Controlled deceleration | <ul style="list-style-type: none"> – OFF state – Starting function – Controlled acceleration – FULL ON | Not available |
| Semiconductor DOL motor controller | Not available | Not available | <ul style="list-style-type: none"> – OFF state – Starting function – FULL ON |
| Semiconductor motor starter | Form 1 controller with motor overload protection | Form 2 controller with motor overload protection | Not available |
| Semiconductor DOL motor starter | Not available | Not available | Form 3 DOL motor controller with motor overload protection |
| Hybrid motor controller HxA ^a where x = 1, 2 or 3 | H1A: <ul style="list-style-type: none"> – Open – OFF state – Starting function – Manoeuvring – Controlled acceleration – Running – Full ON – Controlled deceleration | H2A: <ul style="list-style-type: none"> – Open – OFF state – Starting function – Controlled acceleration – FULL ON | H3A: <ul style="list-style-type: none"> – Open – OFF state – Starting function – FULL ON |
| Hybrid motor controller HxB ^b where x = 1, 2 or 3 | H1B: <ul style="list-style-type: none"> – Open – Starting function – Manoeuvring – Controlled acceleration – Running – FULL ON – Controlled deceleration | H2B: <ul style="list-style-type: none"> – Open – Starting function – Controlled acceleration – FULL ON | H3B: <ul style="list-style-type: none"> – Open – Starting function – FULL ON |
| Hybrid motor starter | Form H1A or H1B with motor overload protection | Form H2A or H2B with motor overload protection | Form H3A or H3B with motor overload protection |
| ^a Two separate controls for the controller and the series mechanical switching device. | | | |
| ^b One control only for the series mechanical switching device. | | | |

3.4 Terms and definitions concerning hybrid motor controllers and starters

3.4.1

hybrid motor controller or starter, form HxA (where x = 1, 2 or 3)

form 1, 2 or 3 semiconductor motor controller or starter in series with a mechanical switching device, all rated as a unit

NOTE 1 Separate control commands are provided for the series mechanical switching device and the semiconductor motor controller or starter. All the control functions appropriate to the form of motor controller or starter specified are provided, together with an OPEN position.

NOTE 2 See [Figure 1](#).

3.4.2

hybrid motor controller or starter, form HxB

form 1, 2 or 3 semiconductor motor controller or starter in series with a mechanical switching device, all rated as a unit. A single control command is provided for both the series mechanical switching device and the semiconductor motor controller or starter

NOTE 1 All the control functions appropriate to the form of motor controller specified are provided, with the exception of an OFF state.

NOTE 2 See [Figure 1](#).

3.4.3

OPEN position

condition of a hybrid semiconductor motor controller or starter when the series mechanical switching device is in the OPEN position

[2.4.21 of IEC 60947-1:2007, modified]

3.4.4

current-limit function

ability of the controller to limit the motor current to a specified value

NOTE It does not include the ability to limit the instantaneous current under conditions of short circuit.

3.4.5

manoeuvre

any deliberate operation that causes current changes which must be characterized and controlled (for example jogging, braking)

NOTE 1 Starting is a mandatory manoeuvre that is recognized separately.

NOTE 2 Braking operations performed by the a.c. semiconductor motor controller or starter are considered to be a manoeuvre within the scope of this standard.

3.4.6

controlled acceleration

control of motor performance while increasing motor speed by acting on the motor supply

3.4.7

controlled deceleration

control of motor performance while decreasing motor speed by acting on the motor supply

3.4.8

controlled running

control of motor performance by acting on the motor supply while the motor is running at normal speed (for example energy saving)

3.4.9

prospective current (of a circuit and with respect to a switching device or a fuse)

current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

NOTE The method to be used to evaluate and to express the prospective current is to be specified in the relevant product standard.

[IEC 60947-1:2007, 2.5.5]

3.4.10

prospective locked rotor current I_{LRP}

prospective current that would flow when the rated voltage is applied to the motor with a locked rotor

3.4.11

ON-state

the condition of a controller when the conduction current can flow through its main circuit

3.4.12

FULL-ON (state of controllers)

the condition of a controller when the controlling functions are set to provide normal full voltage excitation to the load

3.4.13

minimum load current

minimum operational current in the main circuit which is necessary for correct action of a controller in the ON-state

NOTE The minimum load current should be given as the r.m.s value.

3.4.14

OFF-state

the condition of a controller when no control signal is applied, and no current exceeding the OFF-state leakage current flows through the main circuit

3.4.15

OFF-state leakage current I_L

the current which flows through the main circuit of a controller in the OFF-state

3.4.16

operation (of a controller)

transition from the ON-state to the OFF-state, or the reverse

3.4.17

operating cycle (of a controller)

succession of operations from one state to the other and back to the first state

NOTE A succession of operations not forming an operating cycle is referred to as an operating series.