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AMENDMENT 1
AMENDEMENT 1

Safety requirements for power electronic converter systems and equipment – Part 1: General

Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 1: Généralités

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

This amendment has been prepared by the IEC technical committee TC22: Power electronic systems and equipment.

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

FDIS	Report on voting
22/270A/FDIS	22/274/RVD

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

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC website 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- withdrawn,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.

3 Terms and definitions

Replace the existing term and definition 3.35 by the following new term and definition:

3.35
prospective short-circuit current
I_{cp}
r.m.s. value of the current which would flow if the supply conductors to the circuit are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the *PECS*

[SOURCE: IEC 61439-1:2011, 3.8.7], modified – "ASSEMBLY" is replaced by "*PECS*".]

Add the following new terms and definitions:

3.66
conditional short-circuit current
I_{cc}
r.m.s. value of a *prospective short-circuit current* available from a supply source, declared by the *PECS* manufacturer under specified conditions, using a specific type of *short-circuit protective device* protecting the *PECS*

Note 1 to entry: See also Figure N.1.

Note 2 to entry: The supply source might be a mains or non-mains supply.

Note 3 to entry: The declared I_{cc} is the minimum current value used for calibration of the supply source.

[SOURCE: IEC 61439-1: 2011. 3.8.10.4], modified – The definition is modified to fit to the use of PECS applications.]

3.67
current-limiting protective device
protective element that, during its operation and specified current range, limits the current to a substantially lower value than the peak value of the prospective current

Note 1 to entry: A current-limiting device is normally a current-limiting fuse or a current-limiting circuit breaker. See IEC 60050-441:1984, 441-18-10.

3.68
minimum required prospective short-circuit current
$I_{cp,mr}$
r.m.s.value of a minimum short-circuit current, which is needed to be available from a supply source in order to ensure safe interruption of the fault, and which is declared by the *PECS* manufacturer and tested under specified conditions, using a specific type of short-circuit protective device protecting the *PECS*.

3.69
overcurrent protective device
OCPD
device provided to interrupt an electric circuit in case the current in the electric circuit exceeds a predetermined value for a specified duration

[SOURCE: IEC 60050-826:2004 826-14-14, modified – "conductor" deleted]

3.70
peak withstand current

I_{pk}
value of peak short-circuit current, declared by the *PECS* manufacturer, that can be carried without damage under specified conditions, defined in terms of current and time

Note 1 to entry: For the purpose of this standard, I_{pk} refers to the initial asymmetric peak value of the prospective test current.

Note 2 to entry: Time may be specified as the number of successive cycles at 50 Hz or 60 Hz.

[SOURCE: IEC 61439-1:2011, 3.8.10.2, modified – The definition is modified to fit to the use of PECS application.]

3.71
short-circuit protective device
SCPD
device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

Note 1 to entry: A *short-circuit protective device* is suitable for protection against short-circuit only, not for protection against overload. An *OCPD* may also incorporate the function of a *SCPD*.

[SOURCE: IEC 61439-1:2011, 3.1.11, modified – Note added]

3.72
short time withstand current
I_{cw}
r.m.s. value of short time current, declared by the *PECS* manufacturer, that can be withstood under specified conditions, defined in terms of current and time

[SOURCE: IEC 61439-1:2011, 3.8.10.3, modified – "rated" removed from the term and "ASSEMBLY" replaced by "PECS"]

4.2 Fault and abnormal conditions

Add, after the second paragraph, the following new paragraph:

Components in 4.2 also include insulation systems, *ports,* etc.

Add, at the end of the bullet list, the following new bullet:

- electromagnetic force and thermal hazard according to 4.3.

4.3.1 General

Add, after the first paragraph, the following new paragraph:

To ensure proper coordination with *short-circuit protective devices* and the available *prospective short-circuit current*, the *PECS* manufacturer shall specify and test for each *mains supply* input *port* of the *PECS*:

- *conditional short-circuit current* (I_{cc}) according to 4.3.2.2, or
- rated *short time withstand current* (I_{cw}) according to 4.3.5.

Individual *mains supply ports* of a *PECS* shall have specific short-circuit ratings of either I_{cc} or I_{cw}, or of both.

Only in case where compliance does not rely on the characteristic of *SCPD,* the I_{cw} in 4.3.5 can apply.

In case an output *port* is connected or intended to be connected to the input *mains supply port*, the output *port* shall also be specified with an I_{cc} or I_{cw} rating (e.g. bypass between input *mains supply port* and output *port*).

For marking see 6.2.

See Annex N for further information.

4.3.2.2 Input *ports* short-circuit withstand current

Replace the title and text as follows:

4.3.2.2 Specification of the rated *conditional short-circuit current* (I_{cc}) on input *ports*

In case the *PECS* manufacturer selects the *conditional short-circuit current* (I_{cc}) rating according to 4.3.1, the following shall be specified:

- *conditional short-circuit current* (I_{cc}),
- characteristics of the *short-circuit protective device*, and
- *minimum required prospective short-circuit current* ($I_{cp,mr}$).

Compliance is shown, through evaluation according to 4.2 to determine the appropriate combination of testing according to 5.2.4.4, 5.2.4.6 and 5.2.3.11.3 in order to evaluate single fault and abnormal conditions, including insulation faults.

If it is shown by analysis that the result of one test is representative of the worst case, less severe combinations need not be tested.

Add, after 4.3.4, the following new clause:

4.3.5 Input *ports short time withstand current*, I_{cw}

In case the *PECS* manufacturer selects the *short time withstand current* (I_{cw}) rating according to 4.3.1, the following shall be specified:

- rated *short time withstand current* (I_{cw}),
- associated duration, and
- rated *peak withstand current* (I_{pk}).

Compliance is shown, through evaluation according to 4.2 to determine the appropriate combination of testing according to 5.2.3.11.3 and 5.2.4.10 in order to evaluate single fault and abnormal conditions, including insulation faults.

If it is shown by analysis that the result of one test is representative of the worst case, less severe combinations need not be tested.

5.2.4.2 Pass criteria

Add, after the last bullet point, the following new bullet points:

- components, e.g. busbar supports, used for the mounting of *live parts* shall not break away from their initial position,
- no conductor shall get pulled out of its terminal connector.

Add, in Table 22 under "Abnormal operation tests", *the following new test:*

Short time withstand current (I_{cw}) test	X			4.3.5	5.2.4.10

Add, after 5.2.4.9.4, the following new subclause:

5.2.4.10 *Short time withstand current* (I_{cw}) test (*type test*)

5.2.4.10.1 General

As required in 4.3.5, the *short time withstand current* test shall be performed as a *type test* to verify the safety of the *PECS*.

Short-circuits are applied in the *PECS* at locations based on the evaluation in 4.2 so that terminals and other parts in the fault current path are being exposed to the short-circuit current.

5.2.4.10.2 *Short time withstand current* test method

The input *mains supply port* terminals shall be provided with a cable with a cross-section as specified for the *installation*.

If a switching device is used to initiate the short-circuit or switch the power to the *PECS*, it shall not limit the test current.

The complete length of the cable (forth and back) shall be approximately 2 m, unless this length is insufficient, in which case the length shall be as short as practical to perform the test.

The testing shall include individual tests for each input *mains supply port*. The worst case combination of terminals (including neutral and earth) shall be subjected to a short-circuit test. Analysis may be used to reduce the number of tests, if it is shown that the results of one terminal combination are representative of the anticipated results of another combination.

The *PECS* can be tested un-energized and not operating as intended prior to the short-circuit withstand test, if it can be shown that the test result is not affected.

A new sample may be used for each short-circuit test.

Table 37 lists the a.c. current test method as a minimum requirement for *PECS.* Requirements for d.c. current are under consideration.

If the specified I_{cp} value is higher than listed in Table 37, the recommended test current is: 16 kA, 20 kA, 25 kA, 35 kA, 50 kA, 65 kA, 85 kA, 100 kA.

Depending on the characteristics of the *PECS*, the actual values observed during the test may be different from those listed in Table 37, in which case the observed values shall be used for the declaration of I_{cw}.

Table 37 – A.c. *short time withstand current* test, minimum *PECS* requirements

Rated *PECS* input current (r.m.s.) A	Prospective test current [a] (r.m.s.) A [b]	Typical power factor [e]	Initial asymmetric peak current ratio [e] (I_{pk}/I_{cw})	Minimum duration of prospective test current [f, g] (cycles 50 Hz to 60 Hz)
$I \leq 16$	1 000 [c d]	0,95	1,42	1,5
	3 000	0,9		
$16 < I \leq 75$	6 000	0,7	1,53	1,5
$75 < I \leq 400$	10 000	0,5	1,70	1,5
$400 < I \leq 500$	10 000	0,5	1,70	3,0
$500 < I$	20 × I or 50 kA whichever is the lower	0,5 – 0,3 × (I – *500) / 2 000* or 0,2 whichever is the higher	(0,5 I + 3 150) / 2 000 or 2,2 whichever is the lower	3,0

[a] Prospective test current, in the context of this standard, shall be understood as *prospective short-circuit current* (I_{cp}) – refer to 3.70.

[b] Values compatible with Table 4 of IEC 60947-6-1:2005 and IEC 60947-6-1:2005/AMD1:2013.

[c] Pluggable *PECS* only.

[d] The typical fault current of public supply networks rated 75 A and below and intended to supply equipment with a rated current of 16 A or below can be calculated from the reference impedances in IEC TR 60725: 2012: phase conductor 0,24 + j0,15 Ω and neutral conductor 0,16 + j0,10 Ω. For 230 V/400 V supplies, this results in typical fault currents of 0,5 kA (230 V) and 0,7 kA (400 V).

[e] From Table 16 of IEC 60947-1:2007.

[f] In case a lower duration is wanted, the I_{cc} according to 4.3.2.2 can be specifed.

[g] To ensure global compatibility with external *SCPD* to clear the fault in the specified duration, a higher minimum duration should be considered and specified in which case this specified time shall be used for the test. See also IEC 61439-1:2011, 5.3.4.

5.2.4.10.3 Compliance criteria

As a result of the *short time withstand current* (I_{cw}) test, the *PECS* shall comply with the compliance criteria of 5.2.4.2.

6.2 Information for selection

Replace the existing bullet list by the following new bullet list:

- the name or trademark of the manufacturer, supplier or importer;
- catalogue number or equivalent;
- electrical ratings for each power *port*:
  - maximum nominal input voltage;
  - maximum nominal output voltage;
  - maximum nominal output current or nominal output power rating;
  - maximum nominal input current rms for dimensioning overload protective elements and wiring;
  - number of phases (e.g. 3 a.c.);
  - nominal frequency range (e.g. 50 Hz to 60 Hz);
  - protective class (I, II, III);
- the type of electrical supply *system* (e.g. TN, IT) to which the *PECS* may be connected;
- short-circuit current rating(s) in terms of:
  - *conditional short-circuit current* (I_{cc}) and *minimum required prospective short-circuit current* $I_{cp,mr}$ and the characteristics of the *short-circuit protective device* according to clause 4.3.2.2, or
  - *rated short time withstand current* (I_{cw}), duration and the rated *peak withstand current* (I_{pk}) according to 4.3.5.
- *output short-circuit current* in accordance with 4.3.2.3;
- supply requirements of the load (if applicable);
- liquid coolant type and design pressure for liquid cooled *PECS*;
- IP rating for *enclosure*;
- operating and storage environment;
- reference(s) to relevant standard(s) for manufacture, test, or use;
- reference to instructions for installation, use and maintenance.

Add the following new Annex N:

Annex N
(informative)

Guidance regarding short-circuit current

N.1 General

The purpose of Annex N is to provide further in depth informative background pertaining to short-circuit rating of the input and output as specified in 4.3, which needs to be considered during *single fault* and abnormal conditions as specified in 4.2.

Internal short-circuits in a *PECS*, either through component failure or through human error, can lead to significant equipment damage and immediate potential danger based on the high *prospective short-circuit current* that can flow when the *PECS* is connected to an a.c. or d.c. mains supply.

The damage in a circuit exposed to a high *prospective short-circuit current* is mainly due to the very high level of mechanical stress, generated by the magnetic field and by the extreme thermal rise in the circuit and in its components.

The single fault and abnormal analysis, specified in 4.2, relies heavily on the internal design of the *PECS* as well as on some external parameters.

While the internal design is in full control of the manufacturer, the external parameters depend on the circuit characteristics of the *installation*. Especially, the *prospective short-circuit current* of the *installation* is of importance and needs to be taken into account for each *installation*.

The *prospective short-circuit current o*f the *installation* indicates the amount of energy available from the *installation* during a failure in the product. Without any limiting devices, the available energy will increase with higher *prospective short-circuit current,* and the risk of fire, mechanical hazard, electrical shock or other hazard (see 4.2) will increase during a failure.

One of the following two options for short-circuit ratings is to be specified for each input *mains supply* port of a *PECS* (see also 4.3.1).

Option 1 as specified in 4.3.2.2:

- *conditional short-circuit current* (I_{cc});
- *minimum required prospective short-circuit current* $I_{cp,mr}$;
- characteristics or type of the *short-circuit protective device.*

Option 2 as specified in 4.3.5:

- rated *short time withstand current* (I_{cw});
- associated duration (ms);
- rated *peak withstand current* (I_{pk}).

The *prospective short-circuit current* is characterised by two parameters:

- the peak current which is the maximum current, which potentially flows during a short-circuit of negligible impedance;

- the electrical energy (I^2t) generated by the r.m.s. current ($I_{r.m.s.}$) together with the duration (ms, s) of the short-circuit.

The effect of the peak current and I^2t is mainly related to the following two physical risks.

- Hazardous mechanical forces due to the generated magnetic fields caused by the short-circuit current, which might cause mechanical damage to busbars, *enclosure* and reduction of clearance and creepage distances. The mechanical force is proportional to the square of instantaneous short-circuit current.

  NOTE Further information about the mechanical effect of the short-circuit current can be found in IEC 60865-1.

- Hazardous energy inside components leading to dramatic overheating/explosions of components, arc faults and conductive ionization of the air, which might lead to fire, reduction of clearance and creepage distances and destruction of the enclosure. The thermal impact, i.e. heating of conductors, is proportional to the square of r.m.s. value of the short-circuit current.

N.2 Coordination of short-circuit current

N.2.1 General

To ensure that the *PECS* and the components will be able to operate safely under the available short-circuit current during a failure, the *PECS* and other *installation* components need to be designed and specified for the *prospective short-circuit current* at the point where it is installed.

For the calculation of the *prospective short-circuit currents* in three-phase a.c. systems the IEC 60909 series provides guidance. The consequences of the short-circuit are dealt with in the IEC 60865 series.

N.2.2 *Conditional short-circuit current* (I_{cc}) and *minimum required prospective short-circuit current* ($I_{cp,\ mr}$)

N.2.2.1 General

The *conditional short-circuit current* (I_{cc}) rating is defined in 4.3.2.2.

N.2.2.2 *Conditional short-circuit current* (I_{cc})

By specifying the I_{cc}, the protection of the *PECS* depends on the characteristics of the *short-circuit protective device* (e.g. fuse or circuit breaker).

In order to reduce the fault current energy and peak current and limit the damage of the *PECS* and avoid a hazard, a *current-limiting device* may be used. As shown in Figure N.1, both the I^2t and the peak current is limited dramatically due to the current-limiting characteristic of the protective device. Consequently, the damage is significantly reduced and the risk of a hazard is reduced significantly. See Clause N.3 for more information.

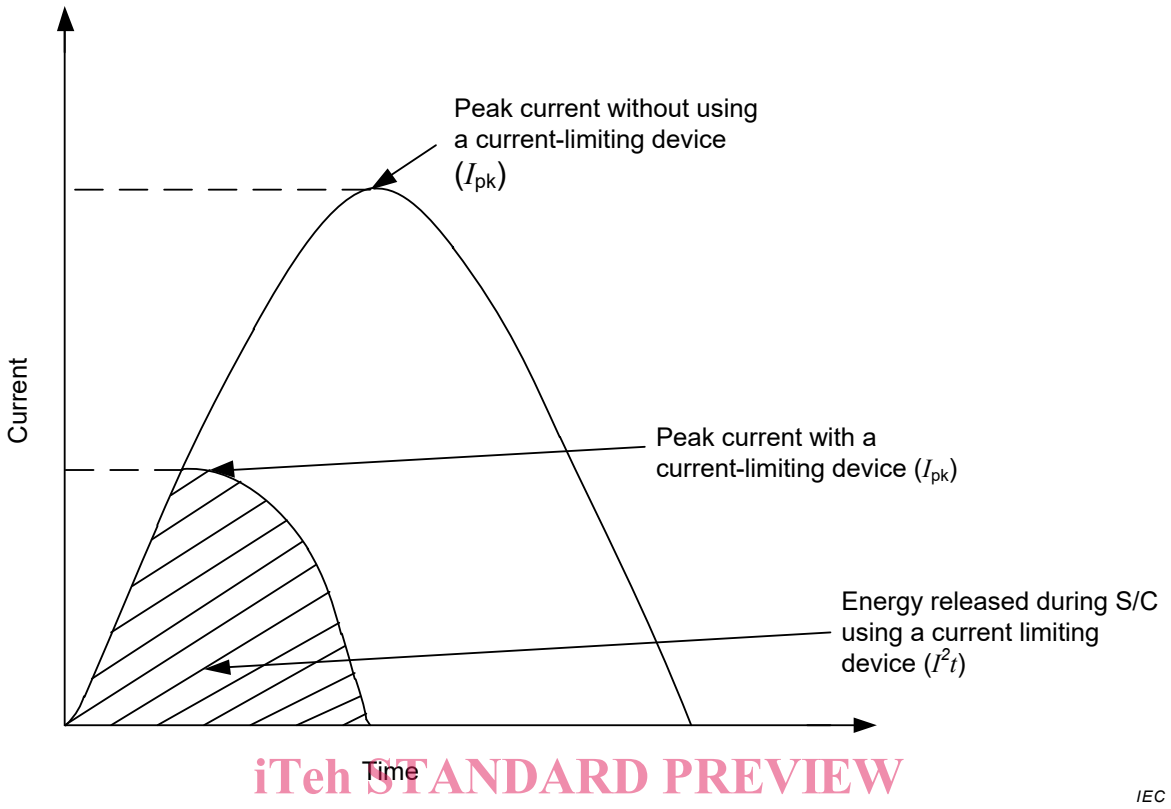

Figure N.1 – Example of short-circuit current curve under specification of I_{cc}

Coordination of the *PECS* with the specified upstream *SCPD* is typically performed by the installer, to ensure that the *SCPD* will be able to interrupt the fault current in a safe manner in case of a short-circuit.

N.2.2.3 *Minimum required prospective short-circuit current* ($I_{cp,mr}$)

Depending on the characteristic of the *short-circuit protective device*, a minimum current during a failure is needed to ensure a proper operation of the *short-circuit protective device*.

While the maximum *prospective short-circuit current* results in the highest fault current, but ensures the shortest operating time of the *short-circuit protective device*, the minimum *prospective short-circuit current* results in a lower fault current, but a significantly longer operation time and consequently an increasing I^2t during the fault.

The manufacturer should be able to show that the *PECS* and the specified *SCPD* have been successfully tested with the specified *minimum required prospective short-circuit current*.

A manufacturer can specify a maximum and *minimum required prospective short current* anywhere within the trip curves of the *SCPD*. However, this selection impacts the operation of the *SCPD* and the amount of energy released during a fault.

To ensure a sufficiently low I^2t value and a quick operation of the *SCPD*, it is recommended to select a *minimum required prospective short-circuit current* in the instananeous tripping or in the current-limiting area of the characteristics of a selected *SCPD*. See Figure N.2 and Figure N.3.

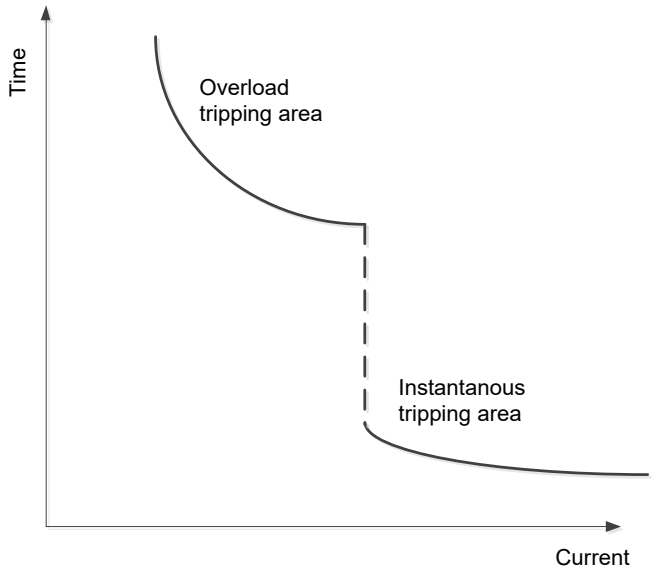

Figure N.2 – Example of tripping characteristic of a circuit breaker

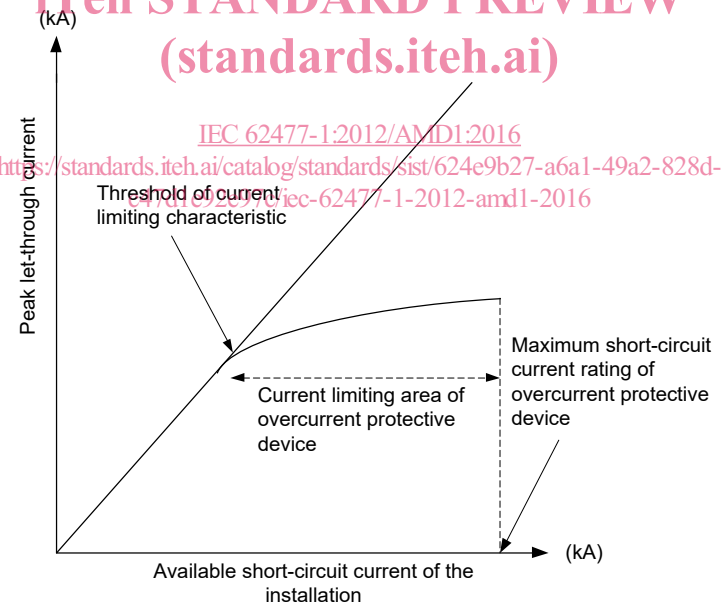

Figure N.3 – Example of tripping characteristic of a current-limiting fuse

The test to show compliance with the *minimum required prospective short-circuit current* may be waived if risk analysis can demonstrate that the peak current and the I^2t values are below the values from the test with the maximum *prospective short-circuit current*.

N.2.3 *Short time withstand current* (I_{cw})

The short-circuit rating is expressed as explained in 4.3.5, and Figure N.4 shows a typical waveform.