400 Hz application

> Technical guide

"400 Hz distribution networks"

01/2015

Schneider Electric

Sommaire


> 1

Fields of application of 400 Hz distribution networks

The 400 Hz frequency is used mainly in the aerospace sector and in a few specific applications such as power supplies for computers or portable machine tools

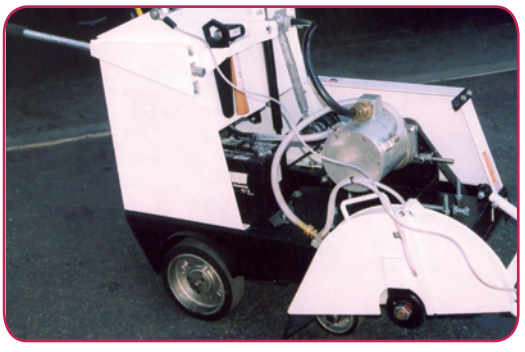
054922-45

The main advantage that led to the use of a higher frequency is that the transformers and motors designed for a frequency of 400 Hz are far more compact and lighter than those built for common 50 or 60 Hz frequencies. On the other hand, the current cannot be economically transported at such frequencies over long distances, which is why the use of 400 Hz remains confined to particular sectors and, in particular, has been adopted as standard for the power supply of commercial and military aircraft. This increase in frequency makes it possible to reduce the weight of on-board generators.

DB406468-53

DB406469-45

DB406470-54



This document deals only with the requirements of 400 Hz distribution networks deployed in the aerospace sector

Fields of application of 400 Hz distribution networks (cont.)

Focus on use of the 400 Hz network in the aerospace sector

There are 4 profiles of applications using a network at 400 Hz:

- Electrical distribution in aircraft
- Infrastructure for the power supply of aircraft on the ground or on-board ships
- Workshops for maintenance of on-board equipment
- Aircraft assembly workshops (airplanes, helicopters).

	Characteristics	Field of use of the switchgear for final distribution
	Electrical distribution on-board aircraft	
DB406774 	The very specific nature of this field of application in terms of performances and requirements (miniaturization, installation characteristics, continuity of service, etc.) and standards led to the development of specific offers by specialist manufacturers	Conventional final distribution switchgear, characterized for the service and industrial sectors, cannot meet the demands and special requirements for on-board electrical distribution equipment (specific standards, form factor, compensated temperature, connectors, etc.)
	Infrastructure for the power supply of aircraft on the ground or on-board (ships, oil platforms)	
63724-35 	■ Airport infrastructure facilities are increasingly developing the provision of access to a 400 Hz power supply network for aircraft on the ground to avoid insofar as possible the use of on-board generators during stopovers (mitigation of environmental nuisances and cost saving) ■ Distribution is ensured by an architecture of a topology adapted to the operating requirements and organization of the airport infrastructure (centralized or decentralized distribution, loop, etc.) ■ The power supply points must deliver sufficient power to allow operation of the facilities needed to ensure passenger comfort, such as air conditioning and lighting. Depending on the size of aircraft, one or two connection points are necessary (e.g. 2 for the Airbus A380) ■ The voltages used are 115 V single-phase and 115 V and 220 V three-phase	Given the power involved (90 kVA per power supply point), final distribution switchgear (<125 A) is not concerned in these 400 Hz network distribution architectures. This switchgear is sometimes used on auxiliary and control circuits
	Avionics and ancillary systems production and maintenance workshop	
DB406471-40 	For the activities of production and maintenance of on-board aerospace equipment, 400 Hz final distribution networks are available to power this equipment during functional tests, for purposes of validation, quality verification and repair	The final distribution switchgear is mainly used for power socket power supply circuits
	Aircraft assembly workshop	
DB406773 	■ Powering up on-board electrical distribution networks for purposes of inspection is performed with converters and low-power distribution switchboards ■ The aim is to check that there is no short circuit or wiring bundle insulation in the airplane, before connecting the avionics and other on-board equipment	Use for power sockets and cabling test devices

Fields of application of 400 Hz distribution networks (cont.)

Development of use of the 400 Hz frequency

Recent commercial aircraft such as the Airbus A380 and Boeing 787 have discarded the 400 Hz fixed-frequency network for variable-frequency networks. Frequency regulation on the alternators driven by the aircraft's jet engines required a mechanical speed regulation system, hence one that is complex, costly and relatively unreliable. The alternators are now driven directly by the motor.
On the A380, for example, the network frequency may vary between 360 Hz and 800 Hz depending on the motor speed, since each of the on-board networks operates at its own frequency.

Characteristics of 400 Hz distribution networks

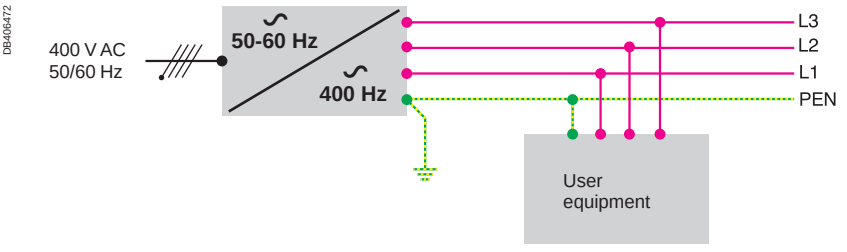
Earthing systems

Given the very often mobile nature of 400 Hz network applications, the most commonly used earthing system is the TN-C system.
Other earthing systems (TT or IT) are also used.

Short-circuit level

The sources used are generally formed of static or rotary converters, with a low internal impedance, which seldom exceed a few hundred kW. As a consequence, short-circuit currents at the output are limited and generally do not exceed a few hundred amperes.
For rotary sources, in transient phase, short-circuit currents do not exceed 4 times their rated current in the great majority of cases.
For static sources, short-circuit currents are limited by the sources to a value which does not exceed twice the rated current.

Model diagram of 400 Hz network with TN-C earthing system




> 2

Specific features and consequences for performance of final distribution switchgear

The performance level of products designed for domestic frequencies of 50 or 60 Hz is impacted by the specific properties of networks of 400 Hz frequency.

Phenomena due to the increased frequency influence the behaviour of the copper components of: transformers, cables and switchgear present in the equipment designed to ensure the production and distribution of a 400 Hz network.
For circuit breakers and earth leakage protection devices, the consequences concern:

- The performance of the magnetic, thermal and cutoff stage functions.
- The level of sensitivity of earth leakage protection devices.

Main phenomena related to the increase in frequency	Effects	Consequences for equipment
Exacerbation of skin effect (reduction in the useful cross section of conductors)	Decreased conductivity	Conductor overheating
Distortion of the hysteresis cycle	Reduction in electromagnetic forces	Magnetic inertia leading to a reduction in induced electromagnetic forces
Increased eddy currents	Increased losses by Joule effect	Overheating
Increased electromagnetic radiation of conductors	Risk of load disturbance	Need to reinforce the immunity of loads

To define an installation, it is necessary to check with the manufacturer on:

- Compatibility of the switchgear with this frequency level
- Application of return current coefficients where necessary

Overload protection

The method for calculating the current rating of the protective device is identical in 400 Hz.
The overload protection devices that can be used in 50 Hz can generally be used at the frequency of 400 Hz.
However, it is necessary to check a possible derating of the rated current specified by the manufacturer.

Short-circuit protection

Magnetic type tripping devices are influenced by the rise in frequency of the current to be switched off. The correction factor specified by the manufacturer should be applied.

Specific features and consequences for performance of final distribution switchgear (cont.)

Protection against indirect contact

Protection against indirect contact is provided in accordance with the rules given in the applicable installation codes.

- Chapter 411.3 of French standard NF C 15-100.
- Part 4-41 of IEC 60364.

The values of the cutoff times defined in these codes are considered valid for frequencies up to 1000 Hertz.
Although the electrical impedance of the human body decreases, the thresholds of perception, let-go and ventricular fibrillation increase with the frequency.

Various studies on the protection of persons against electrical risk have defined the ventricular fibrillation threshold which, for a signal of 50 Hz to 1000 Hz, is translated by a "current/contact time" curve given by international standard IEC 60479-2.
These studies also show that above 50 Hz, the human body is less and less sensitive to passage of a current with the increase in frequency.
This relation between current frequency and level of risk for the human body is also covered by information in the IEC 60479-2 standard that can be used to estimate the risks.
The ventricular fibrillation threshold determined at 30 mA at a frequency of 50 Hz increases with the frequency of the signal in accordance with a curve defined by changes in the frequency factor (Figure 1).
(On the curve below, at 400 Hz the frequency factor is 6, the physiological effect of a 180 mA / 400 Hz current will be the same as that of a 30 mA / 50 Hz current).

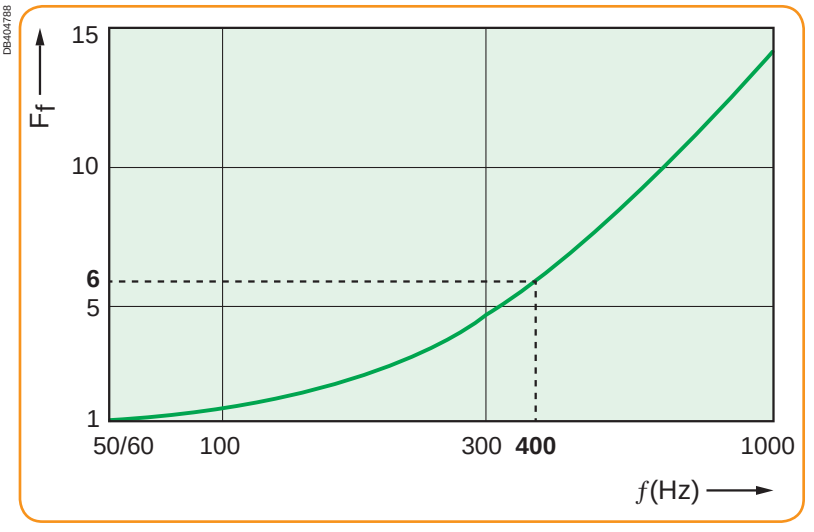


Figure 1. Variations in the ventricular fibrillation threshold for shock durations exceeding the period of cardiac cycle (as per IEC 60479-2).

Quality of service

Leakage currents are greater when the frequency increases, and this increases the risk of unwanted tripping.
This constraint should be taken into account when choosing the protective device.


> 3

Compatibility of final distribution switchgear

Compatibility of Schneider Electric modular offers in a network of frequency 400 Hz

Protection of cables

Most modular circuit breakers of the final distribution offer can be used at frequencies greater than 50 or 60 Hz, for which the thresholds (current, tripping time) are set.

Only the C120 and NG125 product ranges are not compatible for use on a 400 Hz network.

For circuit breakers declared compatible up to a 63 A rating:
- A magnetic tripping threshold magnification factor should be applied.
- There is no derating of the rated thermal current.

PB104437-40

iC60N

	Clario	N40N	C60	iC60	iC120	NG125
Can be used on 400 Hz network	Yes	Yes	Yes	Yes	No	No
Return current coefficient for rated current	1	1	1	1	-	-
Magnetic tripping threshold magnification factor	1.5	1.5	1.48	1.48	-	-

Example

For an iC60N C-curve circuit breaker of 40 A rating the performances at 50 Hz and 400 Hz are as follows:

	Performance when switched on	
	50 Hertz	**400 Hertz**
Rated current In	40 A	40 A
Magnetic tripping threshold	8.5 In (340 A)	11.2 In (448 A)

Compatibility of final distribution switchgear (cont.)

PB104471-35

Vigi iC60

Protection of persons

The characteristics of the earth leakage protection device should be chosen carefully and it should be ensured that its performance has been validated by the manufacturer.
The level and quality of protection can be affected by the type of earth leakage protection device used and by the technology chosen.

In the final distribution offer, 4 types of earth leakage protection are available for use on 50 or 60 Hertz networks.

Type of protection	Possible use on 400 Hz network (*)	Use	Quality of service	
			Product	Level
SI type	Yes	Pulsating DC component + electrical disturbances (lightning, surge of industrial origin, etc.)	ID	★★★☆
			iID	★★★☆
			iDPN	★★★☆
			Vigi C60	★★★★
			Vigi iC60	★★★★
AC type	Yes	Sinusoidal alternating currents	ID	★★☆☆
			iID	★★☆☆
			iDPN	★★☆☆
			Vigi C60	★★☆☆
			Vigi iC60	★★☆☆
A type	No	Sinusoidal alternating currents or currents with pulsating DC component	-	-
B type	No	Applications powered with three-phase current, when the Class 1 equipment installed downstream could produce fault currents with a DC component	-	-

(*) personal protection is ensured in conformance with the specifications of the IEC 60479-2 standard.

At a frequency of 400 Hz, only the AC and ***SI*** types are compatible in principle according to the characteristics defined by the IEC 60479-2 standard.
The A type, for its part, has an incompatible response curve which exceeds the maximum level required by the standard.

Compatibility of final distribution switchgear (cont.)

PB107117-40

IDc

PB107155-40

Vigi i DPN

PB104471-35

Vigi iC60

PB107169-40

i DPN Vigi

PB111761-40

ID

AC type

Provides the required level of protection for human safety but has a higher level of sensitivity and a risk of premature tripping.
This type of protection is not recommended on a 400 Hertz network, especially for applications requiring a very good quality of service.

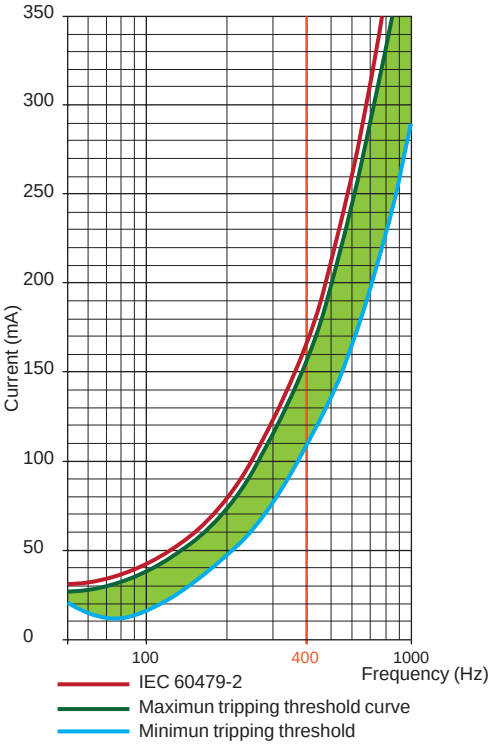
SI type

Has the response curve closest to, but not exceeding, the fibrillation level.
Allows the required level of protection to be combined with a continuity of service requirement.

Each category of product providing protection against indirect contacts has its own tripping curve profile, depending on the technology used and the frequency of the current, within an enclosure defined by a low threshold and a high threshold. Tripping will be effective and ensured between:
- a maximum tripping threshold which must be as close as possible to the curve specified by IEC 60479-2, but remain below it
- and a minimum tripping threshold that must be as close as possible to the top threshold curve to provide the best quality of service..

Decreasing the tripping thresholds, whilst ensuring personal safety, directly impacts the service quality level. The lower the curves, the higher the risk of unwanted tripping.

DB407088



*Example of **SI** type Vigi iC60 tripping curves compared with the reference curve specified by the IEC.*

At a frequency of 400 Hz, the earth leakage protection TEST function of a product intended for 50/60 Hz networks is inoperative, since the threshold for this function is calibrated for a frequency of 50/60 Hz

Compatibility of final distribution switchgear (cont.)

PB100202_SE-40

MN Multi 9

Auxiliary functions

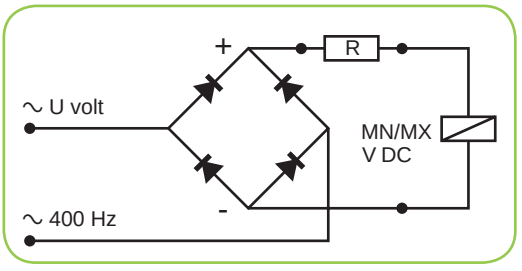
Voltmetric releases

For circuit breakers provided with a voltmetric release for which the control circuit is powered by the 400 Hz network, it is necessary to use:

■ Either an MN undervoltage tripping auxiliary with appropriate characteristics for 400 Hz networks:

Product range	Type	Voltage	Cat. no.
Multi 9	MN undervoltage release	115 V AC, 400 Hz	**26959**
Clario	MN undervoltage release	115 V AC, 400 Hz	**A9N26959**
Acti 9	iMN undervoltage release	115 V AC, 400 Hz	**A9A26959**

DB406392



Connection diagram

■ Or a direct current MN or MX tripping auxiliary, powered via a rectifier bridge and an additional resistance whose characteristics depend on the network voltage.

The choice of component characteristics must be made according to the 400 Hz network voltage, used for powering the release control circuit.

Voltage U 400 Hz network	Type of release	Product	Product range	Choice of rectifier (1)	Additional resistance	Cat. no.
220 V AC	Undervoltage release 48 V DC	MN	Clario	Refer to manufacturer's data	6.8 kΩ - 10 W	**A9N26961**
			Multi 9			**26961**
		iMN	Acti 9			**A9A26961**
	Shunt release 110…130 V DC	MX+OF	Clario			**A9N26946**
			Multi 9			**26946**
		iMX+OF	Acti 9			**A9A26946**
110 V AC	Shunt release 110…130 V DC	MX+OF	Clario	Refer to manufacturer's data	No	**A9N26946**
			Multi 9			**26946**
		iMX+OF	Acti 9			**A9A26946**
48 V AC	Shunt release 48 V DC	MX+OF	Clario			**A9N26947**
			Multi 9			**26947**
		iMX+OF	Acti 9			**A9A26947**

(1) The characteristics of the rectifier bridge remain to be defined according to the network characteristics (voltages, frequencies) and the application (quantity and characteristics of downstream loads)

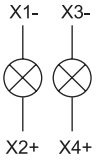
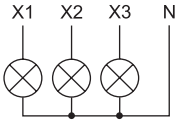
The OF contact of MX + OF tripping auxiliaries is not potential-free, it can only be used for an application at the same voltage level as the tripping auxiliary

Compatibility of final distribution switchgear (cont.)

Indicator lights

The indicator light devices of the iIL offer are compatible for use on a network of frequency 400 Hz, except the "flasher" version reference A9E18326.

iIL indicator lamps

Type	Single					Double		Three-phase voltage presence indicator lamp
	PB105256-40 				PB105257-40 		PB105258-40 	
Diagram	DB122563 				DB122564 		DB122566 	
Colour	Red	Green	White	Blue	Yellow	Green/red	White/white	Red/red/red
Catalogue number								
12…48 V AC/DC	**A9E18330**	**A9E18331**	**A9E18332**	**A9E18333**	**A9E18334**	**A9E18335**	-	-
110…230 V AC 110...130 V DC	**A9E18320**	**A9E18321**	**A9E18322**	**A9E18323**	**A9E18324**	**A9E18325**	**A9E18328**	-
230…400 V AC (3 phase)	-	-	-	-	-	-	-	**A9E18327**
Width in 9-mm modules	2					2		2

Compatibility of final distribution switchgear (cont.)

PB102241-30

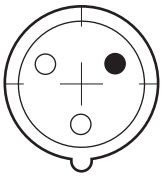
Pratika industrial sockets and plugs, for 400 Hz networks

The high-performance industrial sockets and plugs, in accordance with the IEC 60309 standard and intended for electrical networks of frequency 400 Hz, are green-coloured.
There is a specific model for each use, with different rated characteristics of voltage, frequency, polarity and application, incorporating safety hindrances which make it impossible to insert any plug in a socket which is not the exact corresponding type. Non-interchangeability is ensured by compliance with the different standardised dimension tables which indicate different ground contact positions in relation to a standard fixed reference of the connection.

Low voltage versions > 50 V
In the low voltage versions non-interchangeability is ensured by means of two elements:
- a guide spline on the socket which matches with a corresponding nib on the plug
- a ground contact larger than the other contacts, in a different clock position according to the rated operating characteristics.

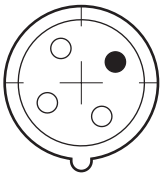
The clock position (h) of the ground contact is checked by observing, with the socket viewed from the front, the position of the ground contact in relation to the main keyway (guide spline), always positioned at 6 o'clock.

DB113182



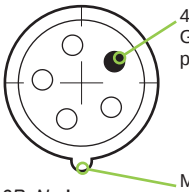
2P+⏚

DB113193



3P+⏚

DB113201



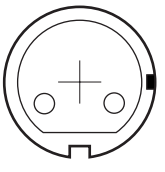
3P+N+⏚

PB102241-30

Extra-low voltage versions ⩽ 50 V
Also for these versions, with no ground contact, non-interchangeability is ensured by means of two reference elements:
- a guide spline on the plug which matches with a corresponding nib on the socket, always at a fixed 6 o'clock position
- a secondary keyway, also this a spline on the plug to which corresponds a nib on the socket, at different clock positions according to the operating characteristics.

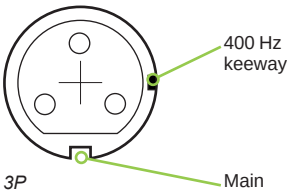
The clock position (h) of the secondary keyway is checked by observing, with the socket viewed from the front, the position of the nib in relation to the main keyway, always positioned at 6 o'clock.

DB406474

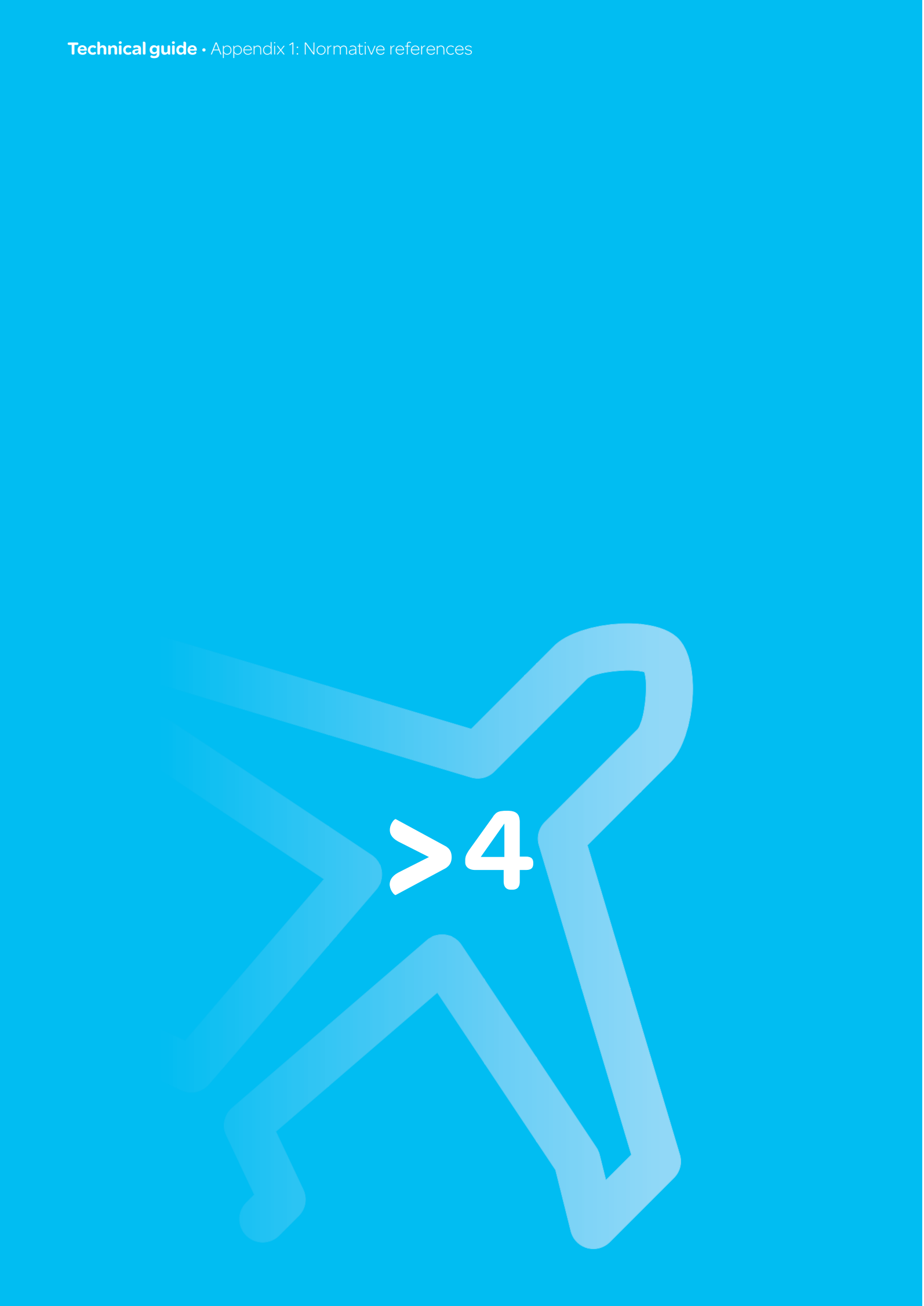


2P

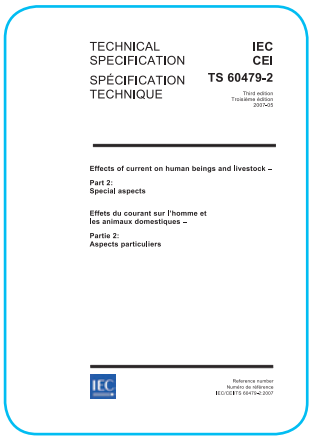
DB113207



3P


>4

Annexe
Normative references


TECHNICAL SPECIFICATION
SPÉCIFICATION TECHNIQUE

IEC
CEI
TS 60479-2

Third edition
Troisième édition
2007-03

Effects of current on human beings and livestock –
Part 2:
Special aspects

Effets du courant sur l'homme et les animaux domestiques –
Partie 2:
Aspects particuliers

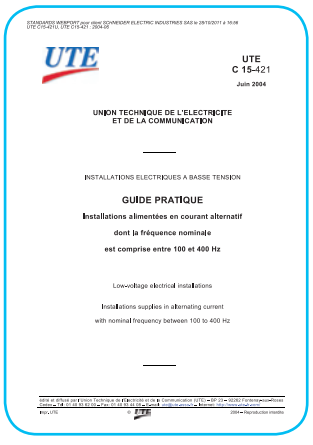
Reference number
Numéro de référence
IEC/TS 60479-2:2007

Standards

IEC 60479-2

Effects of current on human beings and livestock

The IEC 60479-2 standard is a technical specification.
It describes the effects on the human body of sinusoidal alternating currents passing through it, in the frequency range above 100 Hz.


UTE
C 15-421
Juin 2004

UNION TECHNIQUE DE L'ELECTRICITE ET DE LA COMMUNICATION

INSTALLATIONS ELECTRIQUES A BASSE TENSION

GUIDE PRATIQUE

Installations alimentées en courant alternatif dont la fréquence nominale est comprise entre 100 et 400 Hz

Low-voltage electrical installations

Installations supplies in alternating current with nominal frequency between 100 to 400 Hz

Regulations

UTE C 15-421

Practical guide entitled "Installations powered with alternating current of nominal frequency ranging between 100 and 400 Hz"

Ces règles complètent celles de la norme NF C 15-100.

- The NF C 15-100 standard - Low-voltage electrical installations - indicates in its field of application that the rules are valid for alternating current of frequencies 50 Hz, 60 Hz and 400 Hz.

It is also said that for frequencies exceeding 100 Hz, precautions should be taken, especially for busbar trunking, due to their increased resistance and reactance.
As a supplement, the UTE has published additional rules to those of the NF C 15-100 standard.

- The IEC 60364-1 standard, for its part, is applicable for preferential frequencies 50 Hz, 60 Hz and 400 Hz.

- There is no international equivalent of the UTE C 15-421 guide.

Schneider Electric Industries SAS
35, rue Joseph Monier
CS 30323
F- 92506 Rueil Malmaison Cedex

www.schneider-electric.com

This document was printed on environmentally friendly paper.

Publication: Schneider Electric
Photos: Schneider Electric
Printing:

CM909002E

01-2015