



DPC: 24 / 30430891 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

Date: 27 February 2024

Origin: International

Latest date for receipt of comments: 17 April 2024

Project No. 2020/03296

Responsible committee: GEL/9 Railway Electrotechnical Applications

Interested committees:

Title: BS EN IEC 62590-2-1 Railway applications - Fixed installations - Electronic power converters

Part 2-1: DC Traction Applications - Diode rectifiers

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

- i) has any issues related to 3rd party IPR, patent or copyright
- ii) affects other national standard(s)
- iii) requires additional national guidance or information

**WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD.
THIS DRAFT IS NOT CURRENT BEYOND 17 April 2024**

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

No copying is allowed, in any form, without prior written permission from BSI except as permitted under the Copyright, Designs and Patent Act 1988 or for circulation within a nominating organization for briefing purposes. Electronic circulation is limited to dissemination by e-mail within such an organization by committee members.

Further copies of this draft may be purchased from BSI Shop <http://shop.bsigroup.com> or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com. British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from <http://standardsdevelopment.bsigroup.com>

Responsible Committee Secretary: **Ms Bash Berry (BSI)**Direct tel: **0203 142 5620**E-mail: **bash.berry@rssb.co.uk**

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
------------------	------------------------

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

COMMITTEE DRAFT FOR VOTE (CDV)

PROJECT NUMBER:

IEC 62590-2-1 ED1

DATE OF CIRCULATION:

2024-02-23

CLOSING DATE FOR VOTING:

2024-05-17

SUPERSEDES DOCUMENTS:

9/2863/CD, 9/2888A/CC

IEC TC 9 : ELECTRICAL EQUIPMENT AND SYSTEMS FOR RAILWAYS			
SECRETARIAT: France		SECRETARY: Mr Denis MIGLIANICO	
OF INTEREST TO THE FOLLOWING COMMITTEES:		PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.	
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY			
☒ SUBMITTED FOR CENELEC PARALLEL VOTING Attention IEC-CENELEC parallel voting The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.		☐ NOT SUBMITTED FOR CENELEC PARALLEL VOTING	

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any relevant "In Some Countries" clauses to be included should this proposal proceed. Recipients are reminded that the CDV stage is the final stage for submitting ISC clauses. (SEE [AC/22/2007](#) OR [NEW GUIDANCE DOC](#)).

TITLE:

Railway applications – Electronic power converters for fixed installations – Part 2-1: DC Traction applications – Diode rectifiers

PROPOSED STABILITY DATE: 2027

NOTE FROM TC/SC OFFICERS:

Copyright © 2024 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

CONTENTS

1	Scope	6
2	Normative references	6
3	Terms, definitions, symbols and abbreviated terms.....	6
3.1	Terms and definitions	7
3.2	Symbols	9
3.3	Abbreviated terms	10
4	System Configurations and characteristics	10
4.1	General	10
4.2	Main interfaces	10
4.3	Transformer main values	11
4.3.1	General	11
4.3.2	Impedance voltages	11
4.3.3	Coupling factor	12
4.4	Electrical connections	13
4.5	Voltage characteristic	14
4.6	Current characteristic	15
4.7	Current imbalance	16
4.8	Short time withstand capability	16
4.9	Direct voltage harmonic content	17
4.10	3AC power network harmonic current	17
5	Design and Integration.....	17
5.1	General	17
5.2	To be defined by user specification	17
5.2.1	Electrical data	17
5.2.2	Mechanical requirements	18
5.3	To be indicated by manufacturer:	19
5.4	Marking	19
5.4.1	Rating plate	19
5.4.2	Main circuit terminals	20
6	Tests	20
6.1	General	20
6.2	Test specifications	21
6.2.2	Test of accessory and auxiliary components	21
6.2.3	Insulation test	21
6.2.4	Checking of the protective functions	22
6.2.5	Light load functional test	22
6.2.6	Load test	22
6.2.7	Inherent voltage drop	22
6.2.8	Temperature-rise test.....	24
6.2.9	Short time withstand current.....	25
6.2.10	Power loss determination	25
6.2.11	Audible sound	25
6.2.12	Harmonic test	25
6.2.13	Power factor measurement.....	26

Annex A (informative) Determination of the voltage drop and the short-circuit currents of uncontrolled rectifiers	27
A.1 General	27
A.2 Description of the method	28
A.3 Example of a six-pulse rectifier or twelve-pulse rectifier with magnetically not coupled transformer windings ($K \approx 0$)	33
A.4 Example of a twelve-pulse rectifier with closely coupled secondary windings of the converter transformer ($K \approx 1$)	35
Annex B (informative) Examples of power factors of uncontrolled rectifiers	38
B.1 General	38
B.2 Considerations on the variation of the fundamental current and power factor in rectifiers	38
B.2.1 Basic considerations	38
B.2.2 First working zone	38
B.2.3 Second working zone	39
Annex C (informative) Interphase transformer	40
C.1 General	40
C.2 Voltage and currents	40
C.3 Intermittent current conditions	41
C.4 Current unbalance	41
Annex D (informative) Example of a protection curve	42
Figure 1 - General configuration	10
Figure 2 - Reactances of a rectifier transformer	11
Figure 3 - Voltage characteristic	15
Figure 4 - measurement of inherent voltage drop	24
Table 1 - Connections and calculation factors for uncontrolled rectifiers	14
Table 2 – Main rectifier design data	17
Table 3 – Mechanical requirements	18
Table 4 – Summary of tests	21

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –ELECTRONIC POWER CONVERTERS FOR
FIXED INSTALLATIONS –
PART 2-1: DC TRACTION APPLICATIONS – UNCONTROLLED RECTIFIERS**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62590 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This standard is based on IEC 62590 Ed.2, IEC 62589 and IEC 62695.

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

FDIS	Report on voting
9/xxxx/FDIS	9/xxxx/RVD

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

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

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

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

INTRODUCTION

Electronic power converters for traction power supply differ from other converters for industrial use due to special electrical service conditions and due to the large range of load variation and the peculiar characteristics of the load.

For these reasons IEC 60146-1-1 does not fully cover the requirements of railway applications and the decision was taken to have a specific standard for this use.

Uncontrolled rectifiers consist of a rectifier diode assembly and a transformer. Both fulfil common requirements. The transformer determines the voltage versus current characteristic.

Converter transformers for fixed installations of railway applications are covered by IEC 62695.

The series of IEC 62590 consists of the following parts:

IEC 62590-1 Railway applications– Electronic Power Converters for fixed installations – Part 1: General requirements

IEC 62590-2-1 Railway applications – Electronic Power Converters for fixed installations – Part 2-1: DC traction applications – Uncontrolled rectifiers

IEC 62590-2-2 Railway applications – Electronic Power Converters for fixed installations – Part 2-2: DC traction applications – Controlled converters

IEC 62590-3-1 Railway applications – Electronic Power Converters for fixed installations – Part 3-1: AC traction applications – Electronic power compensators

IEC 62590-3-2 Railway applications – Electronic Power Converters for fixed installations – Part 3-2: AC traction applications – Static frequency converters

RAILWAY APPLICATIONS – ELECTRONIC POWER CONVERTERS FOR FIXED INSTALLATIONS – PART 2-1: DC TRACTION APPLICATIONS – UNCONTROLLED RECTIFIERS

1 Scope

This document describes functions and working principles, specifies requirements, interfaces and test methods of uncontrolled rectifiers for DC electric traction systems. Uncontrolled rectifiers connect a 3AC power network with a DC electric traction system with an unidirectional power flow using diode assemblies.

The coordination between the transformer and the rectifier diode assembly is included.

This document applies to fixed installations of following electric traction systems:

- Railway networks
- metropolitan transport networks including metros, tramways, trolleybuses and fully automated transport systems, magnetic levitated transport systems, electric road systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.”

IEC/TR 60146-1-2:2019, *Semiconductor converters - General requirements and line commutated converters - Part 1-2: Application guide*

IEC 62695:2014, *Railway applications - Fixed installations - Traction transformers*

IEC 61000-2-12:2003, *Electromagnetic compatibility (EMC) - Part 2-12: Environment; Compatibility levels for low-frequency conducted disturbances and signalling in public medium-voltage power supply systems; Basic EMC Publication*

IEC 62590-1 as soon as published *Railway applications – Electronic Power Converters for fixed installations – Part 1: General*

IEC 60076-1:2011, *Power transformers - Part 1: General*

3 Terms, definitions, symbols and abbreviated terms

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Terms and definitions

3.1.1

semiconductor device

device whose essential characteristics are due to the flow of charge carriers within a semiconductor

Note 1 to entry: The definition includes devices whose essential characteristics are only in part due to the flow of charge carriers in a semiconductor but that are considered as semiconductor devices for the purpose of specification.

[SOURCE: IEC 60050-521:2002, 521-04-01]

3.1.2

electronic power converter

operative unit for electronic power conversion, comprising one or more electronic valve devices, transformers and filters if necessary and auxiliaries if any

Note 1 to entry: In English, the two spellings "convertor" and "converter" are in use, and both are correct. In this document, the spelling "converter" is used in order to avoid duplications.

[SOURCE: IEC 60050-551:1998 551-12-01, modified – figure not used, and parentheses removed]

3.1.3

rectifier

AC/DC converter for rectification

[SOURCE: IEC 60050-551:1998 551-12-07, modified – figure not used]

3.1.4

rectifier diode assembly

valve device assembly for rectification

Note 1 to entry: Often the term rectifier is used instead of rectifier diode assembly.

3.1.5

ideal no-load direct voltage

U_{di}

theoretical no-load direct voltage of an AC/DC converter assuming no reduction by phase control, no threshold voltages of electronic valve devices, and no voltage rise at small loads

[SOURCE: IEC 60050-551:1998, 551-17-15]

3.1.6

real no-load direct voltage

U_{d00}

actual mean direct voltage at zero direct current

[SOURCE: IEC 60050-551:1998, 551-17-29, modified - "the" removed]

3.1.7

ideal crest no-load voltage

U_{iM}

crest value of the voltage, appearing between the end terminals of an arm neglecting internal and external voltage surge and voltage drops in valves, at no load

3.1.8

transition current

mean direct current of a converter connection when the direct current(s) of the commutation group(s) become(s) intermittent when decreasing the current

[SOURCE: IEC 60050-551:1998, 551-17-20, modified - “the” removed]

3.1.9

leakage reactance of the primary winding <of a three-winding transformer>

X_p

difference between the mean of the short circuit reactance values measured between the primary winding and each secondary winding and one half of the short circuit reactance measured between the two secondary windings

3.1.10

leakage reactance of each of the secondary windings <of a three-winding transformer>

X_{S1}, X_{S2}

sum of the half difference of the short circuit reactance values measured between the primary winding and each secondary winding and one half of the short circuit reactance measured between the two secondary windings

3.1.11

reactance ratio <of a three-winding transformer> coupling factor < of a three-winding transformer>

K

ratio between the leakage reactance of the primary winding and the sum of the leakage reactances of the primary and secondary winding

Note 1 to entry: In case of a traction transformer with two secondary windings, used for a twelve-pulse reaction converter, the reactance ratio is designed to have the same no-load secondary voltages and the same impedance between the primary and each secondary winding, in order to obtain an even sharing of the current on both bridges in case the DC outputs are paralleled. Then $X_{S1} = X_{S2} = X_S$ and

$$K = X_p / (X_S + X_p)$$

3.1.12

interphase transformer

electromagnetic device enabling the operation in parallel of two or more phase displaced commutating groups through inductive coupling between the windings placed on the same core

[SOURCE: IEC 60050-551:1998, 551-14-16, modified - “an” removed]

3.1.13

rated 3AC voltage

rated voltage of the rectifier on the 3AC power network side

3.1.14

rated 3AC voltage of a rectifier diode assembly

highest value of the transformer traction side no load voltage that a rectifier diode assembly is designed for

3.1.15

rated load <of a rectifier>

rated current <of a rectifier>

I_{Nd}

value of a DC current a rectifier is designed for.

142 Note 1 to entry: All rated values of the components are derived from this value

143 Note 2 to entry: A rectifier can have a rated continuous load and rated loads in conjunction with a duty class.

144 3.1.16

145 **rated power <of a rectifier>**

146 rated direct current multiplied with DC voltage at rated current

147 3.1.17

148 **rated short circuit current <of a rectifier diode assembly>**

149 short circuit withstand current of a rectifier diode assembly for every 3AC connection

150 Note 1 to entry: A 12-pulse parallel connection should have 2 times the rated short circuit current as a total short
151 circuit current.

152 Note 2 to entry: It is an initial short circuit current according to IEC 60909.

153

154 3.2 Symbols

155 d_{rN} resistive direct voltage drop of the rectifier related to U_{di} at rated current

156 d_{xN} inductive direct voltage drop of the rectifier related to U_{di} at rated current

157 $I_{dlinmax}$ maximum current value of the range of linear voltage drop

158 I_{Nd} rated DC current on the traction side of the rectifier

159 I_V transformer phase current on the valve side

160 K coupling factor

161 U_{d00} real no-load direct voltage, theoretically resulting from peak value of a symmetrical
162 sinusoidal 3AC voltage U_{v0}

163 U_{di} ideal no-load direct voltage

164 U_{iM} ideal crest no-load voltage

165 u_{kt} impedance voltage of the transformer

166 u_{kt1}, u_{kt2} impedance voltage of a three-winding transformer with one secondary winding
167 shorted for winding 1 respective winding 2

168 U_{Nd} DC voltage at rated DC current in V

169 U_{v0} no-load phase to phase voltage of the transformer valve side

170 X_p leakage reactance of the primary winding (for three winding transformer)

171 X_S mean value of the leakage reactance of each of the secondary windings (for three
172 winding transformer)

173 $X_{S1} X_{S2}$ leakage reactance of each of the secondary windings (for transformer with two
174 secondary windings)

175 $X_{scP/S1}$ short circuit reactance between the primary winding and secondary winding 1
176 (for transformer with two secondary windings)

177 $X_{scP/S2}$ short circuit reactance between the primary winding and secondary winding 2
178 (for transformer with two secondary windings)

179 $X_{scS1/S2}$ short circuit reactance between both secondary windings
180 (for transformer with two secondary windings)

181 $X_{scP/S1S2}$ short circuit reactance between the primary winding and both secondary windings
182 (for transformer with two secondary windings)

3.3 Abbreviated terms

3AC three phase AC

AC alternating current

DC direct current

RMS root mean square

4 System Configurations and characteristics

4.1 General

DC railway systems are normally fed by a 3AC power network via a rectifier, see Figure 1.

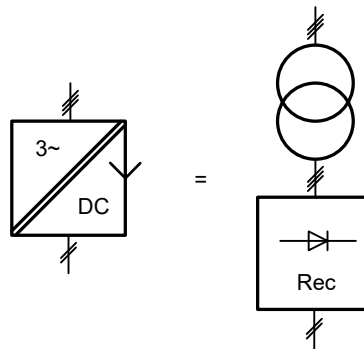


Figure 1 - General configuration

Diode rectifiers allow for a power flow from 3AC power network to the DC traction system only. The voltage versus current characteristic is determined by the connection and the transformer main data.

Rectifier diode assemblies and its transformers can be specified separately if a few parameters are clear:

- Load conditions for the transformer and rectifier diode assembly
- Short circuit withstand of the rectifier diode assembly
- Short circuit current limited by the transformer
- Maximum U_{V0} valve side no-load voltage of transformer

The optional interphase transformer for connection No. 9 is considered to be part of the rectifier diode assembly.

Protection at 3AC power network side is normally realized by a circuit breaker and a dedicated protection relay. In rare cases a combination of load break switch and fuse may be used.

Protection on the DC side is ensured by DC switchgear according to IEC 61992 series.

4.2 Main interfaces

The interface to the 3AC power network is characterized by:

- Rated voltage of the 3AC power network
- Short circuit power of the 3AC power network

- 211 • Voltage Imbalance of the 3AC power network
- 212 • Harmonic predistortion of the 3AC power network
- 213 • Current harmonics by the rectification

214 A method to determine the power factor at the 3AC connection of the rectifier is described in
 215 Annex B.

216

217 The interface to the DC traction network is characterized by:

- 218 • Voltage characteristic of the rectifier
- 219 • Voltage harmonics by the rectification

220 4.3 Transformer main values

221 4.3.1 General

222 A rectifier transformer is characterized by the following main values:

- 223 • 3AC power network voltage
- 224 • Traction side no-load voltage
- 225 • Impedance voltages
- 226 • Coupling factor

227 The traction side no-load voltage is a main value for calculation of all other voltages.

228 The impedance voltage is only one value for 2 winding transformers. For three winding
 229 transformers there is more than one value for the impedance voltage.

230 For a complete transformer specification other values are necessary, see IEC 62695.

231

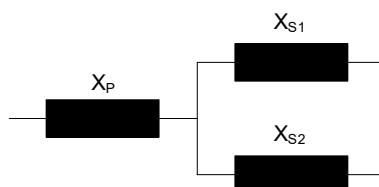
232 4.3.2 Impedance voltages

233 The impedance voltage can be derived from short circuit tests of the transformer. It can also be
 234 expressed as an impedance. For practical purpose the reactance is far more important than the
 235 resistance as for the interesting power range the X/R ratio is 8 or higher.

236

237 For connection 8 from Table 1 only one reactance is applicable. Only one test is applicable.

238 For connection 9 and 12 from Table 1 two reactances are applicable, see Figure 2. All of the
 239 following 4 tests are applicable.



240

241 **Figure 2 - Reactances of a rectifier transformer**

242

243 The different reactances can be determined by measurements.

244 Test 1: application of a voltage on primary side and short circuit on secondary side winding 1
 245 $X_{scP/S1} = X_p + X_{s1}$ is measured. The according impedance voltage is u_{kt1} . For u_{kt1} 50% of the
 246 transformer power is applicable.