BS EN 60947-4-3:2014

BSI Standards Publication

Low-voltage switchgear and controlgear

Part 4-3: Contactors and motor-starters — AC semiconductor controllers and contactors for non-motor loads

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 60947-4-3:2014. It is identical to IEC 60947-4-3:2014. It supersedes BS EN 60947-4-3:2000+ A2:2011 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PEL/17, Switchgear, controlgear, and HV-LV co-ordination, to Subcommittee PEL/17/2, Low voltage switchgear and controlgear.

A list of organizations represented on this committee can be obtained on request to its secretary.

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

Published by BSI Standards Limited 2014

ISBN 978 0 580 81394 8
ICS 29.130.20; 31.180

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2014.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60947-4-3

June 2014

ICS 29.130.20; 31.180

Supersedes EN 60947-4-3:2000

English Version

Low-voltage switchgear and controlgear - Part 4-3: Contactors and motor-starters - AC semiconductor controllers and contactors for non-motor loads (IEC 60947-4-3:2014)

Appareillage à basse tension - Partie 4-3: Contacteurs et démarreurs de moteurs - Gradateurs et contacteurs à semiconducteurs pour charges, autres que des moteurs, à courant alternatif (CEI 60947-4-3:2014)

Niederspannungsschaltgeräte - Teil 4-3: Schütze und Motorstarter - Halbleiter-Steuergeräte und -Schütze für nichtmotorische Lasten für Wechselspannung (IEC 60947-4-3:2014)

This European Standard was approved by CENELEC on 2014-06-11. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

The text of document 121A/2/FDIS, future edition 2 of IEC 60947-4-3, prepared by SC 17B “Low-voltage switchgear and controlgear” of IEC/TC 17 “Switchgear and controlgear" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60947-4-3:2014.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-03-11
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-06-11

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and covers essential requirements of EU Directive 2004/108/EC.

For relationship with EU Directive(s), see informative Annex ZZ, which is an integral part of this document.

This document supersedes EN 60947-4-3:2000.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC).

Endorsement notice

The text of the International Standard IEC 60947-4-3:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60085:2007	NOTE	Harmonized as EN 60085:2008 (modified).
IEC 60146 (series)	NOTE	Harmonized as EN 60146 (series) (not modified).
IEC 60664 (series)	NOTE	Harmonized as EN 60664 (series) (not modified).
IEC 60947-4-2:2011	NOTE	Harmonized as EN 60947-4-2:2012 (modified).
IEC 61439 (series)	NOTE	Harmonized as EN 61439 (series) (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60269-1	2006	Low-voltage fuses -- Part 1: General requirements	EN 60269-1	2007
IEC 60410	1973	Sampling plans and procedures for inspection by attributes	-	-
IEC 60947-1	2007	Low-voltage switchgear and controlgear -- Part 1: General rules	EN 60947-1	2007
+A1	2010		+A1	2011
IEC 61000-4 (series)	-	Electromagnetic compatibility (EMC) -- Part 4-1: Testing and measurement techniques - Overview of IEC 61000-4 series	EN 61000-4 (series)	-
IEC 61000-4-5	2005	Electromagnetic compatibility (EMC) -- Part 4-5: Testing and measurement techniques - Surge immunity test	EN 61000-4-5	2006
CISPR 11 (mod)	2009	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	EN 55011	2009
CISPR 11:2009/A1	2010		EN 55011:2009/A1	2010

Annex ZZ
(informative)

Coverage of Essential Requirements of EU Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers protection requirements of Annex I Article 1 of the EU Directive 2004/108/EC.

Compliance with this standard provides presumption of conformity with the specified essential requirements of the Directives concerned.

NOTE: Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

CONTENTS

INTRODUCTION

This part of IEC 60947 covers low-voltage a.c. semiconductor controllers and contactors (solid-state contactors) intended for the use with non-motor loads. As controllers, they have many capabilities beyond the simple switching on and off of non-motor loads. As contactors, they perform the same functions as mechanical contactors, but utilize one or more semiconductor switching devices in their main poles.

The devices may be single-pole or multi-pole (see 2.3.1 of IEC 60947-1:2007,). This standard refers to complete devices rated as a unit incorporating all necessary heat-sinking material and terminals. It includes devices with all necessary terminals, which are supplied with or without heat-sink in knocked-down form for combination by the users, when the manufacturer gives with the device detailed information about choosing the heat-sink and mounting the device on the heat-sink.

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 "contactor" is used in this standard wherever the feature of simple switching on and off is the most significant point of interest. Specific designations (for example, form 4, form HxB, etc.) are used wherever the unique features of various configurations comprise significant points of interest.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-3: Contactors and motor-starters – AC semiconductor controllers and contactors for non-motor loads

1 Scope

This part of IEC 60947 applies to a.c. semiconductor non-motor load controllers and contactors intended for performing electrical operations by changing the state of a.c. electric circuits between the ON-state and the OFF-state. Typical applications are classified by utilization categories given in Table 2.

As controllers, they may be used to reduce the amplitude of the r.m.s. a.c. voltage on the load terminals from that of the applied voltage – either continuously or for a specified period of time. The half-wave period of the a.c. wave form remains unchanged from that of the applied voltage.

They may include a series mechanical switching device and are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c.

This standard characterizes controllers and contactors for use with or without bypass switching devices.

The semiconductor controllers and contactors dealt with in this standard are not normally intended to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 8.2.5) should form part of the installation but not necessarily of the controller itself.

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

This standard does not apply to:

– operation of a.c. and d.c. motors;
– low-voltage a.c. semiconductor motor controllers and starters covered by IEC 60947-4-2;
– electronic a.c. power controllers covered by the IEC 60146 series;
– all-or-nothing solid-state relays.

Contactors and control-circuit devices used in semiconductor controllers and contactors 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

a) the characteristics of semiconductor controllers and contactors and associated equipment;
b) the conditions with which semiconductor controllers and contactors should comply with reference to:
   – their operation and behaviour;
   – their dielectric properties;
   – the degrees of protection provided by their enclosures, where applicable;

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

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

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

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*
Amendment 1:2010

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

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

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

3 Terms, definitions, symbols and abbreviations

For the purposes of this document, the terms and definitions given in Clause 2 of IEC 60947-1:2007, Amendment 1 (2010), as well as the following additional terms and definitions apply:

Reference

A

AC semiconductor controller 3.1.1.1

B

Bypassed controller 3.1.24

C

Current-limit function 3.1.3

D

Defined-point switching (of a semiconductor controller) 3.1.14.4.1

F

Full-on (state of controllers) 3.1.10

H

Hybrid controllers or contactors, form HxA (where x = 4 or 5) 3.1.2.1
Hybrid controllers or contactors, form HxB 3.1.2.2

I

Instantaneous switching function 3.1.14.3

L

Load control 3.1.4

M

3.1 Terms and definitions concerning a.c. semiconductor (non-motor-load) control devices

3.1.1 AC semiconductor controllers and contactors (solid-state contactors) (see Figure 1)

3.1.1.1
a.c. semiconductor controller
semiconductor switching device that provides a switching function for an a.c. electrical load (non-motor load) and an OFF-state

Note 1 to entry: Because dangerous levels of leakage currents (see 3.1.13) can exist in a semiconductor controller in the OFF-state, the load terminals should be considered to be live at all times.

Note 2 to entry: 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.

Note 3 to entry: See 2.2.3 of IEC 60947-1:2007 for the definition of semiconductor switching device.

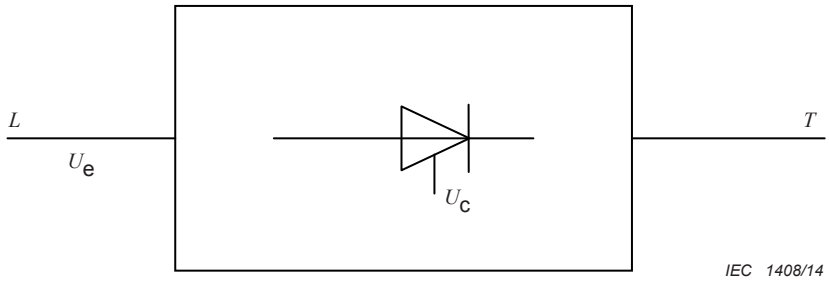
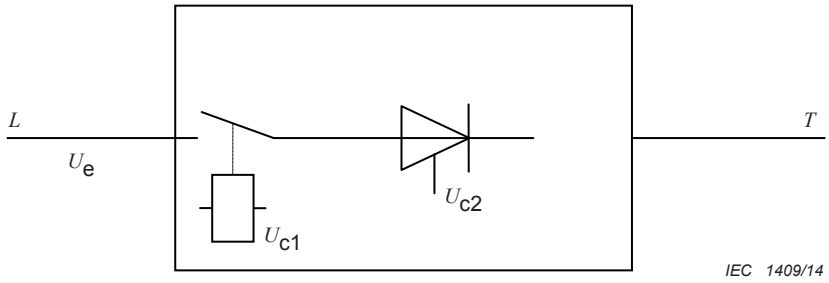
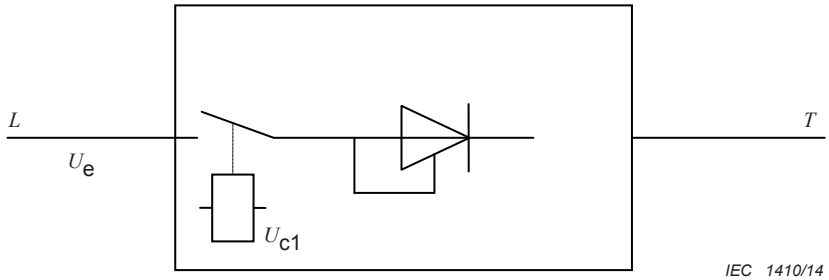
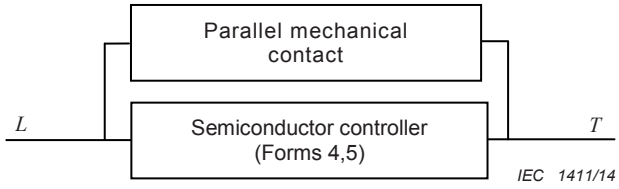
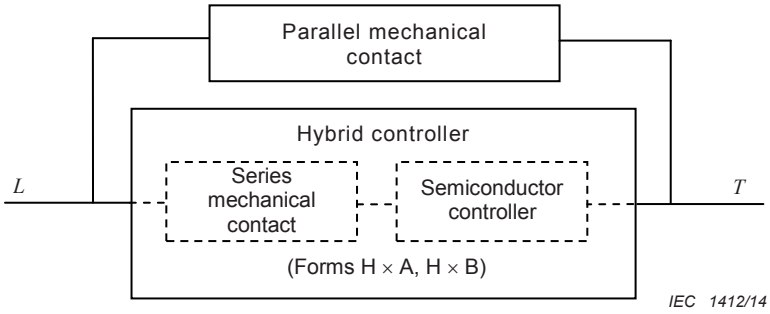
3.1.1.1.1
semiconductor controller (form 4)
a.c. semiconductor controller in which the switching function may comprise any method specified by the manufacturer. It provides control functions which may include any combination of ramp-up, load control or ramp-down. A full-on state may also be provided

3.1.1.1.2
Vacant

3.1.1.1.3
semiconductor direct-on-line controller (form 5)
semiconductor DOL controller (form 5)
special form of a.c. semiconductor controller in which the switching function is limited to the full-voltage, unramped method only and where the additional control function is limited to providing FULL-ON (also known as a semiconductor contactor or solid-state contactor)

Note 1 to entry: It is a device (see 2.2.13 of IEC 60947-1:2007) which performs the function of a contactor by utilizing a semiconductor switching device (see 2.2.3 of IEC 60947-1:2007). It has only one position of rest (OFF-state or Open state in the case of an H*x*B hybrid controller) and is operated by the application of a control signal. It is capable of carrying load currents as well as changing the state of the said load (electrical circuit) between the FULL-ON and the OFF-states (Open) under normal circuit conditions including operating overload conditions.

3.1.1.2
Vacant

Device	
Controller (all forms)	
Hybrid controller HxA [a] where x = 4 or 5	
Hybrid controller HxB [b] where x = 4 or 5	
Bypassed controller	
Bypassed hybrid controller [c]	

[a] Two separate controls for the controller and the series mechanical switching device respectively.
[b] One control only for the series mechanical switching device.
[c] For other configurations, tests can be suitably adapted by agreement between the user and the manufacturer.

Figure 1 – Graphical possibilities of controllers

Table 1 – Functional possibilities of controllers and contactors

Device	Form 4	Form 5
Semiconductor controller	OFF-state Ramp-up Load control FULL-ON state Ramp-down	Not available
Semiconductor DOL contactor	Not available	OFF-state Switch-on function FULL-ON state
Hybrid controller H*x*A [a] where *x* = 4 or 5	H4A: – open state – OFF-state – ramp-up – load control – FULL-ON state – ramp-down	H5A: – open state – OFF-state – switch-on function – FULL-ON state
Hybrid controller H*x*B [b] where *x* = 4 or 5	H4B: – open state – ramp-up – load control – FULL-ON state – ramp-down	H5B: – open state – switch-on function – FULL-ON state

[a] Two separate controls for the controller and the series mechanical switching device, respectively.

[b] One control only for the series mechanical switching device.

3.1.2 **Hybrid controllers and contactors** (see Figure 1)

3.1.2.1
hybrid controllers form H*x*A (where *x* = 4 or 5)
hybrid contactors form H*x*A (where *x* = 4 or 5)
form 4, or form 5 semiconductor controller in series with a mechanical switching device all rated as a unit

Note 1 to entry: Separate control commands are provided for the series mechanical switching device and the semiconductor controller or contactor. All the control functions appropriate to the form of controller specified are provided together with an OPEN position.

3.1.2.2
hybrid controllers form H*x*B (where *x* = 4 or 5)
hybrid contactors form H*x*B (where *x* = 4 or 5)
form 4 or form 5 semiconductor controller in series with a mechanical switching device all rated as a unit

Note 1 to entry: A single control command is provided for both the series mechanical switching device and the semiconductor controller or contactor. All the control functions appropriate to the form of controller specified are provided with the exception of an OFF-state.

3.1.2.3
OPEN position
condition of a hybrid semiconductor controller when the series mechanical switching device is in the OPEN position

Note 1 to entry: See 2.4.21 of IEC 60947-1:2007 for the definition of open position.

3.1.3
current-limit function
ability of the controller to limit the load current to a specified value

Note 1 to entry: It does not include the ability to limit the instantaneous current under conditions of short circuit.

3.1.4
load control
any deliberate operation which causes changes in the effective power available to the load through variation of either

– an imposed operating cycle (i.e. variation of the cyclic duration factor F and/or the number of operating cycles per hour S, see 5.3.4.6)

  or

– the load terminal voltage (for example, through phase-angle control)

  or

– a combination of these

Note 1 to entry: Switch-on is a mandatory form of load control that is recognized separately.

Note 2 to entry: Load control can be performed by a form 5 controller, if an external switching device or control circuit causes the cyclic transition from the OFF-state to the FULL-ON state and back again (i.e. load control by operating cycle).

3.1.5
ramp-up
switching (switch-on) function which causes the transition from the OFF-state (or from the open state, in the case of a HxB hybrid controller) to the ON-state (i.e. to the FULL-ON state or to a load control operation) over a defined period of time (the ramp-up time)

3.1.6
ramp-down
switching (switch-off) function which causes the transition from the ON-state (i.e. either from FULL-ON or from a load control operation) to the OFF-state (or the open state, in the case of an HxB hybrid controller) over a defined period of time (ramp-down time)

3.1.7
Vacant

3.1.8
Vacant

3.1.9
ON-state
condition of a semiconductor controller when the conduction current can flow through its main circuit

3.1.10
FULL-ON
condition of a controller when the controlling functions are set to provide normal full-voltage excitation to the load

3.1.11
minimum load current
minimum operational current in the main circuit which is necessary for correct action of a controller in the ON-state

Note 1 to entry: The minimum load current should be given as the r.m.s. value.

3.1.11.1
minimum load current detection
ability of the controller to detect and signal that the load current is below a specified minimum value, for which signalling can be achieved by the OFF or open states

3.1.12
OFF-state
condition of a controller when no control signal is applied and no current exceeding the OFF-state leakage current flows through the main circuit

3.1.13
OFF-state leakage current
I_L
current which flows through the main circuit of a semiconductor contactor in the OFF-state

3.1.14
operation of a controller
operation of a controller
transition from the ON-state to the OFF-state or the reverse

3.1.14.1
switching function
function designed to make or break the current during the operation of a controller

3.1.14.2
Vacant

3.1.14.3
instantaneous switching function
switching function which causes the instantaneous transition from the ON-state (i.e. either from FULL-ON or from a load control operation) to the OFF-state (or the open state, in the case of an HxB hybrid controller) or vice versa

Note 1 to entry: In the case of switch-off, the term "instantaneous" is used to mean the minimum opening time (see 2.5.39 of IEC 60947-1:2007).

Note 2 to entry: In the case of switch-on, the term "instantaneous" is used to mean make time (see 2.5.43 of IEC 60947-1:2007) plus the transient time determined only by external circuit impedance.

3.1.14.4
switching point
point on the wave form of the applied voltage at which the semiconductor switching device becomes conductive during a switch-on operation

Note 1 to entry: Applied voltage is defined in 2.5.32 of IEC 60947-1:2007.

3.1.14.4.1
defined-point switching
defined-point switching of a semiconductor controller
ability of a semiconductor controller to permit the flow of current through the main circuit only as from the instant the a.c. applied voltage or alternatively the a.c. control circuit voltage reaches a specified point on its wave form

Note 1 to entry: Applied voltage is defined in 2.5.32 of IEC 60947-1:2007.

Note 2 to entry: This form of optimized switching may be used for rush-current damping or the "soft switching" of transformers.

3.1.14.4.2
zero-point switching
zero-point switching of a semiconductor controller
special form of defined point switching applicable only in the case of single pole semiconductor controllers for non-motor loads

Note 1 to entry: The transition from the OFF-state to the ON-state after application of the control signal in such a way, that the semiconductor switching device becomes conductive at the instant a.c. applied voltage passes through zero

Note 2 to entry: Applied voltage is defined in 2.5.32 of IEC 60947-1:2007.

Note 3 to entry: This type of operation is particularly suitable for resistive and incandescent light loads. It should not be used for inductive or capacitive loads since the angular displacement between load current and driving voltage in these loads would cause severe transient current peaks.

3.1.14.4.3
random point switching
random point switching of a semiconductor controller
absence of the ability of a semiconductor controller to permit the flow of current through the main circuit only as from the instant the a.c. applied voltage or alternatively the a.c. control circuit voltage reaches a specified point on its wave form

Note 1 to entry: Applied voltage is defined in 2.5.32 of IEC 60947-1:2007.

3.1.15
operating cycle
operating cycle of a controller
succession of operations from one state to the other and back to the first state

Note 1 to entry: A succession of operations not forming an operating cycle is referred to as an operating series.

3.1.16
operating capability
under prescribed conditions, ability to perform a series of operating cycles without failure

3.1.17
overload current profile
current-time coordinate specifying the requirement to accommodate overload currents for a period of time (see 5.3.5.1)

3.1.18
rating index
rating information organized in a prescribed format unifying rated operational current and the corresponding utilization category, overload current profile, and the duty cycle or OFF-time (see 6.1 e))

3.1.19
tripping operation
tripping operation of a controller
operation to establish and maintain an OFF-state (or open position in the case of a form H*x*B controller) initiated by a control signal

3.1.20
trip-free controller
controller which establishes and sustains an OFF-state condition which cannot be overridden in the presence of a trip condition

Note 1 to entry: In the case of form H*x*B, the term "OFF-state condition" is replaced by the term "OPEN position".

3.1.21
overcurrent protective means
OCPM
means that cause a switching device to revert to the OFF-state or open position with or without time-delay when the current exceeds a predetermined value

3.1.22
ON-time
period of time during which the controller is on-load

Note 1 to entry: For example as in Figure F.1.

3.1.23
OFF-time
period of time during which the controller is off-load

Note 1 to entry: For example as in Figure F.1.

3.1.24
bypassed controller
equipment wherein the main circuit contacts of a mechanical switching device are connected in parallel with the main circuit terminals of a semiconductor switching device, and wherein the operating means of the two switching devices are co-ordinated

3.2 Vacant

3.3 Symbols and abbreviations

A_f	Final ambient temperature (9.3.3.3.4)
C_f	Final case temperature (9.3.3.3.4)
EMC	Electromagnetic compatibility
EUT	Equipment under test
I_c	Current made and broken (Table 10)
I_e	Rated operational current (5.3.2.3)
I_F	Leakage current after the blocking and commutating capability test (9.3.3.6.4)
I_L	OFF-state leakage current (3.1.13)
I_o	Leakage current before the blocking and commutating capability test (9.3.3.6.4)
I_{th}	Conventional free air thermal current (5.3.2.1)
I_{the}	Conventional enclosed thermal current (5.3.2.2)
I_u	Rated uninterrupted current (5.3.2.4)
SCPD	Short-circuit protective device
U_c	Rated control circuit voltage (5.5)
U_e	Rated operational voltage (5.3.1.1)
U_i	Rated insulation voltage (5.3.1.2)
U_{imp}	Rated impulse withstand voltage (5.3.1.3)
U_r	Power frequency recovery voltage (Table 8)
U_s	Rated control supply voltage (5.5)

4 Classification

All data which could be used as criteria for classification is given in 5.2.

5 Characteristics of a.c. semiconductor controllers and contactors

5.1 Summary of characteristics

The characteristics of controllers and contactors shall be stated in the following terms, where such terms are applicable:

– type of equipment (see 5.2);
– rated and limiting values for main circuits (see 5.3);
– utilization category (see 5.4);
– control circuits (see 5.5);
– auxiliary circuits (see 5.6);
– types and characteristics of relays and releases (under consideration);
– coordination with short-circuit protective devices (see 5.8).

5.2 Type of equipment

The following shall be stated.

a) Form of equipment

Forms of controllers and contactors (see 3.1.1 and 3.1.2).

b) Number of poles
   1) Number of main poles
   2) Number of main poles where the operation is controlled by a semiconductor switching element

c) Kind of current

AC only.

d) Interrupting medium (air, vacuum, etc.)

Applicable only to mechanical switching devices of hybrid controllers and contactors.

e) Operating conditions of the equipment
   1) Method of operation

For example:

– symmetrically controlled controller (such as semiconductor with fully controlled phases);
– non-symmetrically controlled controller (such as thyristors and diodes).

   2) Method of control

For example:

– automatic (by pilot switch or sequence control);
– non-automatic (that is push-buttons);
– semi-automatic (that is partly automatic, partly non-automatic).

   3) Method of connecting

For example (see Figure 2):

– load in star, thyristors connected between load and supply;

– load in delta, thyristors connected between load and supply;
– single-phase load, thyristors connected between load and supply.

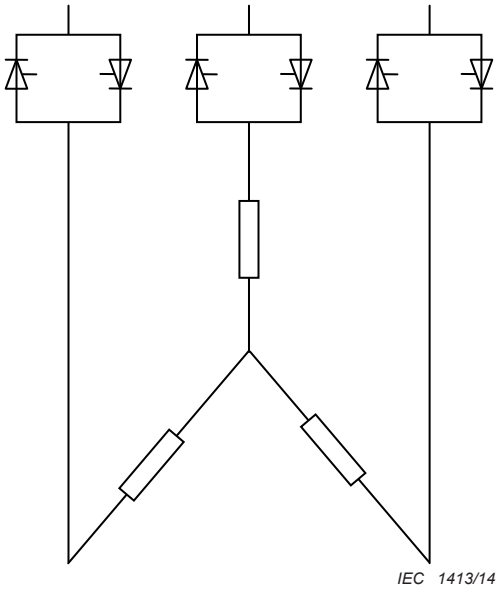


Figure 2a – Load in star Thyristors between load and supply

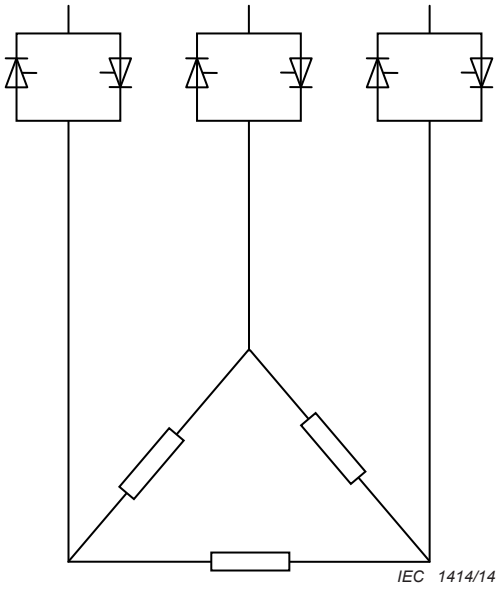


Figure 2b – Load in delta Thyristors between load and supply

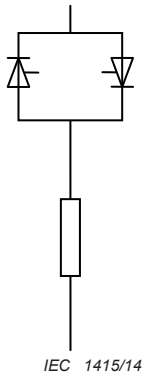


Figure 2c – Single-phase load Thyristors between load and supply

Figure 2 – Methods of connecting

5.3 Rated and limiting values for main circuits

The rated and limiting values established for controllers and contactors shall be stated in accordance with 5.3.1 to 5.3.6, but it may not be necessary to establish all applicable values by tests.

5.3.1 Rated voltages

A controller or a contactor is defined by the following rated voltages.

5.3.1.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1:2007 applies with the following addition.

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.

5.3.1.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

5.3.2 Currents

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

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

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

5.3.2.3 Rated operational current (I_e)

The rated operational current, I_e, of controllers and contactors is the normal operating current when the device is in the FULL-ON state and takes into account the rated operational voltage (see 5.3.1.1), the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the utilization category (see 5.4), the overload characteristics (see 5.3.5) and the type of protective enclosure, if any.

5.3.2.4 Rated uninterrupted current (I_u)

Subclause 4.3.2.4 of IEC 60947-1:2007 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

5.3.4 Rated duty

The rated duties considered as normal are as follows.

5.3.4.1 Eight-hour duty

A duty in which the controller remains in the FULL-ON state while carrying a steady current long enough for the equipment to reach thermal equilibrium but not for more than 8 h, without interruption.

5.3.4.2 Uninterrupted duty

A duty in which the controller remains in the FULL-ON state while carrying a steady current without interruption 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 IEC 60947-1:2007 applies except that the first paragraph is changed to read:

"A duty with on-load periods in which the controller remains in the FULL-ON state (or load control state), having a definite relation to off-load periods, both periods being too short to allow the equipment to reach thermal equilibrium."

5.3.4.4 Temporary duty

Duty in which the semiconductor controller remains in the FULL-ON state (or load control state) for periods of time insufficient to allow the equipment to reach thermal equilibrium, the current-carrying periods being separated by no-load periods of sufficient duration to restore equality of temperature with the cooling medium. Standard values of temporary duty are:

30 s, 1 min, 3 min, 10 min, 30 min, 60 min and 90 min.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of IEC 60947-1:2007 applies.

5.3.4.6 Duty cycle values and symbols

For the purpose of this standard, the duty cycle is expressed by two symbols, F and S. This describes the duty and also sets the time that must be allowed for cooling.

F is the ratio of the on-load period to the total period, expressed as a percentage.

The preferred values of F are:

F = 1 %, 5 %, 15 %, 25 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 %, 99 %.

S is the number of operating cycles per hour. The preferred values of S are:

S = 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, 60 operating cycles per hour.

NOTE Other values of F and/or S can be declared by the manufacturer.

5.3.5 Normal load and overload characteristics

Subclause 4.3.5 of IEC 60947-1:2007 applies with the following additions.

5.3.5.1 Overload current profile

The overload current profile gives the current/time coordinates for the controlled overload current. It is expressed by two symbols, X and T_X.

X denotes the overload current as a multiple of I_e selected from the array of values in Table 6 and represents the maximum value of operating current under operational overload conditions.

Deliberate overcurrents not exceeding ten cycles of the power-line frequency which may exceed the stated value of $X \times I_e$ are disregarded for the overload current profile.

T_x denotes the sum of duration times for the operational overload currents during the switching function (for example pre-heater elements of metal vapour lamps), load control and steady-state operating. See Table 6.

5.3.5.2 Operating capability

Operating capability represents the combined capabilities of

– current commutation and current carrying in the ON-state, and

– establishing and sustaining the OFF-state (blocking),

at full voltage under normal load and overload conditions in accordance with utilization category, overload current profile and specified duty cycles.

Operating capability is characterized by:

– rated operational voltage (see 5.3.1.1);

– rated operational current (see 5.3.2.3);

– rated duty (see 5.3.4);

– overload current profile (see 5.3.5.1);

– utilization category (see 5.4).

Requirements are given in 8.2.4.1.

5.3.5.3 Switch-on, ramp-up, ramp-down and load control characteristics

Typical service conditions for controllers and contactors are described in Annex B.

5.3.6 Rated conditional short-circuit current

Subclause 4.3.6.4 of IEC 60947-1:2007 applies.

5.4 Utilization category

Subclause 4.4 of IEC 60947-1:2007 applies with the following addition.

For controllers and contactors the utilization categories as given in Table 2 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 (see Table 2) is characterized by the values of the currents, voltages, power-factors and other data of Tables 3, 4, 5 and 6 and by the test conditions specified in this standard.

The first digit of the utilization category identification designates a semiconductor switching device (e.g., within this standard, a semiconductor controller or contactor).

The second digit designates a typical application. In the case of AC-55 and AC-56 respectively, the a- or b-suffix serves to define the application more closely.

NOTE As opposed to the convention used in IEC 60947-4-2 for a.c. semiconductor motor controllers and starters, these suffixes do not refer to the use of a bypass switching device.

5.4.1 Assignment of ratings based on the results of tests

A designated semiconductor controller or contactor with a rating for one utilization category which has been verified by testing can be assigned other ratings without testing, provided that:

- the rated operational current and voltage that are verified by testing shall not be less than the ratings that are to be assigned without testing;
- the utilization category and duty cycle requirements for the tested rating shall be equal to or more severe than the rating that is to be assigned without testing; the relative levels of severity are given in Table 3;
- the overload current profile for the tested rating shall be equal to or more severe than the rating that is to be assigned without testing, in accordance with the relative levels of severity in Table 3. Only values of X lower than the tested value of X may be assigned without testing.

Table 2 – Utilization categories

Utilization category	Typical application
AC-51	Non-inductive or slightly inductive loads, resistance furnaces
AC-55a	Switching of electric discharge lamp controls
AC-55b	Switching of incandescent lamps
AC-56a	Switching of transformers
AC-56b	Switching of capacitor banks
NOTE 1 A means of bypassing the semiconductor controller after attainment of the FULL-ON condition can be provided. This can be integral with the semiconductor contactor or installed separately. NOTE 2 If the utilization category applies only in conjunction with the use of a bypass as described in Note 1 above, then this is stated by the manufacturer. See 6.1.	

Table 3 – Relative levels of severity

Severity level	Utilization category	Overload current profile	ON-time/OFF-time requirements
Most severe	AC-51 AC-55a AC-55b AC-56a AC-56b all without bypass	Highest value of $(X \times I_e)^2 \times T_x$ (Note 1)	Highest value of $F \times S$ (Note 2)
	AC-55a only in conjunction with bypass	Highest value of $(X \times I_e)^2 \times T_x$ (Note 1)	Lowest value of OFF-time (Note 3)
NOTE 1 When the highest value of $(X \times I_e)^2 \times T_x$ occurs at more than one value of $X \times I_e$, then the highest value of $X \times I_e$ applies. NOTE 2 When the highest value of $F \times S$ occurs at more than one value of S, then the highest value of S applies. NOTE 3 When the highest value of $(X \times I_e)^2 \times T_x$ occurs at more than one value of OFF-time, then the lowest value of OFF-time applies.			

5.5 Control circuits

Subclause 4.5.1 of IEC 60947-1:2007, Amendment 1 (2010) applies with the following additions.

The characteristics of electronic control circuits are:

– kind of current;
– power consumption;
– rated frequency (or d.c.);
– rated control circuit voltage, U_c (nature: a.c./d.c.);
– rated control supply voltage, U_s (nature: a.c./d.c.);
– nature of control circuit devices (contacts, sensors).

NOTE A distinction is made between control circuit voltage, U_c, which is the controlling input signal, and control supply voltage, U_s, which is the voltage applied to energize the power supply terminals of the control circuit equipment and can be different from U_c due to built-in transformers, rectifiers, resistors, etc.

5.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies with the following additions.

Electronic auxiliary circuits perform useful functions (for example monitoring, data acquisition, etc.) that are not necessarily relevant to the direct task of governing the intended performance characteristic.

Under normal conditions, auxiliary circuits are characterized in the same way as control circuits and are subject to the same kinds of requirements. If the auxiliary functions include unusual performance features, the manufacturer should be consulted to define the critical characteristics.

Digital inputs and/or digital outputs contained in controllers and contactors, and intended to be compatible with PLCs, shall fulfil the requirements of Annex S of IEC 60947-1:2007.

5.7 Vacant

5.8 Coordination with short-circuit protective devices (SCPD)

Controllers and contactors are characterized by the type, ratings and characteristics of the SCPD to be used to provide an adequate protection of the controller or contactor against short-circuit currents.

Requirements are given in 8.2.5 of this standard and in 4.8 of IEC 60947-1:2007, Amendment 1 (2010).

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer.

Identification

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

Characteristics, basic rated values and utilization

d) rated operational voltages (see 5.3.1.1);

e) rated operational currents, corresponding utilization category (see 5.4), overload current profile (see 5.3.5.1), and duty cycle (see 5.3.4.6) or OFF-time, comprising the rating index.

The prescribed format for AC-51 is shown by this example:

100 A: AC-51: 1,5 $\times$ I_e *– 46 s: 50 – 30*

This indicates 100 A current rating for general applications with non-inductive or slightly inductive loads. The device can accommodate 150 A for 46 s, 50 % on-load factor, 30 standard operating cycles per hour.

If the rated operational current only applies if the controller is used in conjunction with a bypass, then this shall be indicated by the following prescribed form of the rating index, shown by example for AC-55a:

100 A: AC-55a: 2 $\times$ I_e *– 30 s: 180 s*

This indicates 100 A current rating for the switching on of electric discharge lamp controls. The device can accommodate 200 A for 30 s, the OFF-time shall not be less than 180 s before any subsequent switch-on may be initiated.

f) either the value of the rated frequency 50 Hz/60 Hz,
or other rated frequencies for example 16 2/3 Hz, 400 Hz;

g) indication of the rated duties as applicable (see 5.3.4.3);

h) form designation (for example form 4 or form H4A, see Table 1).

Safety and installation

j) rated insulation voltage (see 5.3.1.2);

k) rated impulse withstand voltage (see 5.3.1.3);

l) IP code, in case of an enclosed equipment (see 8.1.11);

m) pollution degree (see 7.1.3.2);

n) rated conditional short-circuit current and type of coordination of the controller and the type, current rating and characteristics of the associated SCPD (see 5.8);

p) vacant.

Control circuits

q) rated control circuit voltage U_c, nature of current and rated frequency, and, if necessary, rated control supply voltage U_s, nature of current and rated frequency and any other information (for example impedance matching requirements) necessary to ensure satisfactory operation of the control circuits (see Annex U of IEC 60947-1:2007, Amendment 1 (2010) for examples of control circuit configurations);

Auxiliary circuits

r) nature and ratings of auxiliary circuits (see 5.6);

Overcurrent protective means

s) vacant.

EMC emission and immunity levels

t) the equipment class and the specific requirements necessary to maintain compliance (see 8.3.2); if an EMC filter is required to fulfil the emission levels given in Table 15, its reference and characteristics from 9.4.1.1 have to be stated;

u) the immunity levels attained and the specific requirements necessary to maintain compliance (see 8.3.3).

6.2 Marking

Subclause 5.2 of IEC 60947-1:2007, Amendment 1 (2010) applies to controllers and contactors with the following addition.

Data under d) to u) in 6.1 shall be included on the nameplate, or on the equipment, or in the manufacturer's published literature.

Data under c) and l) in 6.1 shall preferably be marked on the equipment.

6.3 Instructions for installation, operation and maintenance

Subclause 5.3 of IEC 60947-1:2007 applies, with the following addition.

For products complying with this standard, the following are specific items to be considered:

– in the event of a short-circuit;
– in the event of temperature rise above 50 K of the metallic radiator surface of the device.

7 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007 applies with the following exception.

7.1 Normal service conditions

Subclause 6.1 of IEC 60947-1:2007 applies with the following exception.

7.1.1 Ambient air temperature

The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.

The lower limit of the ambient air temperature is 0 °C.

Ambient air temperature is that existing in the vicinity of the equipment if supplied without enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

NOTE If the equipment is to be used at ambient air temperatures above +40 °C (e.g. within switchgear and controlgear assemblies and in forges, boiler rooms, tropical countries) or below 0 °C (e.g. –25 °C, as required by IEC 61439 series for outdoor installed low-voltage switchgear and controlgear assemblies) the manufacturer should be consulted. Information given in the manufacturer's catalogue may satisfy this requirement.

7.1.2 Altitude

Subclause 6.1.2 of IEC 60947-1:2007 applies with the following modification.

The altitude of the site of installation does not exceed 1 000 m.

For equipment to be used at higher altitudes, it is necessary to take into account the reduction of the dielectric strength and the cooling effect of the air. Electrical equipment intended to operate in these conditions should be designed or used in accordance with an agreement between manufacturer and user.

7.1.3 Atmospheric conditions

7.1.3.1 Humidity

Subclause 6.1.3.1 of IEC 60947-1:2007 applies.

7.1.3.2 Degrees of pollution

Unless otherwise stated by the manufacturer, controllers and contactors are intended for use in pollution degree 3 environmental conditions, as defined in 6.1.3.2 of IEC 60947-1:2007. However, other pollution degrees may be considered applicable, depending upon the micro-environment.

7.1.4 Shock and vibrations

Subclause 6.1.4 of IEC 60947-1:2007 applies.

7.2 Conditions during transport and storage

Subclause 6.2 of IEC 60947-1:2007 applies.

7.3 Mounting

Subclause 6.3 of IEC 60947-1:2007 applies for EMC considerations, see 8.3 and 9.4 of this standard.

7.4 Electrical system disturbances and influences

For EMC considerations, see 8.3 and 9.4.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 7.1.1 of IEC 60947-1:2007 applies.

8.1.2 Materials

8.1.2.1 General materials requirements

Subclause 7.1.2.1 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.1.2.2 Glow wire testing

Subclause 7.1.2.2 of IEC 60947-1:2007, Amendment 1 (2010) applies with the following addition.

When tests on the equipment or on sections taken from the equipment are used, parts of insulating materials necessary to retain current-carrying parts in position shall conform to the glow-wire tests in 8.2.1.1.1 of IEC 60947-1:2007 at a test temperature of 850 °C.

8.1.2.3 Test based on flammability category

Subclause 7.1.2.3 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.1.3 Current-carrying parts and their connections

Subclause 7.1.3 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.1.4 Clearances and creepage distances

Subclause 7.1.4 of IEC 60947-1:2007 applies with the following note.

NOTE The nature of a semiconductor makes it unsuitable for use for isolation purposes.

8.1.5 Actuator

Vacant

8.1.6 Indication of the contact position

Vacant

8.1.7 Additional requirements for equipment suitable for isolation

Vacant

8.1.8 Terminals

Subclause 7.1.8 of IEC 60947-1:2007, Amendment 1 (2010) applies with, however, the following additional requirements.

8.1.8.4 Terminal identification and marking

Subclause 7.1.8.4 of IEC 60947-1:2007 applies with additional requirements as given in Annex A.

8.1.9 Additional requirements for equipment provided with a neutral pole

Vacant

8.1.10 Provisions for protective earthing

Subclause 7.1.10 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.1.11 Enclosures for equipment

Subclause 7.1.11 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.1.12 Degrees of protection of enclosed equipment

Subclause 7.1.12 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.1.13 Conduit pull-out, torque and bending with metallic conduits

Subclause 7.1.13 of IEC 60947-1:2007, Amendment 1 (2010) applies.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

Auxiliary devices used in controllers and contactors shall be operated in accordance with the manufacturer's instructions and their relevant product standard.

8.2.1.1.1 Controller and contactors shall be so constructed that they

a) are trip-free (see 3.1.20);
b) can be caused to return to the OPEN or OFF-state by the operating means at any time during switching from the OFF to the ON-state or while in the FULL-ON state.

Compliance is verified in accordance with 9.3.3.6.4.

8.2.1.1.3 Controllers and contactors shall not malfunction due to mechanical shock or electromagnetic interference caused by operation of their internal devices.

Compliance is verified in accordance with 9.3.3.6.4.

8.2.1.1.4 The moving contacts of the series mechanical switching device in hybrid load controllers and contactors shall be so mechanically coupled that all poles make and break substantially together whether operated manually or automatically.

8.2.1.2 Limits of operation of controllers

Controllers and contactors shall function satisfactorily at any voltage between 85 % and 110 % of their rated operational voltage U_e, and rated control supply voltage U_s, when tested in accordance with 9.3.3.6.4. Where a range is declared, 85 % shall apply to the lower value and 110 % to the higher.

8.2.1.3 Relays and releases associated with controllers

Relays and releases to be associated with a controller to provide protection for the load shall operate within a time T_x at a current $X \times I_e$, where X and T_x are the values given by the declared rating index. In the case of more than one declared rating index, X and T_x are the values corresponding to the rating index giving the highest product $(X \times I_e)^2 \times T_x$.

8.2.1.4 Vacant

8.2.1.5 Vacant

8.2.1.5.1 Vacant

8.2.1.5.2 Vacant

8.2.1.6 Type-tested components in bypassed controllers

8.2.1.6.1 Switching devices which meet the requirements of their own relevant product standard shall be considered as partially type-tested devices subject to the following additional requirements:

a) the temperature rises of mechanical switching devices shall comply with 8.2.2;
b) the making and breaking capacity of mechanical switching devices shall comply with 8.2.4.2;
c) semiconductor switching devices shall comply with 8.2.4.1 for the utilization category according to the intended ratings of the bypassed controllers.

8.2.1.6.2 For the purpose of setting requirements for bypassed controllers, switching devices which meet all of the requirements of 8.2.1.6.1, before they are installed, shall be identified as type-tested components suitable for unrestricted use in a bypassed controller (see Annex J).

8.2.1.7 Dependent components in bypassed controllers

For the purpose of setting requirements for bypassed controllers, switching devices which do not meet all of the requirements of 8.2.1.6.1, before they are installed, shall be identified as dependent components suitable only for restricted use in a bypassed controller (see Annex J).

8.2.1.8 Unrestricted use of switching devices in bypassed controllers

When both the mechanical switching device and the semiconductor switching device are identified as type tested components, these devices shall be arranged and connected to comply with the assigned rating, duty and the end use intended by the manufacturer. There shall be no further restrictions.

8.2.1.9 Restricted use of switching devices in bypassed controllers

When either one or both switching devices are identified as dependent components, the switching devices shall comply with the following:

a) the switching devices shall be combined, rated and tested as a unit;

b) the switching devices shall be interlocked, by any of the following means, either individually or in combination: electrical, electronic or mechanical means, such that the mechanical switching contacts shall not be required to make or break overload currents without direct intervention by the semiconductor switching device;

c) the semiconductor switching device shall be enabled to take over the control of the current flowing in the main circuit whenever it is necessary to make or break overload currents.

8.2.2 Temperature rise

The requirements of 7.2.2 of IEC 60947-1:2007 apply to controllers and contactors in a clean, new condition.

NOTE Contact resistance due to oxidation can impact the temperature rise test at test voltages below 100 V. In the case of conducting the test at a voltage below 100 V, mechanical switching devices can have the contacts cleaned either by any non-abrasive method or by carrying out operating cycles with or without load several times prior to initiating the test at any voltage.

Temperature rise deviations on the metallic radiator surface of semiconductor devices are permitted: 50 K in the case where they need not be touched during normal operation.

If the limit of 50 K is exceeded, the manufacturer shall provide a suitable warning (e.g. symbol IEC 60417-5041 (2002-10))[1)] in accordance with 6.3. Provision of suitable guarding and location to prevent danger is the responsibility of the installer.

8.2.2.1 Vacant

8.2.2.2 Vacant

8.2.2.3 Vacant

8.2.2.4 Main circuit

8.2.2.4.1 General

The main circuit of a controller or contactor, which carries current in the FULL-ON state, shall be capable of carrying, without the temperature rises exceeding the limits specified in 7.2.2.1 of IEC 60947-1:2007 when tested in accordance with 9.3.3.3.4,

– for a controller or contactor intended for 8 h duty: its conventional thermal current (see 5.3.2.1 and/or 5.3.2.2);

– for a controller or contactor intended for uninterrupted duty, intermittent or temporary duty: the relevant rated operational current (see 5.3.2.3).

8.2.2.4.2 Series mechanical switching devices for hybrid controllers

For hybrid controllers, the temperature rise of the components in series with the main circuit shall be verified by the procedures given in 9.3.3.3.4 and 9.3.3.6.2 (see Table 13).

---

1) IEC 60417, *Graphical symbols for use on equipment*

8.2.2.4.3 Parallel mechanical switching devices for bypassed controllers

Devices identified as type tested components (see 8.2.1.6) shall be capable of carrying the current I_e without the temperature rises exceeding the limits specified in 7.2.2.1 of IEC 60947-1:2007.

For devices identified as dependent components (see 8.2.1.7), the temperature rise shall be verified by the procedures given in 9.3.3.3.4 and 9.3.3.6.2 (including Table 7 and Table 13). The device shall be tested as an integral part of a unit where the prescribed on-load periods for the two switching devices (Table 7) shall be determined by a sequence of operations which is the same as intended in normal service.

8.2.2.4.4 Semiconductor devices connected in the main circuit

The temperature rise of the semiconductor devices connected in the main circuit shall be verified by the procedures given in 9.3.3.3.4 and 9.3.3.6.2 (thermal stability test).

8.2.2.5 Control circuits

Subclause 7.2.2.5 of IEC 60947-1:2007 applies.

8.2.2.6 Windings of coils and electromagnets

8.2.2.6.1 Uninterrupted and 8 h duty windings

With the maximum value of current flowing through the bypass circuit, the coils windings shall withstand under continuous load and at rated frequency, if applicable, their maximum rated control supply voltage without the temperature rise exceeding the limits specified in Table 4 and 7.2.2.2 of IEC 60947-1:2007.

NOTE The temperature rise limits given in Table 4 and in 7.2.2.2 of IEC 60947-1:2007 are applicable only if the ambient air temperature remains within the limits –5 °C, +40 °C.

8.2.2.6.2 Intermittent duty windings

With no current flowing through the bypass circuit, the windings of the coils shall withstand, at the rated frequency, if applicable, their maximum rated control supply voltage applied as detailed in Table 5 according to their intermittent duty class, without the temperature rise exceeding the limits specified in Table 4 and 7.2.2.2 of IEC 60947-1:2007.

NOTE The temperature rise limits given in Table 4 and in 7.2.2.2 of IEC 60947-1:2007 are applicable only if the ambient air temperature remains within the limits –5 °C, +40 °C.

8.2.2.6.3 Specially rated (temporary or periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

NOTE Specially rated windings can include coils of contactors or controllers which are energised during the starting period only, trip coils of latched contactors and magnetic valve coils for inter-locking pneumatic contactors.

Table 4 – Temperature rise limits for insulated coils in air and in oil

Class of insulating material (according to IEC 60085)	Temperature rise limit (measured by resistance variation) K	
	Coils in air	Coils in oil
A	85	60
E	100	60
B	110	60
F	135	–
H	160	–

Table 5 – Intermittent duty test cycle data

Intermittent duty class	One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
1	3 600 s	ON-time should correspond to the on-load factor specified by the manufacturer
3	1 200 s	
12	300 s	
30	120 s	
120	30 s	
300	12 s	
1 200	3 s	

8.2.2.7 Auxiliary circuits

Subclause 7.2.2.7 of IEC 60947-1:2007 applies.

8.2.2.8 Other parts

Subclause 7.2.2.8 of IEC 60947-1:2007 applies, replacing words “plastics and insulating materials” with “insulating parts”.

8.2.3 Dielectric properties

The following requirements are based on the principles of the IEC 60664 series and provide the means of achieving coordination of insulation of equipment with the conditions within the installation.

The equipment shall be capable of withstanding

– the rated impulse withstand voltage (see 5.3.1.3) in accordance with the overvoltage category given in Annex H of IEC 60947-1:2007;

– the impulse withstand voltage across the contact gaps of devices suitable for isolation as given in Table 14 of IEC 60947-1:2007;

– the power-frequency withstand voltage.

NOTE 1 A direct voltage can be used instead, provided its value is not less than the projected alternating test voltage crest value.

NOTE 2 The correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the equipment is given in Annex H of IEC 60947-1:2007.

The rated impulse withstand voltage for a given rated operational voltage (see Notes 1 and 2 of 4.3.1.1 of IEC 60947-1:2007) shall be not less than that corresponding in Annex H of IEC 60947-1:2007 to the nominal voltage of the supply system of the circuit at the point where the equipment is to be used, and the appropriate overvoltage category.

The requirements of this subclause shall be verified by the tests of 9.3.3.4.

8.2.3.1 Impulse withstand voltage

1) Main circuit

Subclause 7.2.3.1 1) of IEC 60947-1:2007 applies.

2) Auxiliary and control circuits

Subclause 7.2.3.1 2) of IEC 60947-1:2007 applies with 2) a) modified as follows:

a) For auxiliary and control circuits which operate directly from the main circuit at the rated operational voltage, clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 12 of IEC 60947-1:2007 appropriate to the rated impulse withstand voltage.

NOTE Solid insulation of equipment associated with clearances are subjected to the impulse voltage.

8.2.3.2 Power-frequency withstand voltage of the main, auxiliary and control circuits

Subclause 7.2.3.2 of IEC 60947-1:2007 applies.

8.2.3.3 Clearances

Subclause 7.2.3.3 of IEC 60947-1:2007 applies.

8.2.3.4 Creepage distances

Subclause 7.2.3.4 of IEC 60947-1:2007 applies.

8.2.3.5 Solid insulation

Subclause 7.2.3.5 of IEC 60947-1:2007 applies.

8.2.3.6 Spacing between separate circuits

Subclause 7.2.3.6 of IEC 60947-1:2007 applies.

8.2.4 Normal load and overload performance requirements

Requirements concerning normal load and overload characteristics according to 5.3.5 are given in 8.2.4.1 and 8.2.4.2.

8.2.4.1 Operating capability requirements

Controllers and contactors shall be required to establish an ON-state, to commutate, to carry designated levels of load and, if applicable, overload currents, and to establish and sustain an OFF-state condition without failure or any type of damage, when tested in accordance with 9.3.3.6.

For controllers and contactors designated for the utilization categories AC-51, -55a, -55b, -56a, -56b and intended for use without a bypass, values of T_X corresponding to X values shall be not less than those given in Table 6.

Controllers and contactors designated for the utilization category AC-55a and intended for use with a bypass shall be capable of accommodating those applications where long switch-on times at currents greater than the rated continuous current are required (for example switching of lamps with preheating times). It shall be understood that the maximum thermal capacity of the controller may be fully depleted during the on-load period. Therefore, a suitable off-load period (for example bypass means) shall be provided for the controller immediately after the on-load period has expired. The values of T_x and the corresponding X values as well as the minimum off-load period shall be subject to agreement between manufacturer and user and shall be declared in the rating index using the prescribed format (see 6.1).

Ratings shall be verified under the conditions stated in Table 7 and Table 8 and in the relevant parts of 8.3.3.5.2 and 8.3.3.5.3 of IEC 60947-1:2007.

Where $X \times I_e$ is greater than 1 000 A, verification of the overload capability shall be subject to agreement between manufacturer and user (for example by computer modelling).

In Tables 7 and 8, the duty cycle for utilization categories AC-51, -55a, -55b, -56a, -56b all without bypass ($F - S = 50 - 1$), and the OFF-time for utilization categories AC-55a with bypass (OFF-time = 1 440 s), are the least severe requirements for an 8 h duty. The manufacturer may claim compliance with a more severe duty in which case he shall conduct a test for the most severe duty in accordance with Table 3.

For utilization categories AC-51, -55a, -55b, -56a, -56b without bypass, more severe test values for ON-time and OFF-time may be calculated by:

ON-time (s) = $36\ F/S$

OFF-time (s) = $36(100 - F)/S$

For utilization categories AC-55a with bypass, the manufacturer may claim compliance with the capability to perform starting duty operations with OFF-times that are less than the 1 440 s that are allowed as standard. However, this shall be verified by testing with the OFF-time declared by the manufacturer.

For controllers and contactors intended for intermittent, temporary or periodic duty, the manufacturer shall select from the arrays for F and S given in 5.3.4.6.

Table 6 – Minimum overload current withstand time (T_x) in relation to overload current ratio (X)

	T_x = 20 ms	T_x = 200 ms	T_x = 1 s	T_x = 10 s	T_x = 60 s	T_x = 300 s	Continuous
AC-51	X = 1,4	X = 1,4	X = 1,4	X = 1,2	X = 1,1	X = 1	X = 1
AC-55a	X = 10	X = 6	X = 4	X = 3	X = 2	X = 1,8	X = 1
AC-55b	X = 10	X = 6	X = 1,2	X = 1,1	X = 1	X = 1	X = 1
AC-56a	X = 30	X = 6	X = 1,2	X = 1,1	X = 1	X = 1	X = 1
AC-56b	X = 30	X = 1,4	X = 1,1	X = 1	X = 1	X = 1	X = 1

Table 7 – Minimum requirements for thermal stability test conditions

Utilization category	Form of controller	Test current, I_T, Operating cycle ON-time s		Operating cycle [a]
		Test level		OFF-time
Without bypass		I_T	ON-time s	s
AC-51	4, H4	$X \times I_e$	T_x	T_x
AC-55a	5, H5			
AC-55b				
AC-56a				
AC-56b				
With bypass		I_T	ON-time s	
AC-55a	4, H4	3 × I_e	240	≤ 1 440
	5, H5			

Parameters of the test circuit:

I_e = rated operational current

I_T = test current

U_T = test voltage (may be any value)

Cos φ = test circuit power factor (may be any value)

number of operating cycles [a]

[a] The number of operating cycles will depend upon the length of time required for the controller to reach thermal equilibrium.

Table 8 – Minimum requirements for overload capability test conditions

Utilization category	Parameters of the test circuit			Operating cycle[d] ON-time	Operating cycle[d] OFF-time	Number of operating cycles
	I_c/I_e	U_r/U_e [a]	Cos φ [b]	s	s	
AC-51	X	1,1	0,8	T_X [c]	≥ 10	5
AC-55a	3,0	1,1	0,45	0,05	≥ 10	5
AC-55b	1,5	1,1	[e]	0,05	60	50
AC-56a	30	1,1	≤ 1	0,05	≥ 10	5
AC-56b	[g]	1,1	[f]	0,05	≥ 10	1 000

I_c = test current

I_e = rated operational current

U_e = rated operational voltage

U_r = power-frequency recovery voltage

Temperature conditions

The initial case temperature C_i, for each test shall be not less than 40 °C plus the maximum case temperature rise during the temperature rise test (9.3.3.3), or alternatively the case temperature corresponding to the respective minimum requirement for the thermal stability test condition (Table 7). During the test, the ambient air temperature shall be between +10 °C and +40 °C.

a U_r/U_e may be any value during the test sequence except for the last three full periods of power frequency of the ON-time plus the first second of the OFF-time.

b Cos φ may be any value during the reduced voltage periods.

c See Table 6.

d Changeover time shall not be greater than three full periods of the power frequency.

e Tests to be carried out with an incandescent light load.

f Tests to be carried out with a capacitive load.

g Capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula:

$$I_{pmax} \leq I_{TSM} \sqrt{2}$$

where I_{pmax} is the peak inrush current of capacitor and I_{TSM} is the non-repetitive surge on-state current.

Table 9 – Minimum requirements and conditions for performance testing, including blocking and commutating capability

Utilization category	Test load parameters of the test circuit			Test cycles	
	U/U_e	Power	Cos φ	ON-time s	OFF-time s
AC-51	1,0	[a]	0,8 ….1,0	0,5	0,5
AC-55a	1,0	[b]	0,45	0,5	0,5
AC-55b	1,0	[c]	[c]	[f]	0,5
AC-56a	1,0	[d]	≤0,45	[f]	[g]
AC-56b	1,0	[e]	e	f	h
The following tests are to be carried out: – test 1: 100 operating cycles with 85 % U_e and 85 % U_s; – test 2: 1 000 operating cycles with 110 % U_e and 110 % U_s. During the tests: – the load and the ambient air may be at any temperature between 10 °C and 40 °C; – true r.m.s. voltage measuring means shall be connected between the line side terminal and the load side terminal on each pole of the EUT; – settings are limited to only those external adjusting means provided by the manufacturer in the normal product offerings. Controllers fitted with ramp-up functions shall be set at the maximum ramping time or 10 s, whichever is less. Results to be obtained: 1) 1a) or 1b) shall be fulfilled 1a) $I_O < 1$ mA and $I_F < 1$ mA 1b) if $I_O > 1$ mA or $I_F > 1$ mA, then: – $\Delta I < 1$ for each pole where $\Delta I = (I_F - I_O) / I_O$ and – I_O and I_F shall be within the limits given in the datasheet for the semiconductor. 2) No visual evidence of damage (i.e. smoke, discoloration). 3) No loss of functionality as specified by the manufacturer.					
a The test load shall be any convenient slightly inductive load. b The test load shall be any convenient inductive load. c The test load shall be any convenient incandescent lamp. d The test load shall be any convenient transformer. e The test load shall be any convenient capacitor or capacitor bank. f The on-time shall be greater than that time required to reach the steady-state nominal current. g The off-time is that time required for the current to become less than 10 % of the nominal ON-state current value. h The off-time is that time required for the voltage on the capacitor to become less than 10 % of the nominal voltage due to the discharge of the capacitor through any convenient discharge resistor.					

8.2.4.2 Making and breaking capacities for switching devices in the main circuit

8.2.4.2.1 General

The controller or contactor, including the mechanical switching devices associated with it, shall be capable of operating without failure in the presence of overload current.

The capability of making and breaking currents without failure, shall be verified under the conditions stated in both Table 10 and Table 11, for the required utilization categories, and the number of operations indicated.

Table 10 – Making and breaking capacity test – Making and breaking conditions according to utilization categories for the mechanical switching device of hybrid semiconductor controller and contactor H4, H5

Utilization category	Make and break conditions					
	I_c/I_e	U_r/U_e	Cos φ	ON-time s	OFF-time s	Number of operating cycles
AC-51	1,5	1,05	0,80	0,05	[a]	50
AC-55a	3,0		0,45			
AC-55b	1,5[b]		[b]			
AC-56a	30		[c]			
AC-56b	[d]		[d]			

I_c = current made and broken, expressed in a.c. r.m.s. symmetrical values

I_e = rated operational current

U_e = rated operational voltage

U_r = power-frequency recovery voltage

Current I_c A	OFF-time s
$I_c \leq$ 100	10
100 $< I_c \leq$ 200	20
200 $< I_c \leq$ 300	30
300 $< I_c \leq$ 400	40
400 $< I_c \leq$ 600	60
600 $< I_c \leq$ 800	80
800 $< I_c \leq$ 1 000	100
1 000 $< I_c \leq$ 1 300	140
1 300 $< I_c \leq$ 1 600	180
1 600 $< I_c$	240

[a] OFF-time shall not be greater than the values given in the chart.

[b] Tests to be carried out with incandescent light load.

[c] I_c peak = 30 × I_e $\sqrt{2}$

Cos φ preferred: ≤ 0,45

[d] Capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience.

Table 11 – Conventional operational performance – Making and breaking conditions according to utilization categories for the mechanical switching device of hybrid controllers and contactors H4B, H5B

Utilization category	Make and break conditions					
	I_c/I_e	U_r/U_e	Cos φ	ON-time s	OFF-time s	Number of operating cycles
AC-51	1,0	1,05	0,80	0,05	[a]	6 000[d]
AC-55a	2,0		0,45		[a]	
AC-55b	1,0[b]		[b]		60	
AC-56a	[c]		[c]			
AC-56b	[c]		[c]			

I_c = current made and broken, expressed in a.c. r.m.s. symmetrical values

I_e = rated operational current

U_e = rated operational voltage

U_r = power-frequency recovery voltage

[a] OFF-times shall not be greater than the values given in Table 10.

[b] Tests to be carried out with incandescent light load.

[c] Under consideration.

[d] For manually operated switching devices, the number of operating cycles shall be 1 000 on load, followed by 5 000 off load.

8.2.4.2.2 Series mechanical switching devices of hybrid controllers

The series mechanical switching devices in the main circuit of controllers and contactors shall meet the requirements of their own product standards, and the additional requirements of 8.2.4.2 when tested as a stand-alone device.

For bypassed hybrid controllers and contactors (see Figure 1), the series mechanical switching device may be designated with a duty rating that is aligned with the intermittent duty rating of the semiconductor controller.

The making and breaking capacity shall be verified by the procedures of 9.3.3.5.1 and 9.3.3.5.2.

8.2.4.2.3 Type tested, parallel mechanical switching devices of bypassed controllers

The making and breaking capacity shall be verified when tested as a stand-alone device in accordance with the procedures of 9.3.3.5.1 and 9.3.3.5.3.

8.2.4.2.4 Dependent, parallel mechanical switching devices of bypassed controllers

The making and breaking capacity shall be verified when tested as a combined unit in accordance with the procedures of 9.3.3.5.1 and 9.3.3.5.4.

8.2.4.2.5 Semiconductor switching devices

The capability to control overload currents shall be verified by the procedures of 9.3.3.6.3 and 9.3.3.6.4.

8.2.4.3 Requirements for an initiating load

The initiating load for short-circuit testing (see Figure I.1) shall be any convenient passive load with the following characteristics:

a) the rated voltage shall be equal to or greater than U_e for the device to be tested;

b) the power factor shall be between 0,8 and 1,0;

c) with voltage U_e applied to the initiating load, the current flow may be any value greater than 1 A.

8.2.5 Coordination with short-circuit protective devices

8.2.5.1 Performance under short-circuit conditions

The rated conditional short-circuit of controllers and contactors backed up by short-circuit device(s) (SCPDs) shall be verified by short-circuit tests as specified in 9.3.4. These tests are mandatory.

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Two types of coordination are permissible, type 1 or type 2. Test conditions for both are given in 9.3.4.3.

Type 1 coordination requires that, under short-circuit conditions, the device shall cause no danger to persons or to the installation and may not be suitable for further service without repair and replacement of parts.

Type 2 coordination requires that, under short-circuit conditions, the device shall cause no danger to persons or to the installation and shall be suitable for further use. For hybrid controllers and contactors, the risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations can invalidate the coordination.

8.2.5.2 Vacant

8.3 EMC requirements

8.3.1 General

It is widely accepted that the achievement of electromagnetic compatibility between different items of electrical and electronic apparatus is a desirable objective. Indeed, in many countries mandatory requirements for EMC exist.

The requirements specified in the following subclauses are included to permit the achievement of electromagnetic compatibility for controllers and contactors. All relevant immunity and emission requirements are covered and additional tests are not required or necessary. EMC performance is not guaranteed in the event that the contactor is subject to electronic component failure. These conditions are not considered and do not form part of the test requirements.

All phenomena, whether emission or immunity, are considered individually: the limits given are for conditions which are not considered to have cumulative effects.

For EMC tests, the minimum system to be considered is the controller interconnected with a load, cables and the needed auxiliaries for fully exercise.

These subclauses do not describe or affect the safety requirements for a semiconductor controller or contactor such as protection against electric shocks, insulation coordination and related dielectric tests, unsafe operation, or unsafe consequence of a failure.

8.3.2 Emission

Subclause 7.3.3.2 of IEC 60947-1:2007 applies according to the relevant set of environmental conditions defined in subclause 7.3.1 of IEC 60947-1:2007, Amendment 1 (2010).

The relevant set of environmental condition must be stated in the information to be given with the equipment.

8.3.2.1 Low-frequency emission with reference to main power frequency

8.3.2.1.1 Harmonics

Subclause 7.3.3.2.2 of IEC 60947-1:2007 applies with the following addition:

Because no significant harmonic emission are produced in the FULL-ON state, tests are not required on those controllers or contactors which run only in the FULL-ON state or which are by-passed by a mechanical switching device after completing a start.

8.3.2.1.2 Voltage fluctuation

This phenomenon does not arise from the action of a semiconductor controller, therefore no tests are required.

8.3.2.2 High-frequency emission

8.3.2.2.1 Conducted radiofrequency (RF) emission

The limits given in Table 15 shall be verified in accordance with the procedures of 9.4.1.1.

8.3.2.2.2 Radiated emissions

The limits given in Table 16 shall be verified in accordance with the procedures of 9.4.1.2.

8.3.3 Immunity

8.3.3.1 General

Electrical system influences may be destructive or non-destructive depending on the intensity of the influence. Destructive influences (voltage or current) cause irreversible damage to a controller. Non-destructive influences may cause temporary malfunction or abnormal operation, but the controller returns to normal operation after the influence has been minimized or removed; in some cases this may require manual intervention.

The manufacturer should be consulted in those instances where severe external influences may occur, which are greater than the levels for which the controller has been tested, for example installations in remote locations with long power transmission lines, close proximity to ISM equipment as defined in CISPR 11.

NOTE The careful application of de-coupling practices during installation helps to minimize the external transient influences. For example, control-circuit wiring can be separated from power-circuit wiring. Where closely coupled wiring cannot be avoided, twisted pairs or shielded wiring can be used for control-circuit connections.

A number of requirements are listed. The test results are specified using the performance criteria of IEC 61000-4 series. For convenience, the performance criteria are quoted here and described in more specific detail in Table 12.

These criteria are:

1) the normal performance within the specification limits;
2) the temporary degradation or loss of function or performance which is self-recoverable;
3) the temporary degradation or loss of function or performance which requires operator intervention or system reset. Normal functions must be restorable by simple intervention, for example by manual reset or restart. There must not be any damaged components.

In Table 12, the acceptable performance criteria, which are used when a complete controller is tested, are described for overall performance (A). When it is not possible to test the complete controller, the individual circuit elements (B, C) are used.

Table 12 – Specific performance criteria when EM disturbances are present

Item	Performance criteria during tests		
	1	2	3
A Overall performance	No noticeable changes of the operating characteristic. Operating as intended.	Noticeable changes (visual or audible) of the operating characteristic. Self-recoverable.	Changes in operating characteristic. Triggering of protective devices. Not self-recoverable.
B Operation of displays and control panels	No changes to visible display information. Only slight light intensity fluctuation of LED's, or slight movement of characters.	Temporary visible changes or loss of information. Undesired LED illumination.	Shut-down. Permanent loss or display of wrong information. Unpermitted operating mode. Not self-recoverable.
C Information processing and sensing functions	Undisturbed communication and data interchange to external devices.	Temporarily disturbed communication with possible error reports of the internal and external devices.	Erroneous processing of information. Loss of data and/or information. Errors in communication. Not self-recoverable.

8.3.3.2 Electrostatic discharges

The test values and procedures are given in 9.4.2.1.

8.3.3.3 Radiofrequency electromagnetic fields

The test values and procedures are given in 9.4.2.2.

8.3.3.4 Fast transients (5/50 ns)

The test values and procedures are given in 9.4.2.3.

8.3.3.5 Surges (1,2/50 μs – 8/20 μs)

The test values and procedures are given in 9.4.2.4.

8.3.3.6 Harmonics and commutation notches

The test values and procedures are given in 9.4.2.5.

8.3.3.7 Voltage dips and short-time interruptions

The test values and procedures are given in 9.4.2.6.

8.3.3.8 Power-frequency magnetic field

Tests are not required. Immunity is demonstrated by the successful completion of the operating capability test (see 9.3.3.6).

9 Tests

9.1 Kinds of tests

9.1.1 General

Subclause 8.1.1 of IEC 60947-1:2007 applies.

9.1.2 Type tests

Type tests are intended to verify compliance of the design of controllers and contactors of all forms with this standard. They comprise the verification of

a) temperature-rise limits (see 9.3.3.3);
b) dielectric properties (see 9.3.3.4);
c) operating capability (see 9.3.3.6);
d) operation and operating limits (see 9.3.3.6.4);
e) rated making and breaking capacity and conventional operational performance of series mechanical switching devices of hybrid equipment (see 9.3.3.5);
f) performance under short-circuit conditions (see 9.3.4);
g) mechanical properties of terminals (8.2.4 of IEC 60947-1:2007, Amendment 1 (2010) applies);
h) degrees of protection of enclosed controllers and contactors (Annex C of IEC 60947-1:2007, Amendment 1 (2010) applies);
i) EMC tests (see 9.4).

9.1.3 Routine tests

Subclause 8.1.3 of IEC 60947-1:2007 applies where sampling tests (see 9.1.4) are not made instead.

Routine tests for controllers and contactors comprise

– operation and operating limits (see 9.3.6.2);
– dielectric tests (see 9.3.6.3).

9.1.4 Sampling tests

Sampling tests for controllers and contactors comprise

– operation and operating limits (see 9.3.6.2);
– dielectric tests (see 9.3.6.3).

Subclause 8.1.4 of IEC 60947-1:2007 applies with the following amplification.

A manufacturer may use sampling tests instead of routine tests at his own discretion. Sampling shall meet or exceed the following requirements as specified in IEC 60410 (see Table II-A of IEC 60410:1973).

Sampling is based on AQL ≤ 1:

– acceptance number Ac = 0 (no defect accepted);
– rejection number Re = 1 (if one defect, the entire lot shall be tested).

Sampling shall be made at regular intervals for each specific lot.

Alternative statistical methods that ensure compliance with IEC 60410 requirements can be used, for example statistical methods controlling continuous manufacturing or process control with capability index.

Sampling tests for clearance verification according to 8.3.3.4.3 of IEC 60947-1:2007 are under consideration.

9.1.5 Special tests

Special tests comprise damp heat, salt mist, vibration and shock tests. For these tests, Annex Q of IEC 60947-1:2007, Amendment 1 (2010) applies. The conditions of application are under consideration.

9.2 Compliance with constructional requirements

Subclause 8.2 of IEC 60947-1:2007, Amendment 1 (2010) applies.

9.3 Compliance with performance requirements

9.3.1 Test sequences

Each test sequence is made on a new sample.

NOTE 1 With the agreement of the manufacturer more than one test sequence or all sequences can be conducted on one sample. However, the tests are to be conducted in the sequence given for each sample.

NOTE 2 Some tests are included in the sequences solely to reduce the number of samples required, the results have no significance for the preceding or following tests in the sequence. Therefore, for convenience of testing and by agreement with the manufacturer, these tests can be conducted on separate new samples and omitted from the relevant sequence. This only applies to the following tests when called for:

– 8.3.3.4.1 item 7) of IEC 60947-1:2007, Amendment 1 (2010): Verification of creepage distance;

– 8.2.4 of IEC 60947-1:2007, Amendment 1 (2010): Mechanical properties of terminals;

– Annex C of IEC 60947-1:2007, Amendment 1 (2010): Degrees of protection of enclosed equipment.

For convenience of testing, compliance with 8.2.4.2 is omitted from the following test sequence. None the less, the manufacturer is obliged to verify compliance by other convenient means.

The test sequence shall be as follows:

a) Test sequence I
   1) Verification of temperature rise (see 9.3.3.3)
   2) Verification of dielectric properties (see 9.3.3.4)
b) Test sequence II: operating capability verification (see 9.3.3.6)
   1) Thermal stability test (see 9.3.3.6.2)
   2) Overload capability test (see 9.3.3.6.3)

3) Blocking and commutating capability test (see 9.3.3.6.4) including verification of operation and operating limits

c) Test sequence III

Performance under short-circuit conditions (see 9.3.4)

d) Test sequence IV

1) Verification of mechanical properties of terminals (8.2.4 of IEC 60947-1:2007, Amendment 1 (2010))

2) Verification of degrees of protection of enclosed equipment (see Annex C of IEC 60947-1:2007, Amendment 1 (2010))

e) Test sequence V

EMC tests (see 9.4).

9.3.2 General test conditions

Subclause 8.3.2 of IEC 60947-1:2007, Amendment 1 (2010) applies with the following addition.

Except for devices specifically rated for only one frequency, tests performed at 50 Hz cover 60 Hz applications and vice-versa.

The selection of samples to be tested for a series of devices with the same fundamental design and without a significant difference in construction shall be based on engineering judgement.

Unless otherwise specified in the relevant test clause, the clamping torque for connections shall be that specified by the manufacturer or, if not specified, the torque given in Table 4 of IEC 60947-1:2007.

In the case where several heat sinks are specified, the one which has the higher thermal resistance shall be used.

True r.m.s. voltage and current measuring means shall be used.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Vacant

9.3.3.2 Vacant

9.3.3.3 Temperature rise

9.3.3.3.1 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007 applies.

9.3.3.3.2 Measurement of the temperature of parts

Subclause 8.3.3.3.2 of IEC 60947-1:2007, Amendment 1 (2010) applies.

9.3.3.3.3 Temperature rise of a part

Subclause 8.3.3.3.3 of IEC 60947-1:2007.

9.3.3.3.4 Temperature rise of the main circuit

Subclause 8.3.3.3.4 of IEC 60947-1:2007 applies with the exception that a single phase test shall be conducted with all poles in the main circuit loaded at their individual maximum rated currents and as stated in 8.2.2.4, and with the following additions:

For semiconductor switching devices connected in the main circuit (see 8.2.2.4), temperature sensing means shall be attached to the outer surface of the case of the semiconductor switching device that is most likely to produce the highest temperature rise during this test. The final case temperature, C_f, and the final ambient temperature, A_f, shall be recorded for use in the test of 9.3.3.6.3.

For mechanical switching devices (see 8.2.2.4.2 and 8.2.2.4.4), temperature sensing means shall be attached in accordance with the requirements of 8.3.3.3 of IEC 60947-1:2007, Amendment 1 (2010).

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltages.

9.3.3.3.5 Temperature rise of control circuits

Subclause 8.3.3.3.5 of IEC 60947-1:2007 applies, with the following addition.

The temperature rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.6 Temperature rise of coils and electromagnets

Subclause 8.3.3.3.6 of IEC 60947-1:2007 applies with the following addition.

Electromagnets of mechanical switching devices intended for duty within semiconductor controllers or for mechanical bypass switching means shall comply with 8.2.2.6 with rated current flowing through the main circuit for the duration of the test. The temperature rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.7 Temperature rise of auxiliary circuits

Subclause 8.3.3.3.7 of IEC 60947-1:2007 applies with the following addition.

The temperature rise shall be measured during the test of 9.3.3.3.4.

9.3.3.4 Dielectric properties

9.3.3.4.1 Type tests

1) General conditions for withstand voltage tests

   Subclause 8.3.3.4.1 1) of IEC 60947-1:2007, Amendment 1 (2010) applies except the last note. See also 8.2.3.

2) Verification of impulse withstand voltage

   a) General

      Subclause 8.3.3.4.1 2) a) of IEC 60947-1:2007, Amendment 1 (2010) applies.

   b) Test voltage

      Subclause 8.3.3.4.1 2) b) of IEC 60947-1:2007, Amendment 1 (2010) applies with the following sentence added.

      For any part for which the dielectric properties are not sensitive to altitude (e.g. optocoupler, potted parts, etc.) the correction factor for altitude is not applicable.

   c) Application of test voltage

With the equipment mounted and prepared as specified in item 1) above, the test voltage is applied as follows:

i) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the enclosure or mounting plate, with the contacts, if any, in all normal positions of operation;

ii) for poles of the main circuit declared galvanically separated from the other poles: between each pole and the other poles connected together and to the enclosure or mounting plate, with the contacts, if any, in all normal positions of operation;

iii) between each control and auxiliary circuit not normally connected to the main circuit and

- the main circuit;
- the other circuits;
- the exposed conductive parts;
- the enclosure or mounting plate, which, wherever appropriate, may be connected together;

iv) for equipment suitable for isolation, across the poles of the main circuit, the line terminals being connected together and the load terminals connected together. The test voltage shall be applied between the line and load terminals of the equipment with the contacts in the isolated open position and its value shall be as specified in item 1) b) of 7.2.3.1 of IEC 60947-1:2007.

d) Acceptance criteria

Subclause 8.3.3.4.1 2) d) of IEC 60947-1:2007, Amendment 1 (2010) applies.

3) Power-frequency withstand verification of solid insulation

a) General

Subclause 8.3.3.4.1 3) a) of IEC 60947-1:2007, Amendment 1 (2010) applies.

b) Test voltage

Subclause 8.3.3.4.1 3) b) of IEC 60947-1:2007, Amendment 1 (2010) applies with the following sentence added at the end of the first paragraph.

If an alternating test voltage cannot be applied due to the EMC filter components, which cannot easily be disconnected, a direct test voltage may be used having the same value as the crest value of the projected alternating test voltage.

c) Application of test voltage

Subclause 8.3.3.4.1 3) c) of IEC 60947-1:2007, Amendment 1 (2010) applies with the two last sentences modified as follows:

The test voltage shall be applied for 5 s, with the following conditions:

- in accordance with items i), ii) and iii) of 2) c) above;
- for hybrid semiconductor controllers or contactors, across the poles of the main circuit, the line terminals being connected together and the load terminals connected together.

d) Acceptance criteria

Subclause 8.3.3.4.1 3) d) of IEC 60947-1:2007, Amendment 1 (2010) applies.

4) Power-frequency withstand verification after switching and short-circuit tests

a) General

Subclause 8.3.3.4.1 4) a) of IEC 60947-1:2007, Amendment 1 (2010) applies.

b) Test voltage

Subclause 8.3.3.4.1 4) b) of IEC 60947-1:2007, Amendment 1 (2010) applies.

c) Application of test voltage

Subclause 8.3.3.4.1 4) c) of IEC 60947-1:2007, Amendment 1 (2010) applies with the following sentence added at the end of the paragraph.

The use of a metal foil, as mentioned in 8.3.3.4.1 1) of IEC 60947-1:2007, Amendment 1 (2010), is not required.

d) Acceptance criteria

Subclause 8.3.3.4.1 4) d) of IEC 60947-1:2007, Amendment 1 (2010) applies.

5) Vacant

6) Verification of d.c. withstand voltage

Subclause 8.3.3.4.1 6) of IEC 60947-1:2007, Amendment 1 (2010) applies.

7) Verification of creepage distances

Subclause 8.3.3.4.1 7) of IEC 60947-1:2007, Amendment 1 (2010) applies (see also 8.1.3).

8) Verification of leakage current of equipment suitable for isolation

The maximum leakage current shall not exceed the values of 7.2.7 of IEC 60947-1:2007.

9.3.3.4.2 Vacant

9.3.3.4.3 Sampling tests for verification of clearances

1) General

Subclause 8.3.3.4.3 1) of IEC 60947-1:2007 applies.

2) Test voltage

The test voltage shall be that corresponding to the rated impulse withstand voltage.

Sampling plans and procedure are under consideration.

3) Application of test voltage

Subclause 8.3.3.4.3 3) of IEC 60947-1:2007 applies.

4) Acceptance criteria

Subclause 8.3.3.4.3 4) of IEC 60947-1:2007 applies.

9.3.3.5 Making and breaking capacity of mechanical switching devices

9.3.3.5.1 General

It shall be verified that mechanical switching devices meet the requirements of 8.2.4.2.

If the mechanical switching device has not passed previous tests, compliance with 8.2.4.2 and the following subclauses is required. The making and breaking capacity shall be verified in accordance with 8.3.3.5 of IEC 60947-1:2007.

9.3.3.5.2 Series mechanical switching devices of hybrid controllers

The verification shall be made using one of the following methods:

a) the subject device may be tested as a separate component, or

b) the complete hybrid controller may be tested with the subject devices installed as in normal service and with the semiconductor components of each pole shorted out.

9.3.3.5.3 Type tested, parallel mechanical switching devices of bypassed controllers

The subject device shall be tested as a separate device.

9.3.3.5.4 Dependent, parallel mechanical switching devices of bypassed controllers

The complete unit with bypass installed shall be tested as in normal service. The operational sequence, to simulate switching (ON and OFF), shall be the same as in normal service.

9.3.3.6 Operating capability

9.3.3.6.1 General

Compliance with the operating capability requirements of 8.2.4.1 shall be verified by the following three tests.

a) thermal stability tests;

b) overload capability tests;

c) blocking and commutation capability test.

The tests simulate 8 h duty.

Connections to the main circuit shall be similar to those intended to be used when the equipment is in service. The control voltage shall be fixed at 110 % of the rated control supply voltage U_s.

Table 13 – Thermal stability test specifications

Test details	Level	Instructions
Test objective	To verify that the temperature variation between successive identical operating cycles in a sequence reduces to less than 5 % within an 8 h period To verify that the temperature rise of the accessible terminals of the mechanical switching device in the main circuit does not exceed the limit prescribed by Table 2 of IEC 60947-1:2007	
Test duration	Run test until $\Delta_n \leq 0{,}05$ or 8 h have elapsed $\Delta_n = (C_n - C_{n-1} - A_n + A_{n-1})/(C_{n-1})$	
Test conditions	Table 7	
EUT [a] temperature	C_n, case temperature	Temperature sensing means attached to the outer surface of one semiconductor switching device (see 9.3.3.3.4) Monitor the semiconductor switching device that is likely to be the hottest
Ambient temperature	A_n, any level convenient	Temperature sensing means to monitor changes in ambient temperature (8.3.3.3.1 of IEC 60947-1:2007 applies)
Results to be obtained	1) $\Delta_n \leq 0{,}05$ within 8 h 2) No visual evidence of damage (such as smoke, discoloration) 3) The temperature rise of the accessible terminals of the mechanical switching device in the main circuit shall not exceed the limit prescribed by Table 2 of IEC 60947-1:2007 4) When the terminals are not accessible, the values of Table 2 of IEC 60947-1:2007 may be exceeded provided that adjacent parts are not impaired	
[a] Equipment under test.		

Table 14 – Initial case temperature requirements

Operating cycle number	Initial case temperature, C_i °C
1	Not less than 40 °C.
2	Highest temperature enabling resetting after the first operating cycle of the overcurrent protective means recommended by the manufacturer to be used together with the controller or the contactor.
3 and 4	≥40 °C plus the maximum case temperature rise during the temperature-rise test (see 9.3.3.3).

9.3.3.6.2 Thermal stability test procedure

Test specifications and acceptance criteria are given in Table 13. The test profiles are illustrated in Figure F.1.

1) Assign a sequence number, n, to each on-load period in the test series (i.e. n = 0, 1, 2, ... n – 1, N).
2) Record initial case temperature C_0. Record initial ambient temperature A_0.
3) Set test current, I_T (see Table 7). Change n to a new value where $n = n + 1$.
4) Apply test voltage U_T, to the input main circuit terminals of the EUT (equipment under test). U_T may remain applied for the duration of the test or, may be switched ON-OFF in synchronism with the operation of control voltage U_C.

   Switch EUT to ON-state (EUT control voltage, U_C, is ON).

NOTE The time span of T_x commences at the instant when the test current reaches the value $X \times I_e$. Therefore, the time for the test current ramp to reach $X \times I_e$ increases the total test time.

5) After time interval T_x (Table 7), switch EUT to OFF-state.
6) Record case temperature C_n. Record ambient temperature A_n.
7) Decision to terminate (or continue) test:
   a) Calculate case temperature-rise change factor:

      $\Delta_n = (C_n - C_{n-1} - A_n + A_{n-1})/(C_{n-1})$

   b) Check compliance with results to be obtained (see Table 13)

      If $\Delta_n > 0{,}05$, and total test time is less than 8 h and results to be obtained 1) and 2) of Table 13) are not violated, repeat steps 3 through 7.

      If $\Delta_n > 0{,}05$, and total test time is greater than 8 h or results to be obtained are violated, end test. This is a failure.

      If $\Delta_n \leq 0{,}05$, and total test time is less than 8 h, and results 1), 2), 3) and 4) of Table 13 are not violated, end test. This is successful compliance.

9.3.3.6.3 Overload capability test procedure

1) Test conditions
   a) Refer to Table 8. The test profile is represented in Figure F.2.
   b) Controllers and contactors utilizing a current-controlled cut-out device in addition to an overcurrent protective means that provides protection against overload conditions during running in the FULL-ON state, shall be tested with the cut-out device in place. In this test, it is acceptable for the cut-out device to switch the EUT to the OFF-state in a time shorter than the specified ON-time.
2) EUT adjustments
   a) EUT shall be adjusted to minimize the time to establish the test current level.

b) EUT fitted with a current-limit function shall be set to the highest value of X specified for I_e.

3) Test
   a) Establish initial conditions.
   b) Apply test voltage to the input main circuit terminals of the EUT.

      (With form H*x*A, the series mechanical switching device contact is closed. With form H*x*B, the series mechanical switching device is open.)

      The test voltage shall be applied for the duration of the test.
   c) Switch the EUT to ON-state.
   d) After the ON-time (see Table 8), switch the EUT to the OFF-state.

      NOTE In the case of form H*x*B, the OFF-state will be replaced by the OPEN-state.
   e) Repeat steps c) and d) twice. End test.
4) Verify the criteria (see 9.3.3.6.5)
   a) No loss of commutating capability.
   b) No loss of blocking capability.
   c) No loss of functionality.
   d) No visual evidence of damage.

9.3.3.6.4 Blocking and commutating capability test

Test specifications are given in Table 9. The test profiles are shown in Figure F.3.

For form H*x*A, the contacts of the series mechanical switching device shall be maintained in the closed position for the duration of the test.

For form H*x*B, the contacts of the series mechanical switching device may be operated to perform the testing cycles. However, the measurements of voltage across the poles shall be performed with the series contacts closed, and with the semiconductor switching devices in the OFF-state. The manufacturer shall provide instructions for fitting the EUT with special features that will permit compliance with the voltage measurement requirements.

1) The EUT shall be mounted and connected as in normal use with cable length between the EUT and test load not greater than 10 m.
2) The current measuring means shall be installed in a manner that is appropriate for recording the values of the leakage current through the controller in steps 3) and 7).

   If other auxiliary circuits or devices are connected in parallel with the semiconductor elements, care shall be taken in order to avoid measuring the parallel currents; only the leakage current of the semiconductor elements shall be measured and the means for obtaining those measures shall be installed accordingly.
3) With the voltages (see Table 9) applied to the EUT, and with the control voltage U_c OFF, measure the current through each pole of the EUT and record these measurements as a set of initial data points, I_o.

   The test circuit shall remain closed from the start of step 4) through the completion of step 7). The current measuring means may be shorted by remote control means during steps 5) and 6), but it may not be removed by opening the circuit.
4) To start the test, the test voltages (as specified in Table 9) are applied to the EUT and maintained for the duration of the test through the completion of step 7).
5) By means of the control voltage U_c, cycle the EUT between the ON-state and the OFF-state as specified in Table 9. If the controller does not perform as intended, or if evidence of damage develops, the test is discontinued, and considered a failure.

6) After the required number of operating cycles, turn U_C to OFF with the test voltages remaining ON, allow the EUT to return to the initial ambient temperature.
7) Repeat the current measurement procedure of step 3) and record as a set of final data points, I_F, corresponding to the set of initial data points, I_O.
8) Determine the values regarding the leakage currents through each pole as specified under item 1) of Table 9.

To obtain successful compliance, the criteria given under items 1), 2) and 3) of Table 9 shall be fulfilled.

9.3.3.6.5 Behaviour of the semiconductor controller during, and condition after, the operating capability tests

a) Commutating capability

If semiconductor devices do not commutate properly, the early stage of the failure mode is evidenced by degraded performance. Continued operation in this mode will cause thermal runaway. The ultimate result will be excessive heating and loss of blocking capability.

b) Thermal stability

Semiconductor devices subject to rapid operating cycles may not cool properly. The early effects may initiate a thermal runaway condition leading to loss of blocking capability.

c) Blocking capability

Blocking capability is the ability to turn OFF and remain OFF whenever required. Excessive thermal stress will degrade blocking capability. The failure mode is evidenced by a partial or total loss of control.

d) Functionality

Some failure modes may not be catastrophic in the early stages. These failures are evident from gradual loss of function. Early detection and correction may prevent permanent damage.

e) Visual inspection

Ultimately, excessive thermal stresses due to elevated temperatures may cause permanent damage. Visual evidence (smoke or discoloration) provides early warning of ultimate failure.

9.3.4 Performance under short-circuit conditions

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5.1. Specific requirements regarding test procedure, test sequence, condition of equipment after the test and types of coordination are given in 9.3.4.1 and 9.3.4.3.

9.3.4.1 General conditions for short-circuit tests

General conditions for short-circuit tests are as follows:

– "O" operation: as a pre-test condition, the contactor/controller shall be sustained in the ON-state by an initiating load. The pre-test current may be held at any arbitrary low level of current that is greater than the minimum load current (see 3.1.11) of the contactor/controller. The short-circuit current is applied to the contactor/controller by closing the shorting switch. The SCPD shall interrupt the short-circuit current and the contactor/controller shall withstand the let-through current;
– "CO" operation for direct on-line equipment.

Initial case temperature shall not be less than 40 °C. In some cases, it may be impossible to pre-heat the EUT and maintain the initial case temperature at a test site that is fitted for short-circuit testing only. In these cases, the manufacturer and user may agree to test the EUT at ambient temperature. If used, the lower temperature shall be recorded in the test report.

9.3.4.1.1 General requirements for short-circuit tests

The general requirements of 8.3.4.1.1 of IEC 60947-1:2007 apply with the following modification.

The enclosure shall be in accordance with the manufacturer's specifications. In the case where multiple enclosure options are provided, the enclosure with the smallest volume shall be taken.

If devices tested in free air may also be used in enclosures, they shall be additionally tested in the smallest of such enclosures stated by the manufacturer. For devices tested only in free air, information shall be provided to indicate that they are not suitable for use in an individual enclosure.

9.3.4.1.2 Test circuit for the verification of short-circuit ratings

Subclause 8.3.4.1.2 of IEC 60947-1:2007, Amendment 1 (2010) applies except that for type 1 coordination, the fusible element F and the resistance R_L are replaced by a solid 6 mm^2 wire 1,2 m to 1,8 m in length, connected to the neutral, or with the agreement of the manufacturer, to one of the poles.

NOTE This larger size of wire is not used as a detector but to establish an earth condition allowing the damage to be evaluated.

The test circuit of 8.3.4.1.2 of IEC 60947-1:2007, Amendment 1 (2010) shall be modified and wired as shown in Figure I.1. The initiating load and the shorting switch shall have the following characteristics:

a) the initiating load shall be in accordance with the requirements given in 8.2.4.3;
b) the shorting switch (not a part of the EUT) shall be capable of making and carrying the short-circuit current with no tendency to interfere with the process of applying the short-circuit current (e.g. bounce or other intermittent openings of the contacts).

9.3.4.1.3 Power factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies.

9.3.4.1.4 Vacant

9.3.4.1.5 Calibration of the test circuit

Subclause 8.3.4.1.5 of 60947-1:2007 applies.

9.3.4.1.6 Test procedure

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies with the following additions.

The controller or contactor and its associated SCPD shall be mounted and connected as in normal use. They shall be connected in the circuit using a maximum of 2,4 m of cable (corresponding to the operational current of the controller or contactor) for each main circuit.

If the SCPD is separate from the controller or contactor, it shall be connected using the cable specified above (the total length of cable shall not exceed 2,4 m).

Three-phase tests are considered to cover single-phase applications.

The time-line for the test sequence is shown in Figure I.2.

a) The test is started with the shorting switch in the open position (time T0).

b) The test voltage is then applied and the initiating load shall limit the current to a level that is, at least, sufficient to maintain the controller in the ON-state (time T1).

c) At any arbitrary time after the current through the contactor/controller has stabilized, the shorting switch may then be closed at random and thereby establish a short-circuit current path through the EUT (time T2) which shall be cleared by the SCPD (time T3).

9.3.4.1.7 Vacant

9.3.4.1.8 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

9.3.4.2 Vacant

9.3.4.3 Conditional short-circuit current of controllers and contactors

9.3.4.3.1 General

The controller or contactor and the associated SCPD shall be subjected to the tests given in 9.3.4.4.2.

No further testing is required for bypassed controllers with independent components.

Bypassed controllers having dependent components shall be submitted to two separate short-circuit tests in accordance with 9.3.4.

a) Test 1: The test is conducted with the semiconductors in the conducting mode and with the bypass contacts open. This is intended to simulate short-circuit conditions occurring while starting in a mode that is controlled by the semiconductors.

b) Test 2: The test is conducted with the semiconductors bypassed with the bypass contacts closed. This is intended to simulate short-circuit conditions occurring while the semiconductors of the EUT are bypassed.

The tests shall be conducted under conditions corresponding to the maximum I_e and the maximum U_e for utilization category AC-51.

When the same semiconductor component is used for several ratings, the test shall be performed under the conditions corresponding to the highest rated current I_e.

The controls shall be energized by a separate electrical supply at the specified control voltage. The SCPD used shall be as stated in 8.2.5.1.

If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be done with the circuit-breaker adjusted to the maximum setting for type 1 coordination and to the maximum declared setting for type 2 coordination.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A controller or contactor covering a range of load ratings and equipped with interchangeable overcurrent protective means shall be tested with the overcurrent protective means with the highest impedance and the overcurrent protective means with the lowest impedance together with the corresponding SCPDs.

The O or CO operation shall be performed with one sample at I_q.

9.3.4.3.2 Test at the rated conditional short-circuit current at I_q

The circuit shall be adjusted to the prospective short-circuit current I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse then, if possible, the fuse shall be selected to allow the maximum value of cut-off current I_c (according to Figure 4 of IEC 60269-1:2006) and the maximum let-through I^2t values.

Except for direct on-line contactors, one breaking operation of the SCPD shall be performed with the contactor in the full-ON state and the SCPD closed; the short-circuit current shall be switched on by a separate switching device.

For direct on-line contactors, one breaking operation of the SCPD shall be performed by closing the contactor on to the short circuit.

9.3.4.3.3 Results to be obtained

The controller or contactor shall be considered to have passed the tests at the prospective current I_q if the following conditions are met for the claimed type of coordination.

For both types of coordination,

a) the fault current has been successfully interrupted by the SCPD or the contactor. In addition, the fusible element or solid connection between the enclosure and supply shall not have melted;

b) the door or cover of the enclosure has not been blown open, and it is possible to open the door or cover. Deformation of enclosure is considered acceptable, provided the degree of protection by the enclosure is not less than IP2X;

c) there is no damage to the conductors or terminals and the conductors have not been separated from the terminals;

d) there is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired;

Type 1 coordination:

e) there has been no discharge of parts beyond the enclosure. Damage to the controller and overcurrent protective means is acceptable. The contactor or the controller may be inoperative after the test;

Type 2 coordination:

f) no damage to the overcurrent protective means or other parts has occurred and no replacement of parts is permitted during the test. For hybrid controllers and contactors, welding of contacts is permitted, if they are easily separated (e.g. by a screwdriver) without significant deformation. In the case of welded contacts as described above, the functionality of the device shall be verified under the conditions of Table 8 for the declared utilization category by carrying out 10 operating cycles (instead of five);

g) the tripping of the overcurrent protective means shall be verified at a multiple of the current setting and shall conform to the published tripping characteristics both before and after the short-circuit test;

h) the adequacy of the insulation shall be verified by a dielectric test on the controller or contactor. The test voltage shall be applied as specified in 9.3.3.4.1 4).

9.3.5 Disponible

9.4 General

All emission and immunity tests are type tests and shall be carried out under representative conditions, both operational and environmental, using the manufacturer's recommended wiring practices and including any enclosures specified by the manufacturer.

An incandescent light load and a capacitive load are required for the purpose of testing in the case of AC-55b and AC-56b, respectively. However, for a device intended to be used for several utilization categories, the tests shall be made only with a load corresponding to AC-51. If the device is not intended for AC-51 category use, the tests shall be made for the utilization category defined by agreement between manufacturer and user. Except for the harmonic emission test, it is not necessary to load the lighting circuit or capacitor. If the load used in any test is of lower power than the intended power range of the semiconductor controller, it shall be stated in the test report. For category AC-51, the equipment under test shall be tested at the rated operational current and with a $\cos \varphi = 1^{-0,05}$. For devices of current $I_e \leq 16$ A, the test current shall be I_e. For devices of current $I_e > 16$ A, the test current shall be the object of an agreement between the manufacturer and the user, provided this current is more than 16 A. This value shall be stated in the test report. Tests are not required on the power output port. Unless otherwise specified by the manufacturer, the length of the connections to the test load shall be 3 m.

NOTE The scanning time for frequency analysis is often much longer than the transition time. According to the current IEC 61000-4 series, relevant result of measurement can only be obtained in steady-state conditions.

The test report shall give all the relevant information relating to the tests (for example load conditions, cable arrangement, etc.). A functional description and a definition of specification limits for the performance criteria shall be provided by the manufacturer and noted in the test report. The test report shall include any special measures that have been taken to achieve compliance, for example the use of shielded or special cables. A list of auxiliary equipment which, together with the controller, comprises the equipment necessary to comply with the immunity or emission requirements, shall also be included in the report. The tests shall be carried out at the rated supply voltage U_s and in a reproducible manner.

Form 4 controllers, in which the power switching elements, for example thyristors, are not fully conducting during some or all steady-state modes of operation, shall be tested under conditions of minimum conduction chosen by the manufacturer to represent the operation of the controller at the points of sustained maximum emission or susceptibility (see 9.4.1).

9.4.1 EMC emission tests

9.4.1.1 Conducted radiofrequency emission test

The description of the test, the test method and the test set-up are given in CISPR 11.

It shall be sufficient to test two samples from a range of controllers of different power ratings which represent the highest and lowest power ratings of the range.

The emission shall not exceed the levels given in Table 15.

All emission tests shall be performed under steady-state conditions.

If an EMC filter is required to fulfil the emission levels given in Table 15, its reference or characteristics has to be stated in the test report.

Table 15 – Terminal disturbance voltage limits for conducted radiofrequency emission

Frequency range MHz	Environment A [a] rated input power ≤ 20 kVA		Environment A [a, b] rated input power > 20 kVA		Environment B [a]	
	Quasi-peak dB (μV)	Average dB (μV)	Quasi-peak dB (μV)	Average dB (μV)	Quasi-peak dB (μV)	Average dB (μV)
0,15 to 0,5	79	66	100	90	66 to 56 (decrease with log of frequency)	56 to 46 (decrease with log of frequency)
0,5 to 5	73	60	86	76	56	46
5 to 30	73	60	90 to 73 (decrease with log of frequency)	80 to 60 (decrease with log of frequency)	60	50

At the transition frequency, the more stringent limit shall apply.

[a] Defined by IEC 60947-1.

[b] These limits apply to equipment with a rated input power > 20 kVA. The manufacturer and/or supplier shall provide information on installation measures that can be used to reduce emissions from the installed equipment. In particular, it shall be indicated that this equipment is intended to be powered by a dedicated power transformer or generator and not LV overhead power lines.

Limits in accordance with CISPR 11, Group 1.

9.4.1.2 Radiated radiofrequency emission test

The description of the test, the test method and the test set-up are given in CISPR 11.

NOTE In the USA, digital devices with power consumption less than 6 nW, are exempt from RF emission tests.

It shall be sufficient to test a single representative sample from a range of controllers and contactors of different power ratings.

The emission shall not exceed the levels given in Table 16.

Table 16 – Radiated emissions test limits

Frequency range MHz	Environment A [a] Quasi-peak dB (μV)			Environment B [a] Quasi-peak dB (μV)	
	at 30 m	at 10 m	at 3 m	at 10 m	at 3 m
30 to 230	30	40	50	30	40
230 to 1 000	37	47	57	37	47

At the transition frequency, the more stringent limit shall apply.

[a] Tests may be carried out at 3 m distance only to small equipment (equipment, either positioned on a table top or standing on the floor which, including its cables fits in a cylindrical test volume of 1,2 m in diameter and 1,5 m above the ground plane).

9.4.2 EMC immunity tests

Where a range of controllers comprise similarly configured control electronics, within similar frame sizes, it is only necessary to test a single representative sample of the controller or contactor as specified by the manufacturer.

9.4.2.1 Electrostatic discharge

Subclause 8.4.1.2.2 of IEC 60947-1:2007 applies with the following addition:

The performance criterion 2 of Table 12 of this standard applies.

Tests are not required on power terminals. Discharges shall be applied only to points which are accessible during normal usage.

Tests are not possible if the controller is an open frame or chassis unit or of degree of protection IP00. In this case, the manufacturer shall attach a label to the unit advising of the possibility of damage due to static discharge.

9.4.2.2 Radiofrequency electromagnetic field

For conducted immunity tests, the subclause 8.4.1.2.6 of IEC 60947-1:2007 applies with the following addition:

The performance criterion 1 of Table 12 of this standard applies.

For radiofrequency electromagnetic field strength, the subclause 8.4.1.2.3 of IEC 60947-1:2007 applies with the following addition:

The performance criterion 1 of Table 12 of this standard applies.

9.4.2.3 Fast transients (5/50 ns)

Subclause 8.4.1.2.4 of IEC 60947-1:2007 applies with the following additions:

Terminals for control and auxiliary circuits intended for the connection of conductors which extend more than 3 m shall be tested.

The controller shall comply with performance criterion 2 of Table 12 of this standard.

9.4.2.4 Surges (1,2/50 μs – 8/20 μs)

Subclause 8.4.1.2.5 of IEC 60947-1:2007 applies.

The preferred phase angle is 90° or 270°. Other phase angles according to IEC 61000-4-5 shall be also tested if they correspond to the worst case.

NOTE By principle, 90° and 270° are the worst testing cases for the power semiconductor valves.

The controller shall comply with performance criterion 2 of Table 12 of this standard.

9.4.2.5 Harmonics and commutation notches

No requirements, the test levels are under study for the future.

9.4.2.6 Voltage dips and short time interruptions

Subclause 8.4.1.2.8 of IEC 60947-1:2007 applies with the performance criterion 3 of Table 12 of this standard, class 3 as given in Table 23 of IEC 60947-1 2007, Amendment 1 (2010), except for 0,5 cycle and 1 cycle for which the performance criterion 2 of Table 12 of this standard applies.

9.5 Routine and sampling tests

9.5.1 General

Routine tests are tests to which each individual controller or contactor is subjected during or after manufacture to verify that it complies with the stated requirements.

Routine or sampling tests shall be carried out under the same or equivalent conditions to those specified for type tests in the relevant parts of 9.1.2. However, the limits of operation in 9.5.2 may be verified at the prevailing ambient air temperature and on the overcurrent protective means alone but a correction may be necessary to allow for the normal ambient conditions.

9.5.2 Operation and operating limits

It shall be verified that the equipment operates according to the requirements of 8.2.1.2 and 8.2.1.5.

The functionality specified in 8.2.1.2 shall be verified by a blocking and commutating capability test according to Table 9 and 9.3.3.6.4. Two operating cycles are required, one at 85 % U_e with 85 % U_s, and one at 110 % U_e with 110 % U_s.

The 2 following tests shall be made.

a) Functionality shall be verified by a blocking and commutating capability test according to Table 9.

   Two operating cycles are required, one at 85 % U_e with 85 % U_s, and one at 110 % U_e with 110 % U_s. No loss of functionality as specified by the manufacturer is permitted.

b) It shall be verified that the equipment operates according to the requirements of 8.2.1.5.

9.5.3 Dielectric tests

The metal foil need not be applied. The tests shall be conducted on dry and clean controllers and contactors.

Verification of dielectric withstand may be performed before final assembly of the device (that is, before connecting sensitive devices such as filter capacitors).

1) Impulse withstand voltage

Subclause 8.3.3.4.2 of IEC 60947-1:2007 applies.

2) Power-frequency withstand voltage

Subclause 8.3.3.4.2 of IEC 60947-1:2007 applies.

3) Combined impulse voltage and power-frequency withstand voltage

The tests of items 1) and 2) above may be replaced by a single power-frequency withstand test where the peak value of the sinusoidal wave corresponds to the value stated in items 1) or 2), whichever is the higher.

Annex A
(normative)

Marking and identification of terminals

A.1 General

The purpose of identifying terminals is to provide information regarding the function of each terminal or its location with respect to other terminals or for other use.

A.2 Marking and identification of terminals of controller and contactors

A.2.1 Marking and identification of terminals of main circuits

The terminals of the main circuits shall be marked by single figure numbers and an alphanumeric system.

Table A.1 – Main circuit terminal markings

Terminals	Markings
Main circuit	1/L1-2/T1 3/L2-4/T2 5-L3-6/T3 7/L4-8/T4

For particular types of controllers and contactors (see 5.2.e)3) the manufacturer shall provide the wiring diagram.

A.2.2 Marking and identification of terminals of control circuits

A.2.2.1 Control-circuit power supply terminals

Under consideration.

A.2.2.2 Control-circuit input/output signal terminals

Under consideration.

A.2.3 Marking and identification of auxiliary circuits

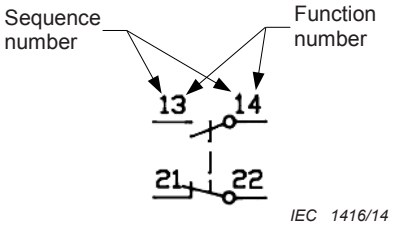
A.2.3.1 General

The terminals of auxiliary circuits shall be marked or identified on the diagrams by two figure numbers:

– the unit is a function number;

– the figure of the tens is a sequence number.

The following examples illustrate such a marking system.



A.2.3.2 Function number

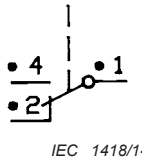
Function numbers 1, 2 are allocated to circuits with break contacts and function numbers 3, 4 to circuits with make contacts.

NOTE 1 The definitions for make contacts and break contacts are given in 2.3.12 and 2.3.13, respectively, of IEC 60947-1:2007.

Examples:

NOTE 2 The dots in the above examples take the place of the sequence numbers which are added according to the application.

The terminals of circuits with change-over contact elements shall be marked by the function numbers 1, 2 and 4.

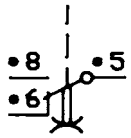


Function numbers 5 and 6 (for break contacts) and 7 and 8 (for make contacts) are allocated to terminals of auxiliary circuits containing auxiliary contacts with special functions.

Example:

The terminals of circuits with change-over contact elements with special functions shall be marked by function numbers 5, 6 and 8.

Example:



Change-over contact
delayed in both directions

IEC 1420/14

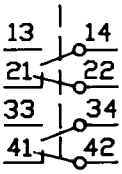
A.2.3.3 Sequence number

Terminals belonging to the same contact element shall be marked by the same sequence number.

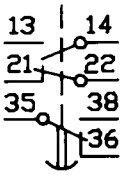
All contact elements having the same function shall have different sequence numbers.

The sequence number may be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such number.

Example:



Four contact elements



Three contact elements

IEC 1421/14

Annex B
(informative)

Typical service conditions for controllers and contactors

B.1 Control of resistive heating elements

Three typical methods of control a), b) and c) are described:

a) simple contactor function of switching on and off. Single-pole semiconductor controllers or contactors (form 5 controllers) with zero-point switching may be used to minimize the switching-on transient (AC-51);

b) in the case of wire-wound resistor elements, the switch-on current may be as high as 1,4 times the rated current. Ramp-up switch-on of such heating elements by means of a gradual increase in the terminal voltage can minimize mechanical and electrical stressing;

c) load control of resistance-heating elements by adjusting the load terminal voltage (voltage control) and the ratio of ON to OFF time (full voltage switching), or a combination of these. The load control may be achieved by means of a feed-back signal from the load to a comparator circuit or device which determines the operating cycle and/or output voltage of the semiconductor controller. This comparator or control device may be incorporated in the semiconductor controller or be used merely to generate the switching signal (for example in the case of a form 5 controller, i.e. a semiconductor contactor).

B.2 Switching of electric discharge lamp controls

The relevant utilization category should be selected with the following items a) to d) into account;

a) During the normal switch-on phase, fluorescent lamps without power factor correction or those in a twin lamp lead-lag connection, draw pre-heating currents which may attain values of about twice the rated current for a short period of time (AC-55a).

In the case of parallel compensated fluorescent lamps, transient inrush currents of 20 times the capacitor rated current can occur (AC-56b).

In the case of fluorescent lamps with electronic ballast units, inrush currents of 10 times the lamp rated current can occur for short periods of time.

b) High-pressure mercury-vapour and metal halide lamps (with or without power-factor correction) are switched on via ballast units in the form of series inductors and, in the case of the metal halide lamps, with the aid of ignition devices. During the initial 3 min to 5 min after switch-on, and before the lamps achieve their normal operating condition at rated current, a predominantly inductive current is drawn. This current may be as high as twice the rated current of the lamp. The over-current profile of the semiconductor contactor shall permit this value of current (AC-55a).

c) High-pressure sodium vapour lamps (without power-factor correction) draw an inductive current of approximately 1,7 to 2,2 times their rated current for 5 min to 10 min before achieving their operational condition. The over-current profile of the semiconductor contactor shall permit this value of current (AC-55a).

d) High-pressure mercury vapour, metal halide and sodium vapour lamps with power-factor correction, draw high transient capacitive inrush currents. These should be taken into account when selecting semiconductor contactors for such loads (AC-56b).

B.3 Switching of incandescent lamps

Semiconductor contactors can be used to switch incandescent lighting circuits often associated with high switch-on transient currents (AC-55b).

Short circuits between filament turns in incandescent lamps can cause extreme overcurrents to flow through the series connected switching device. This phenomena is classified as a short-circuit condition. The coordination between the semiconductor contactor and the short-circuit protection device (possibly incorporated in the lamp) is covered by 8.2.5.

B.4 Switching of transformers

Semiconductor contactors with defined point switching and special ramp-up switching function may be used to optimize the switching of transformer loads (surge limitation), since the high transient inrush currents associated with the switching-on of transformers is strongly dependent on the phase angle of the applied voltage at the instant current begins to flow.

B.5 Switching of capacitor banks

The amplitude and frequency of transient switch-on currents are not only determined by the capacitance of the load but also by the reactances in the associated circuit and supply lines as well as the point on the wave form of the applied a.c. voltage at which current begins to flow. In the case of capacitor banks (for example of a power-factor correction system), capacitors already in circuit present an additional energy source and can discharge into the switched capacitive load via low inductance linking conductors and the item of switchgear (for example semiconductor contactor). These high-inrush currents shall be taken into account when selecting the switching device (AC-56b).

Moreover, care should be taken regarding the overvoltage (difference between the capacitor voltage and the supply voltage).

Annex C

Vacant

Annex D

Vacant

Annex E

Vacant

Annex F
(informative)

Operating capability

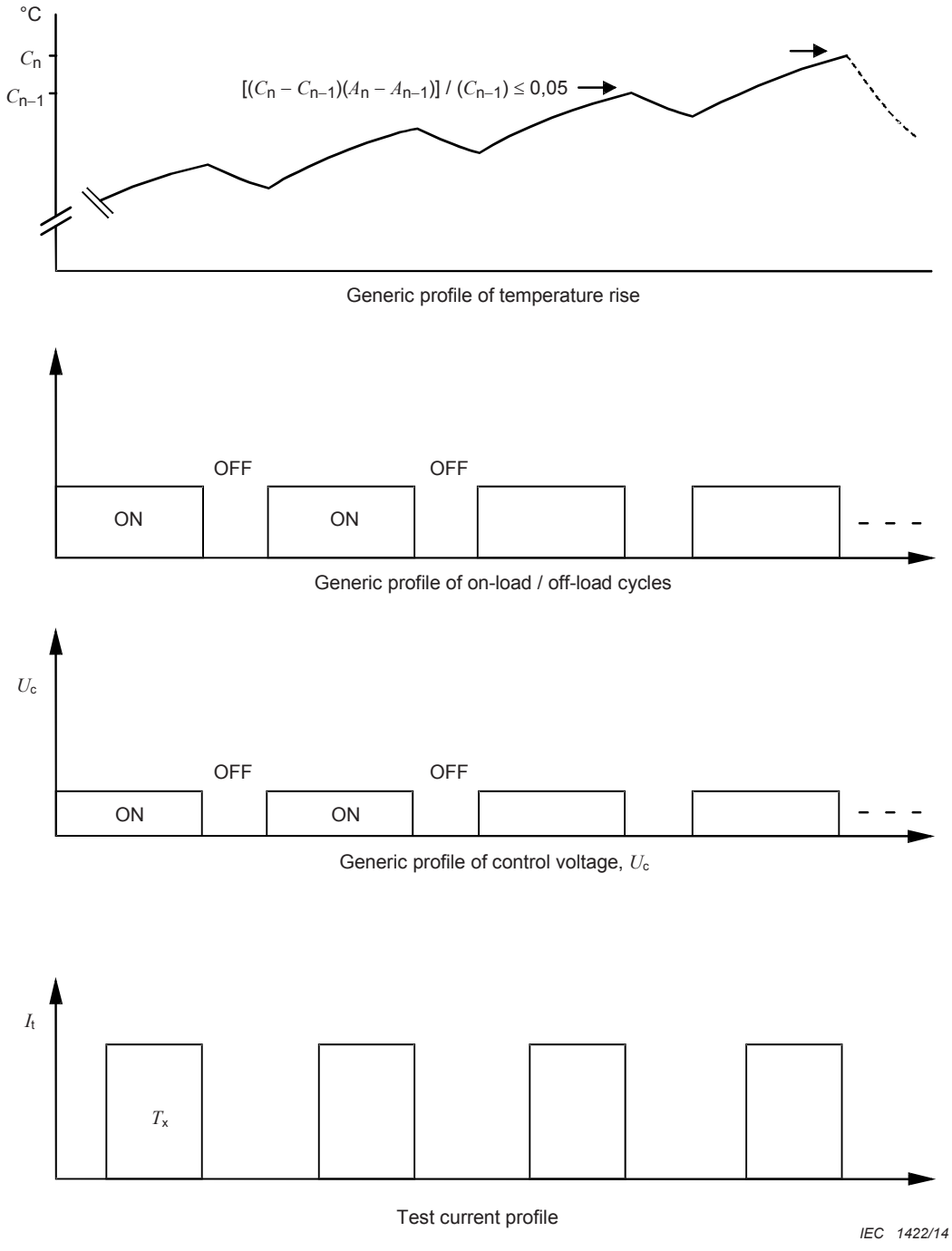


Figure F.1 – Thermal stability test profile

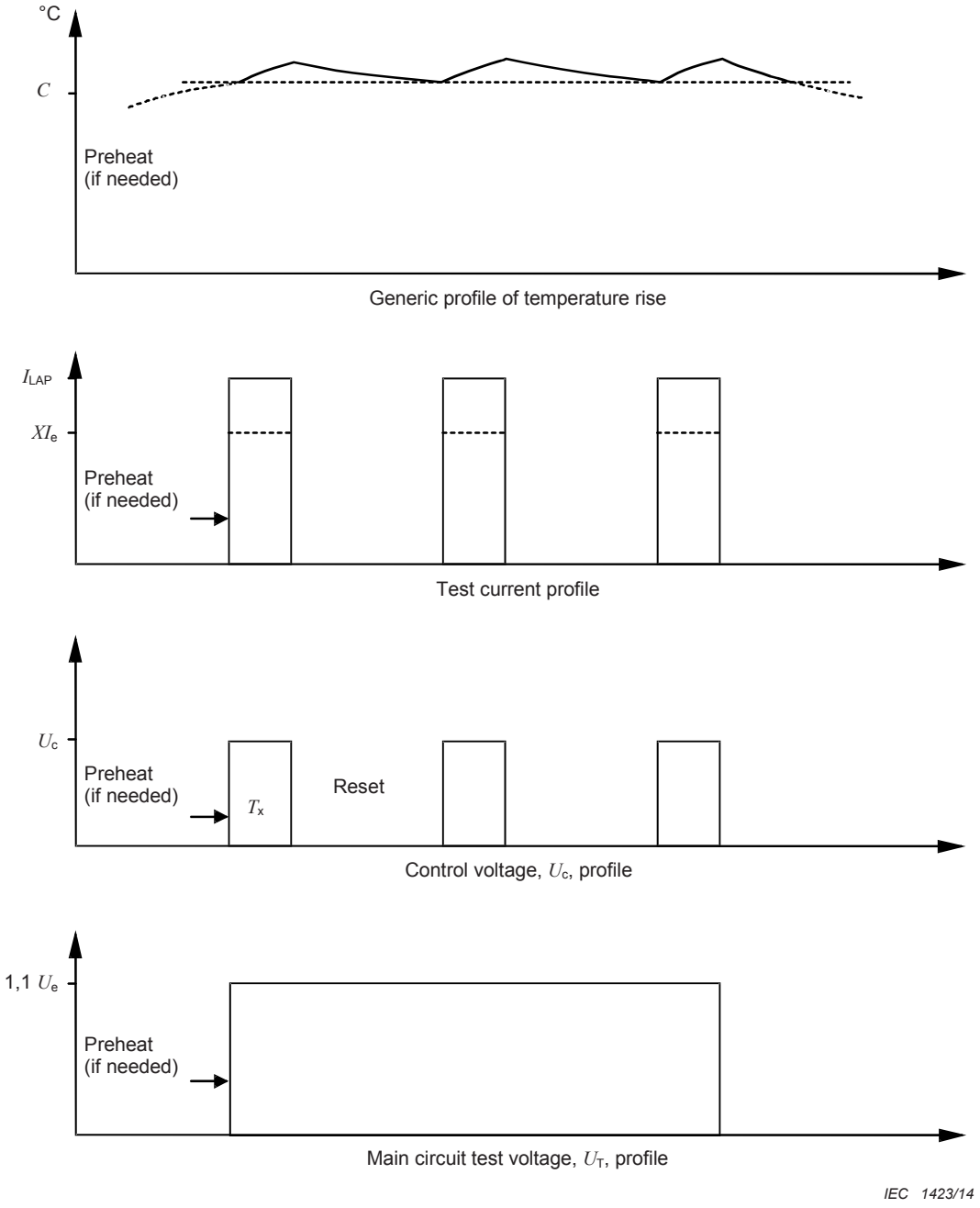


Figure F.2 – Overload capability test profile

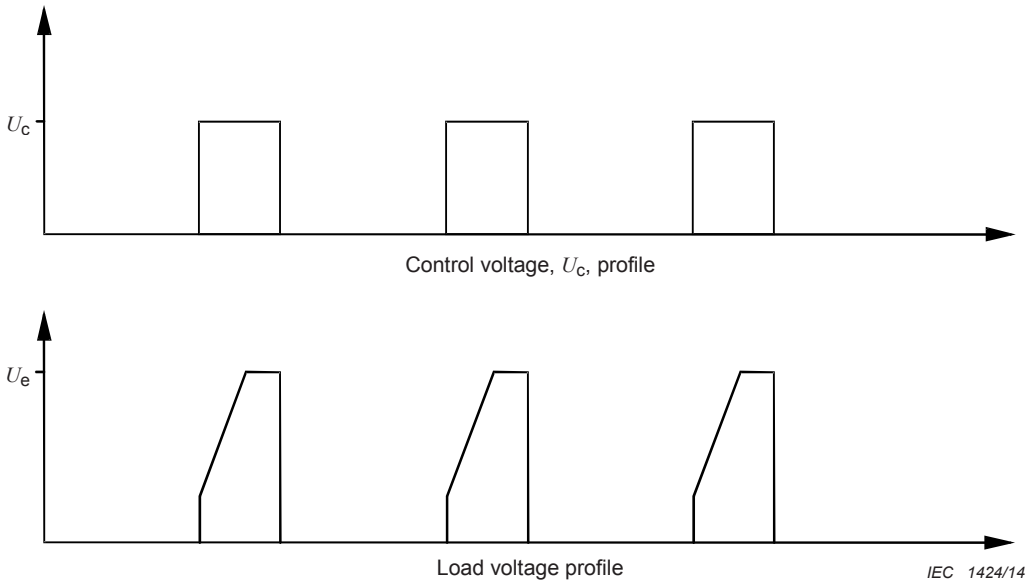


Figure F.3 – Blocking and commutating capability test profile

Annex G

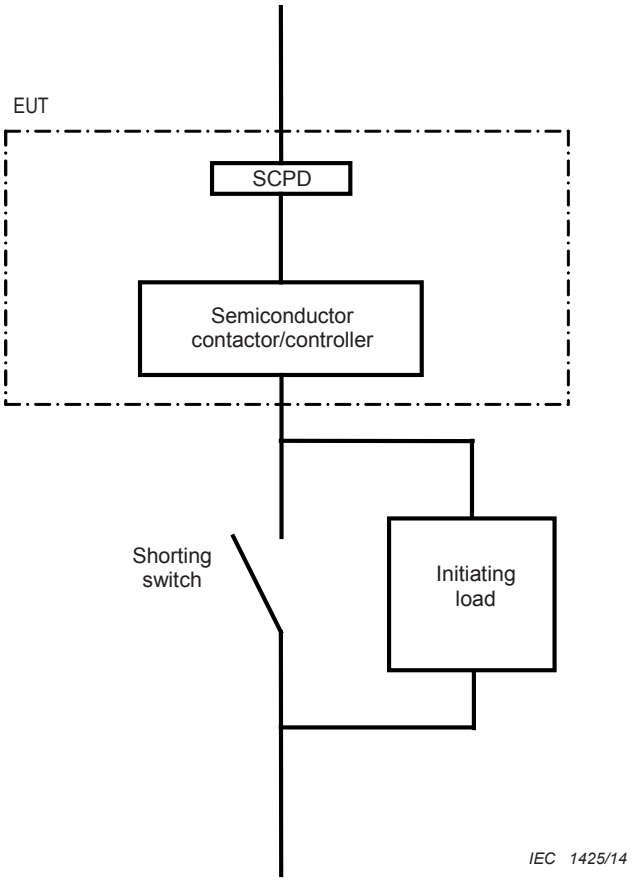
Vacant

Annex H

Vacant

Annex I
(normative)

Modified test circuit for short-circuit testing of semiconductor contactors and controllers



Key

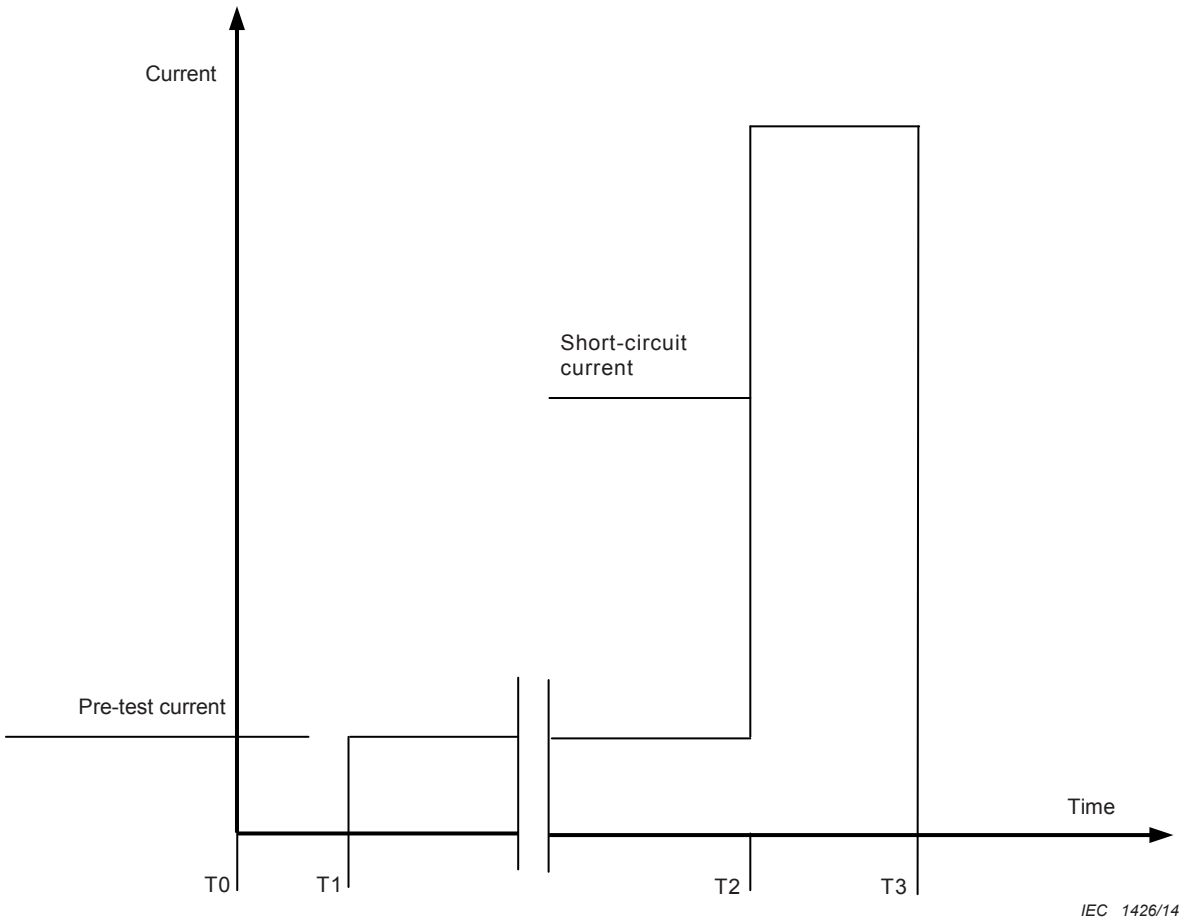
EUT Equipment under test (including connecting cables)

NOTE Outline includes metallic screen or enclosure.

Figure I.1 – Modified circuit for short-circuit testing of semiconductor devices

The standard circuits for short-circuit tests are illustrated in Figures 9 to 12 of IEC 60947-1:2007, Amendment 1 (2010).

This diagram illustrates the modifications to only one phase of the standard test circuit for conducting short-circuit tests of semiconductor controllers. The modifications to each phase of the test circuit are identical for testing polyphase devices. The only modifications to be made are those shown in this figure.



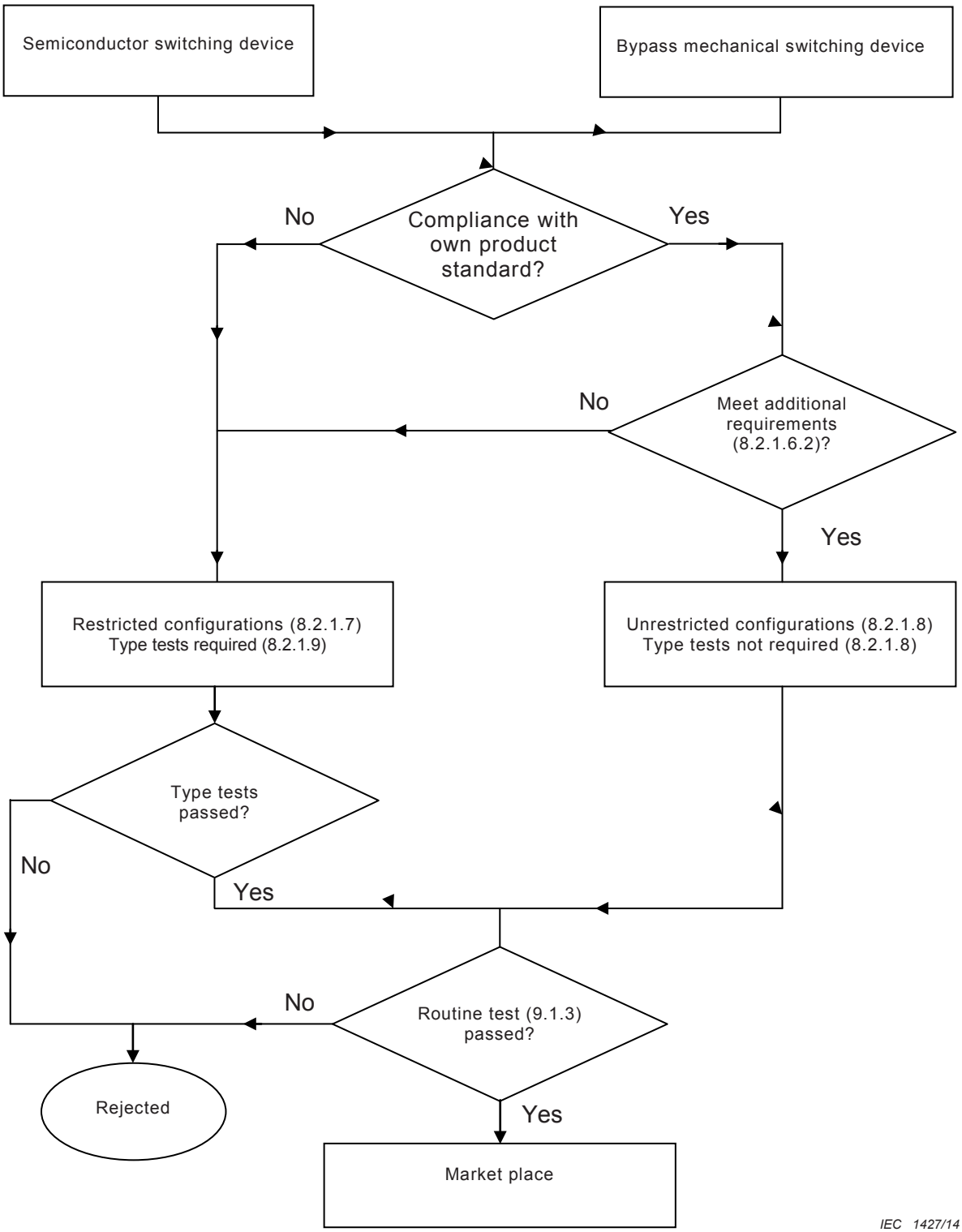
Key

T0	shorting switch opens	(9.3.4.1.6 a))
T1	test circuit is energized	(9.3.4.1.6 b))
T2	shorting switch is closed	(9.3.4.1.6 c))
T3	SCPD clears the fault	

Figure I.2 – Time line for the short-circuit test of 9.3.4.1.6

Annex J
(informative)

Flowchart for constructing bypassed semiconductor controllers tests



Bibliography

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*
Amendment 1:1997
Amendment 2:1998

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

IEC 60146 (all parts), *Semiconductor convertors – General requirements and line commutated convertors*

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

IEC 60947-4-2:2011, *Low-voltage switchgear and controlgear – Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

———————

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

bsi.

...making excellence a habit.™