Prüfbericht-Nr.: *Test report no.*:	**CN2539ZK 001**	**Auftrags-Nr.:** *Order no.*:	326061372	Seite 1 von 48 *Page 1 of 48*
Kunden-Referenz-Nr.: *Client reference no.*:	2028101	**Auftragsdatum:** *Order date:*	2024-10-26	
Auftraggeber: *Client*:	GoodWe Technologies Co., Ltd. No.90 Zijin Rd., New District, Suzhou, 215011, P.R. China			
Prüfgegenstand: *Test item*:	Grid-Tied PV Inverter			
Bezeichnung / Typ-Nr.: *Identification / Type no.*:	GW3K-DNS-G40, GW3.6K-DNS-G40, GW4.2K-DNS-G40, GW5K-DNS-G40, GW6K-DNS-G40, GW3.1K-DNS-L-G40			
Auftrags-Inhalt: *Order content*:	AK Certificate			
Prüfgrundlage: *Test specification*:	IEC 63027:2023			
Wareneingangsdatum: *Date of sample receipt*:	2024-11-13			
Prüfmuster-Nr.: *Test sample no:*	A003863335-001			
Prüfzeitraum: *Testing period*:	2024-11-14 – 2025-02-17			
Ort der Prüfung: *Place of testing*:	No.177, 178, Lane 777 West Guangzhong Road, Jing'an District,Shanghai, China			
Prüflaboratorium: *Testing laboratory:*	TÜV Rheinland (Shanghai) Co., Ltd.			
Prüfergebnis*: *Test result**:	Pass			

geprüft von: tested by:		**genehmigt von:** *authorized by*:	
Datum: *Date:* 2025-02-24	Matt Ma Eric Qiu	**Ausstellungsdatum:** *Issue date:* 2025-02-24	Xingxin Tian
Stellung / Position:	Matt Ma (Trainee)/Eric Qiu(PE) Sachverständige(r)/Expert	**Stellung** / Position:	Xingxin Tian Sachverständige(r)/Expert

Sonstiges / *Other*: See the following pages for General product information and comment.

Zustand des Prüfgegenstandes bei Anlieferung: *Condition of the test item at delivery*: Prüfmuster vollständig und unbeschädigt *Test item complete and undamaged*

* Legende:	P(ass) = entspricht o.g. Prüfgrundlage(n)	F(ail) = entspricht nicht o.g. Prüfgrundlage(n)	N/A = nicht anwendbar	N/T = nicht getestet
** Legend:*	*P(ass) = passed a.m. test specification(s)*	*F(ail) = failed a.m. test specification(s)*	*N/A = not applicable*	*N/T = not tested*

Anmerkungen
Remarks

1	Alle eingesetzten Prüfmittel waren zum angegebenen Prüfzeitraum gemäß eines festgelegten Kalibrierungsprogramms unseres Prüfhauses kalibriert. Sie entsprechen den in den Prüfprogrammen hinterlegten Anforderungen. Die Rückverfolgbarkeit der eingesetzten Prüfmittel ist durch die Einhaltung der Regelungen unseres Managementsystems gegeben. Detaillierte Informationen bezüglich Prüfkonditionen, Prüfequipment und Messunsicherheiten sind im Prüflabor vorhanden und können auf Wunsch bereitgestellt werden. *The equipment used during the specified testing period was calibrated according to our test laboratory calibration program. The equipment fulfils the requirements included in the relevant standards. The traceability of the test equipment used is ensured by compliance with the regulations of our management system. Detailed information regarding test conditions, equipment and measurement uncertainty is available in the test laboratory and could be provided on request.*
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3	Prüfklausel mit der Note * wurden an qualifizierte Unterauftragnehmer vergeben und sind unter der jeweiligen Prüfklausel des Berichts beschrieben. Abweichungen von Prüfspezifikation(en) oder Kundenanforderungen sind in der jeweiligen Prüfklausel im Bericht aufgeführt. *Test clauses with remark of * are subcontracted to qualified subcontractors and descripted under the respective test clause in the report.* *Deviations of testing specification(s) or customer requirements are listed in specific test clause in the report.*
4	Die Entscheidungsregel für Konformitätserklärungen basierend auf numerischen Messergebnisen in diesem Prüfbericht basiert auf der "Null-Grenzwert-Regel" und der "Einfachen Akzeptanz" gemäß ILAC G8:2019 und IEC Guide 115:2021, es sei denn, in der auf Seite 1 dieses Berichts genannten angewandten Norm ist etwas anderes festgelegt oder vom Kunden gewünscht. Dies bedeutet, dass die Messunsicherheit nicht berücksichtigt wird und daher auch nicht im Prüfbericht angegeben wird. Zu weiteren Informationen bezueglich des Risikos durch diese Entscheidungsregel siehe ILAC G8:2019. *The decision rule for statements of conformity, based on numerical measurement results, in this test report is based on the "Zero Guard Band Rule" and "Simple Acceptance" in accordance with ILAC G8:2019 and IEC Guide 115:2021, unless otherwise specified in the applied standard mentioned on Page 1 of this report or requested by the customer. This means that measurement uncertainty is not taken in account and hence also not declared in the test report. For additional information to the resulting risk based of this decision rule please refer to ILAC G8:2019.*

Test Report issued under the responsibility of:

TÜVRheinland®

TEST REPORT IEC 63027 DC arc detection and interruption in photovoltaic power systems	
Report Reference No. ..... :	**CN2539ZK 001**
Date of issue..... :	See cover page
Total number of pages ..... :	See cover page
Name of Testing Laboratory preparing the Report ..... :	**TÜV Rheinland (Shanghai) Co., Ltd.**
Applicant's name ..... :	**GoodWe Technologies Co., Ltd.**
Address..... :	No.90 Zijin Rd., New District, Suzhou, 215011, P.R. China
TRF template used..... :	IECEE OD-2020-F1:2020, Ed.1.3
Standard..... :	IEC 63027: 2023
Test procedure ..... :	AK Certificate
Non-standard test method……:	N/A
Test Report Form No. ..... :	N/A
Test Report Form(s) Originator .... :	TÜV Rheinland (Shanghai) Co., Ltd.
Master TRF ..... :	Dated 2023-05-29

General disclaimer:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the Issuing Testing Laboratory, responsible for this Test Report.

Test item description .....:	Grid-Tied PV Inverter
Trade Mark .....:	GOODWE
Manufacturer .....:	Same as the applicant
Model/Type reference .....:	GW3K-DNS-G40, GW3.6K-DNS-G40, GW4.2K-DNS-G40, GW5K-DNS-G40, GW6K-DNS-G40, GW3.1K-DNS-L-G40
Ratings .....:	See marking label and model list

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):			
☐	**CB Testing Laboratory:**		
Testing location/ address.....:			
Tested by (name, function, signature) .....:			
Approved by (name, function, signature)...:			
☐	**Testing procedure: CTF Stage 1:**		
Testing location/ address.....:			
Tested by (name, function, signature) .....:			
Approved by (name, function, signature)...:			
☐	**Testing procedure: CTF Stage 2:**		
Testing location/ address.....:			
Tested by (name + signature) .....:			
Witnessed by (name, function, signature)..:			
Approved by (name, function, signature)...:			
☐	**Testing procedure: CTF Stage 3:**		
☐	**Testing procedure: CTF Stage 4:**		
Testing location/ address.....:			
Tested by (name, function, signature) .....:			
Witnessed by (name, function, signature)..:			
Approved by (name, function, signature)...:			
Supervised by (name, function, signature) :			

List of Attachments (including a total number of pages in each attachment):

None.

Summary of testing:

Tests performed (name of test and test clause):	**Testing location:**
9.1 General 9.2.7 Arc energy and response time measurement 9.2.8 Test function 9.2.9 Reconnection test Unless otherwise specified, all tests were performed on model GW6K-DNS-G40 which had the max. power and gave rise to worse results to represent other models.	**TÜV Rheinland (Shanghai) Co., Ltd.** No.177, 178, Lane 777 West Guangzhong Road, Jing'an District, Shanghai, China

Summary of compliance with National Differences (List of countries addressed):

N/A

☐ **The product fulfils the requirements of _____ (insert standard number and edition and delete the text in parenthesis, leave it blank or delete the whole sentence, if not applicable)**

Statement concerning the uncertainty of the measurement systems used for the tests

(may be required by the product standard or client)

☐ **Internal procedure used for type testing through which traceability of the measuring uncertainty has been established:**

Procedure number, issue date and title:

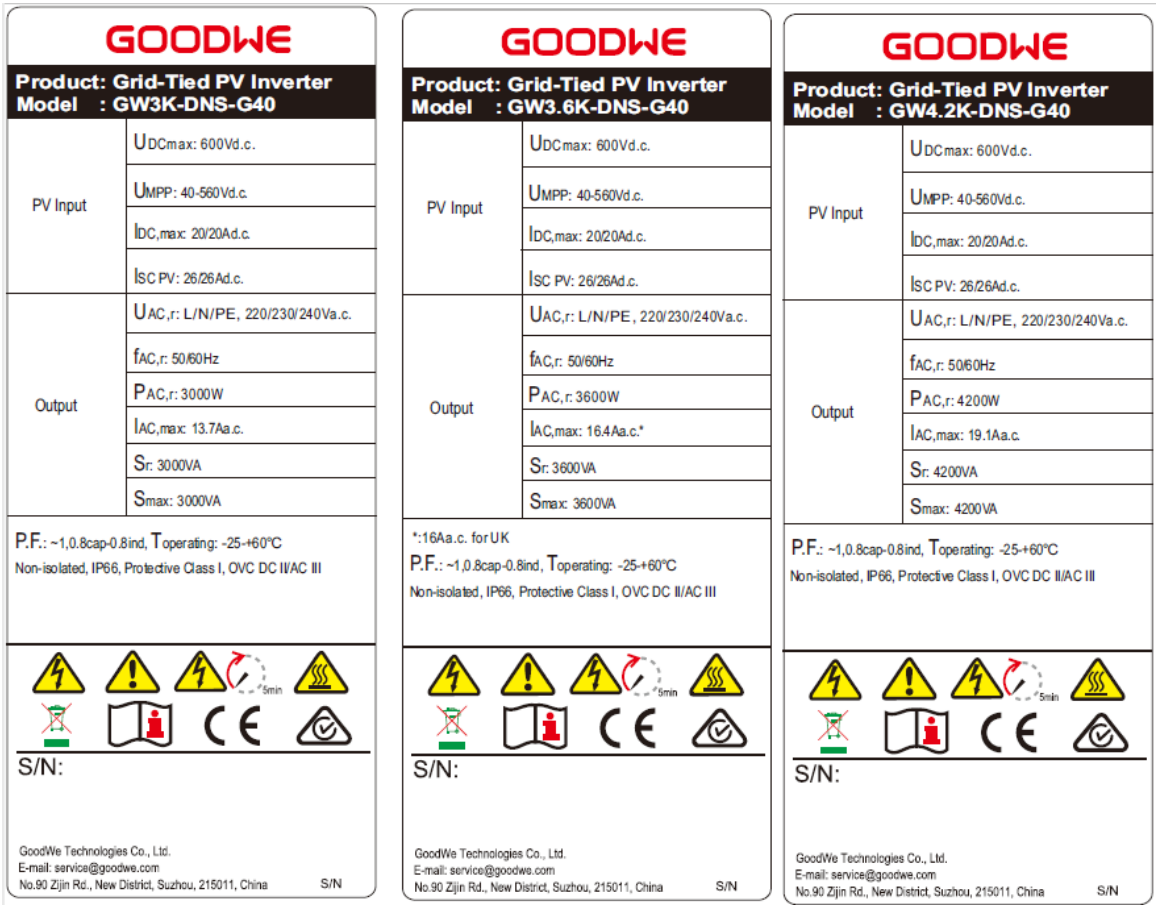
Calculations leading to the reported values are on file with the NCB and testing laboratory that conducted the testing.

☒ **Statement not required by the standard used for type testing**

(Note: When IEC or ISO standard requires a statement concerning the uncertainty of the measurement systems used for tests, this should be reported above. The informative text in parenthesis should be delete in both cases after selecting the applicable option)

Copy of marking plate:

The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCBs that own these marks.



GOODWE

Product: Grid-Tied PV Inverter
Model : GW3K-DNS-G40

PV Input	$U_{DC max}$: 600Vd.c.
	U_{MPP}: 40-560Vd.c.
	$I_{DC,max}$: 20/20Ad.c.
	I_{SC} PV: 26/26Ad.c.
Output	$U_{AC,r}$: L/N/PE, 220/230/240Va.c.
	$f_{AC,r}$: 50/60Hz
	$P_{AC,r}$: 3000W
	$I_{AC,max}$: 13.7Aa.c.
	S_r: 3000VA
	S_{max}: 3000VA

P.F.: ~1,0.8cap-0.8ind, Toperating: -25-+60℃
Non-isolated, IP66, Protective Class I, OVC DC II/AC III

S/N:

GoodWe Technologies Co., Ltd.
E-mail: service@goodwe.com
No.90 Zijin Rd., New District, Suzhou, 215011, China S/N

GOODWE

Product: Grid-Tied PV Inverter
Model : GW3.6K-DNS-G40

PV Input	$U_{DC max}$: 600Vd.c.
	U_{MPP}: 40-560Vd.c.
	$I_{DC,max}$: 20/20Ad.c.
	I_{SC} PV: 26/26Ad.c.
Output	$U_{AC,r}$: L/N/PE, 220/230/240Va.c.
	$f_{AC,r}$: 50/60Hz
	$P_{AC,r}$: 3600W
	$I_{AC,max}$: 16.4Aa.c.*
	S_r: 3600VA
	S_{max}: 3600VA

*:16Aa.c. for UK
P.F.: ~1,0.8cap-0.8ind, Toperating: -25-+60℃
Non-isolated, IP66, Protective Class I, OVC DC II/AC III

S/N:

GoodWe Technologies Co., Ltd.
E-mail: service@goodwe.com
No.90 Zijin Rd., New District, Suzhou, 215011, China S/N

GOODWE

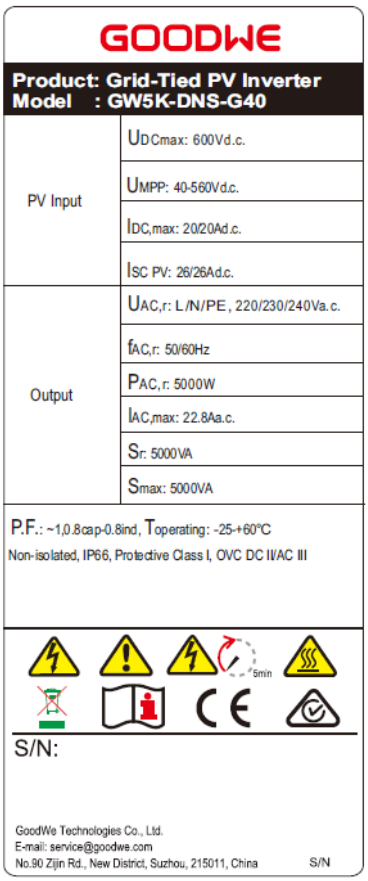
Product: Grid-Tied PV Inverter
Model : GW4.2K-DNS-G40

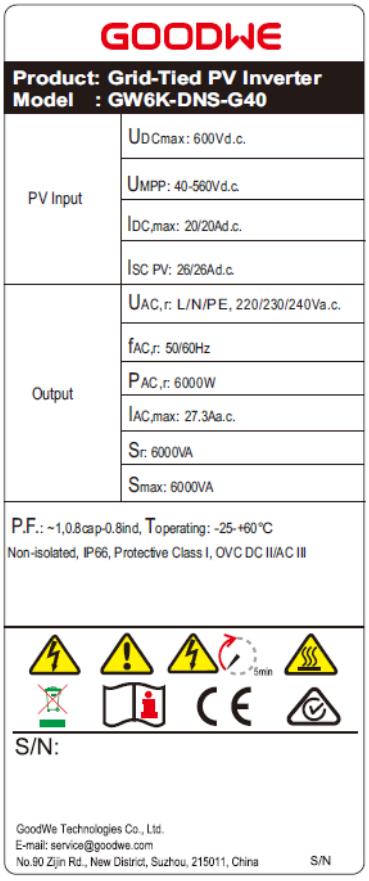
PV Input	$U_{DC max}$: 600Vd.c.
	U_{MPP}: 40-560Vd.c.
	$I_{DC,max}$: 20/20Ad.c.
	I_{SC} PV: 26/26Ad.c.
Output	$U_{AC,r}$: L/N/PE, 220/230/240Va.c.
	$f_{AC,r}$: 50/60Hz
	$P_{AC,r}$: 4200W
	$I_{AC,max}$: 19.1Aa.c.
	S_r: 4200VA
	S_{max}: 4200VA

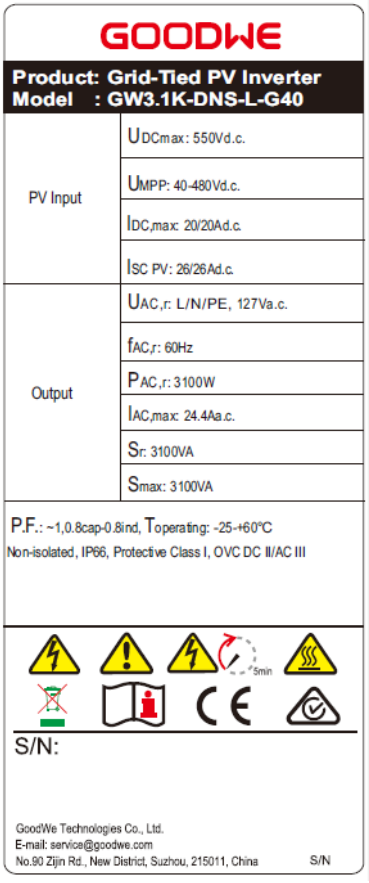
P.F.: ~1,0.8cap-0.8ind, Toperating: -25-+60℃
Non-isolated, IP66, Protective Class I, OVC DC II/AC III

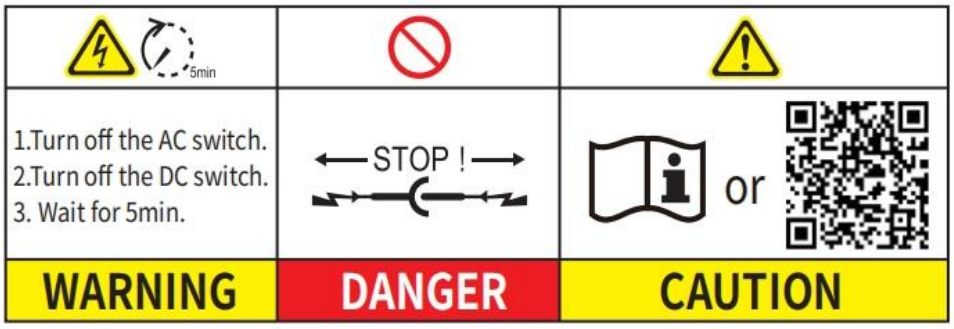
S/N:

GoodWe Technologies Co., Ltd.
E-mail: service@goodwe.com
No.90 Zijin Rd., New District, Suzhou, 215011, China S/N









AFCI label, for models GW3K-DNS-G40, GW3.6K-DNS-G40, GW4.2K-DNS-G40, GW5K-DNS-G40, GW6K-DNS-G40, GW3.1K-DNS-L-G40:

AFCI: F-I-AFPE-1-2-1

Test item particulars ..... :	
Equipment mobility ..... :	☐ movable ☐ hand-held ☒ stationary ☒ fixed ☐ transportable ☐ for building-in
Connection to the mains ..... :	☐ pluggable equipment ☐ direct plug-in ☒ permanent connection ☐ for building-in
Environmental category ..... :	☒ outdoor ☐ indoor unconditional ☐ indoor conditional
Over voltage category Mains ..... :	☐ OVC I ☐ OVC II ☒ OVC III ☐ OVC IV
Over voltage category PV ..... :	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Over voltage category BATT ..... :	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
Mains supply tolerance (%) ..... :	-90 / +110 %
Tested for power systems ..... :	TN, TT
IT testing, phase-phase voltage (V) ..... :	- - -
Class of equipment ..... :	☒ Class I ☐ Class II ☐ Class III ☐ Not classified
Mass of equipment (kg) ..... :	See model list.
Pollution degree ..... :	PD3
IP protection class ..... :	IP66
..... :	
Possible test case verdicts:	
- test case does not apply to the test object .....:	N/A
- test object does meet the requirement .....:	P (Pass)
- test object was not evaluated for the requirement .....:	N/E
- test object does not meet the requirement .....:	F (Fail)
Testing .....:	
Date of receipt of test item .....:	See cover page
Date (s) of performance of tests .....:	See cover page

General remarks:	
"(See Enclosure #)" refers to additional information appended to the report. "(See appended table)" refers to a table appended to the report. **Throughout this report a ☐ comma / ☒ point is used as the decimal separator.**	
Manufacturer's Declaration per sub-clause 4.2.5 of IECEE 02:	
The application for obtaining a CB Test Certificate includes more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ..... :	☐ **Yes** ☒ **Not applicable**
When differences exist; they shall be identified in the General product information section.	
Name and address of factory (ies) ..... :	Address 1: GoodWe Technologies Co., Ltd. No.90 Zijin Rd., New District, Suzhou, 215011, P.R. China Address 2: GoodWe (GuangDe) Power Supply Technology Co., Ltd. No.208, Tong Rui East Road, Guangde, Anhui, P.R. China Address 3: GOODWE VIETNAM TECHNOLOGY COMPANY LIMITED Factory A1, A2, Lot CN1N, Marintime Industrial and Service Park (Deep C2B), Dinh Vu - Cat Hai Economic Zone, Dong Hai 2 Ward, Hai An District, Hai Phong City, Vietnam

General product information:

Brief description:

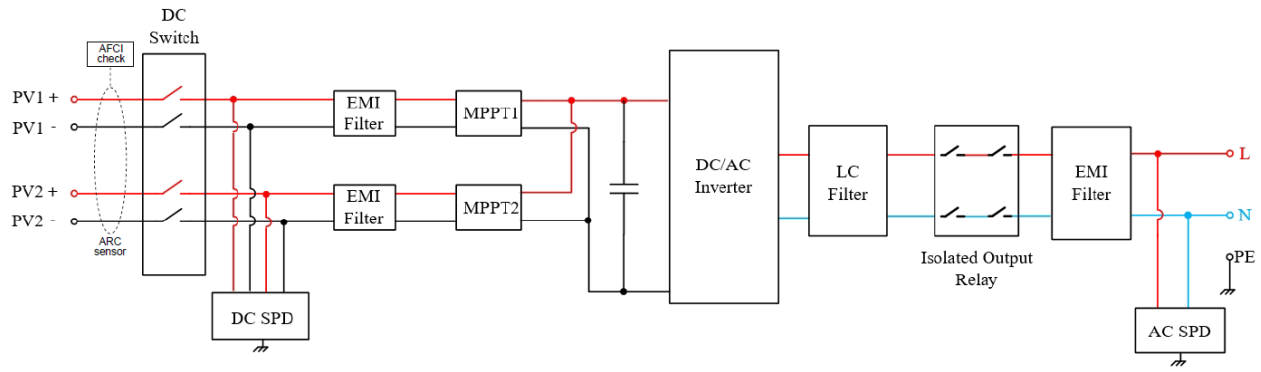
The equipment models GW3K-DNS-G40, GW3.6K-DNS-G40, GW4.2K-DNS-G40, GW5K-DNS-G40, GW6K-DNS-G40, GW3.1K-DNS-L-G40 are grid-tied inverters designed to work with PV panels up to 550Vdc. or 600Vd.c.

They are responsible for converting the direct current generated by photovoltaic panels into single-phase alternative current for feeding into the electrical power distribution grid.

It is intended for professional incorporation into PV system, and it is assessed on a component test basis.

The external circuit breakers or fuses for Grid connection are required, which is specified in the installation manual. The PCE does not provide galvanic separation between the PV input and AC output circuit (non-isolation or transformer-less type). Each phase of the AC output circuits is equipped with two relays in series that controlled by master and slave CPU, which can be switched off when the inverter shuts down for the redundant protection. When single fault occurs to one relay, the other redundant one will still maintain the basic insulation between PV input circuit and AC output circuit to the mains.

See the block diagram for details.



Block diagram

Model difference:

The models GW3K-DNS-G40, GW3.6K-DNS-G40, GW4.2K-DNS-G40, GW5K-DNS-G40, GW6K-DNS-G40, GW3.1K-DNS-L-G40 are identical with each other except for the electrical ratings, model name and differences listed in below table.

Items	GW3K-DNS-G40	GW3.6K-DNS-G40	GW4.2K-DNS-G40	GW5K-DNS-G40	GW6K-DNS-G40	GW3.1K-DNS-L-G40
	Electric data					
V_{MAX} PV [Vd.c.]	600					550
MPP Voltage Range V_{MPP} [Vd.c.]	40-560					40-480
MPPT Voltage Range for Full Power [Vd.c.]	100-500	120-500	140-500	165-500	195-500	110-420
Rated Output Power [W]	3000	3600	4200	5000	6000	3100
Rated Output Current [Aa.c.]	13.7*1	16.4*1	19.1*1	22.8*1	27.3*1	24.4
Max. Output Apparent Power [VA]	3000	3600	4200	5000	6000	3100
Max. Output Current [Aa.c.]	13.7	16.4	19.1	22.8	27.3	24.4
	Hardware Construction					
Number of inputs	2	2	2	2	2	2
Number of MPPT	2	2	2	2	2	2
Number of strings per MPPT	1	1	1	1	1	1
Number of strings detector	1	1	1	1	1	1
Number of external fans	0	0	0	0	0	0
Number of internal fans	0	0	1	1	1	1

Boost module	650V, 40A Q101, Q102	650V, 40A Q101, Q102	650V, 40A Q101, Q102	650V, 40A Q101, Q102	650V, 40A Q101, Q102	650V, 40A Q101, Q102
Inverter Module	650V, 40A Q201, Q202, Q203, Q204, Q205, Q206	650V, 40A Q201, Q202, Q203, Q204, Q205, Q206	650V, 40A Q201, Q202, Q203, Q204, Q205, Q206	650V, 40A Q201, Q202, Q203, Q204, Q205, Q206	650V, 40A Q201, Q202, Q203, Q204, Q205, Q206	650V, 40A Q201, Q202, Q203, Q204, Q205, Q206
BUS filter capacitor	550V, 390uF C202, C203, C205	550V, 390uF C202, C203, C205	550V, 470uF C202, C204, C205	550V, 470uF C202, C204, C205	550V, 470uF C202, C203, C204, C205	550V, 470uF C202, C204, C205
AC filter capacitor	350Vac, 4.7uF C312	350Vac, 4.7uF C312	350Vac, 4.7uF C312	350Vac, 4.7uF C312	350Vac, 4.7uF C312	350Vac, 4.7uF C312
AC current detector	50A	50A	65A	65A	65A	65A
AC relay	30A	30A	30A	30A	30A	30A
DC switch	3 poles	3 poles	3 poles	3 poles	3 poles	3 poles

Note: *1: For the rated output current:
Model GW3K-DNS-G40: 13.7A@220V, 13.1A@230V, 12.5A@240V;
Model GW3.6K-DNS-G40: 16.4A@220V, 15.7A@230V, 15.0A@240V;
Model GW4.2K-DNS-G40: 19.1A@220V, 18.3A@230V, 17.5A@240V;
Model GW5K-DNS-G40: 22.8A@220V, 21.8A@230V, 20.9A@240V;
Model GW6K-DNS-G40: 27.3A@220V, 26.1A@230V, 25.0A@240V;

Model List:

	MODELS LIST	GW3K-DNS-G40	GW3.6K-DNS-G40	GW4.2K-DNS-G40	GW5K-DNS-G40	GW6K-DNS-G40	GW3.1K-DNS-L-G40
PV INPUT	V_{MAX} PV [Vdc]	600					550
	I_{SC} PV [A]	26/26					
	MPP Voltage Range V_{MPP} [Vdc]	40-560					40-480
	Start PV Voltage [Vdc]	50					
	MPP Full Power Voltage Range [Vdc]	100-500	120-500	140-500	165-500	195-500	110-420
	Nominal PV Voltage V_{NOM} [Vdc]	360					230
	Max. Input Current Imax [A]	20/20					
	Backfeed Current [A]	0					
	Overvoltage Category (OVC)	II					
AC OUTPUT	Rated Output Voltage [Va.c.]	220/230/240, L/N/PE					127, L/N/PE
	Rated Output Frequency [Hz]	50/60					60
	Rated Output Power [W]	3000	3600	4200	5000	6000	3100

	Max. Output Apparent Power [VA]	3000	3600	4200	5000	6000	3100
	Rated Output Current [Aa.c.]	13.7*1	16.4*1	19.1*1	22.8*1	27.3*1	24.4
	Max. Output Current [Aa.c.]	13.7	16.4	19.1	22.8	27.3	24.4
	Power Factor [λ]	1 (Default), [-0.80, +0.80]					
	Overvoltage Category (OVC)	III					
System	Type of inverter	Non-isolated					
	Protective Class	I					
	Enclosure Protection	IP66					
	Operating Temperature Range [ºC]	-25 to 60 (derating at +45°C)					
	Operating Altitude [m]	Max. 4000					
	Pollution degree (PD)	PD 2 (inside), PD 3 (outside)					
	Max. Weight [kg]	Max. 9.2					
	Size (W*H*D) [mm]	358*323*165					
	Firmware	V1.00.00					
	Software [version]	V1.00.00					

Note: *1: For the rated output current:
Model GW3K-DNS-G40: 13.7A@220V, 13.1A@230V, 12.5A@240V;
Model GW3.6K-DNS-G40: 16.4A@220V, 15.7A@230V, 15.0A@240V;
Model GW4.2K-DNS-G40: 19.1A@220V, 18.3A@230V, 17.5A@240V;
Model GW5K-DNS-G40: 22.8A@220V, 21.8A@230V, 20.9A@240V;
Model GW6K-DNS-G40: 27.3A@220V, 26.1A@230V, 25.0A@240V;

AFCI Function Description:

The inverters support AFPE (Arc Fault Protection Equipment) for arc detection and interruption, which is combination of AFD and AFI to detect and interrupt arc faults.

The AFPEs are implemented within the inverters connected to the PV array and make use of the housing and terminals of the inverters.

The AFPEs can provide full coverage protection. In this classification, arc fault protection is provided from the PV modules up to the inverter input terminals.

Due to AFPE circuits employ a programmable circuit component to achieve the arc flash detection and interruption, functional safety evaluation was performed according to IEC 60730-1, Annex H.

The AFPE classification is marked on the product according to the requirements in IEC 63027 and specified in manual, with reconnection methods, see the manual instruction for details.

AFCI Configuration:

Model	GW3K-DNS-G40	GW3.6K-DNS-G40	GW4.2K-DNS-G40	GW5K-DNS-G40	GW6K-DNS-G40	GW3.1K-DNS-L-G40
Classification	F-I-AFPE-1-2-1					
Number of monitored strings per input port	1					
Number of input ports per channel	2					

Number of monitored channels	1
Rated channel current [Ad.c.]	40
Maximum current per input port [Ad.c.]	20
Rated interruption current [Ad.c.]	20

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Clause	Requirement – Test	Result – Remark	Verdict

4	**Classification**		P
4.1	General	See below.	P
	The clause gives an overview of the classifications used for AFD and AFPEs in this standard. The classification scheme describes the equipment type and considers the important aspects relevant for testing and installation. Installation standards can refer to this classification to specify requirements for arc fault protection.		P
	Protection coverage: Defines which parts of a PV system or installation are covered by the AFD or AFPE.	Full protection	P
	Method of implementation: Defines the type and design of the AFD or AFPE. The method of implementation especially impacts construction requirements and testing.	PCE integrated device	P
	Functionality: Indicates whether an equipment or device is an AFD or AFPE.	AFPE	P
	Number of monitored strings, inputs and channels: The maximum number of connected PV strings, inputs and measurement channels that can be supported by the AFD or AFPE, and for which it is tested.	See following clause	P
	Reconnection method: Defines which reconnection methods are supported by the product.	See following clause	P
	Annex B provides additional information and introduces measures to group the following classifications into various use cases.		P
	AFPE may have more than one classification, and different ratings may apply for each classification. In this case the manufacturer shall document the installation and connection requirements for each classification. NOTE One example is an inverter that allows for the direct connection of PV strings or the connection of one dc main cable. For direct string connections the classification could be F-I-AFPE-S1-C1-I4 and for the main cable connection the classification could be P-I-AFPE-S6-C1-I1.	No more than one classification.	N/A
	AFPE may provide input ports with different ratings (e.g. number of strings per input port, current rating). In this case the tests shall be performed in the worst-case configuration.	Tests performed on model GW6K-DNS-G40 with most channels and max. power.	P
4.2	**Protection coverage**		P
	The protection coverage defines which circuits and components of the PV system are covered by the AFD or AFPE. Two types of classifications are defined.	Full coverage (F)	P

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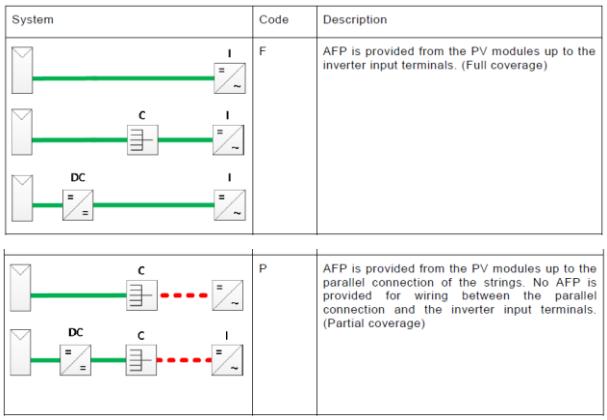
Clause	Requirement – Test	Result – Remark	Verdict
	 NOTE: Typically, full coverage (F) is hard to achieve for high currents in dc main cables. Also, the 750 J protection threshold may be difficult to achieve because of the high currents and the physical limits in interruption times. Fire hazard protection may be provided by means of installation.		P
4.3	**Method of implementation**	See below.	P
4.3.1	**PCE integrated device (I)**		P
	The AFPE is implemented within a PCE connected to the PV array and makes use of the housing and terminals of the PCE.	The AFPE is implemented within the inverter.	P
4.3.2	**Standalone device (S)**		N/A
	The AFPE is a single device, that works independently and makes use of its own enclosure or other dedicated enclosures.	Not stand-alone AFPEs.	N/A
4.3.3	**Distributed detection system (D)**		N/A
	The AFPE comprises more than one device. The devices may be standalone devices or partially integrated within a PCE.	Not distributed detection system	N/A
4.4	**Functionality**	See below.	P
4.4.1	**AFPE: Detection and interruption capability provided**		P
	The device incorporates AFD and AFI for full AFPE functionality.	Detection and interruption capability provided.	P
4.4.2	**AFD: Only detection / no interruption capability provided**		N/A
	The device only detects the arc. An AFD without a dedicated AFI does not fulfill the requirements of an AFPE according to this standard. Such devices may be used to indicate arc events, e.g. in connection with a fire alarm system.	Not only AFD.	N/A
4.5	**Number of monitored strings (S)**	See below.	P
4.5.1	**Single string**		P
	The AFD or AFPE are designed in a way that only	Only one string be connected	P

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Clause	Requirement – Test	Result – Remark	Verdict
	one string of the array or one module shall be connected to one input port for detection and, in the case of AFPE, interruption.	to one input port.	
4.5.2	**Parallel string**		N/A
	The AFD or AFPE are designed in a way that multiple strings or modules may be connected for detection and, in the case of AFPE, interruption. The maximum number of strings for one input port shall be defined by the manufacturer. Parallel strings may be connected directly to the device or at a junction external to the device. NOTE 1 Refer to Annex A for various string configurations.	Only one string be connected to one input port.	N/A
4.6	**Number of Input ports (I)**		P
	An AFD or AFPE may be provided with one or more input ports per monitored channel. In case of more than one input port the maximum arc current typically is not equal to the rated sensing current of the channel. The number of input ports per channel shall be defined by the manufacturer, together with the maximum current per input port. The maximum current (I**pA**) per input port is equal to the maximum arc current in the system. Parallel connection of strings outside the equipment enclosure or cabinet are not considered input ports. NOTE Refer to Annex A for various input configurations.	See AFCI configuration table.	P
4.7	**Number of monitored channels (C)**	See below.	P
4.7.1	**Single channel**		P
	The AFD or AFPE is designed in a way that only one sensing channel is provided to detect arcs.	See AFCI configuration table.	P
4.7.2	**Multi-channel**		N/A
	The AFD or AFPE has two or more independent sensing channels to detect arcs. The number of channels shall be defined by the manufacturer. NOTE Refer to Annex A for various channel configurations.	See AFCI configuration table.	N/A
4.8	**Reconnection method**	See below.	P
	Installation standards can choose from the following reconnection methods in order to define adequate response requirements after arc interruption by the AFPE.		P
4.8.1	**Manual reconnection**		P
	After arc interruption the reconnection can only be performed manually.	Reconnection can be performed in the APP.	P
4.8.2	**Remote manual reconnection**		N/A
	After arc interruption the reconnection can be performed via remote access to the AFPE.	Not available.	N/A

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Clause	Requirement – Test	Result – Remark	Verdict
4.8.3	**Automatic reconnection**		P
	After arc interruption the AFPE provides means to automatically reconnect following measures described in 8.2.3.3.	Automatic reconnection provided according to the requirements in the standard.	P
5	**Ratings of AFPEs and AFDs**		P
5.1	General		P
	This clause identifies the ratings to be defined for AFPEs and AFDs by their classification. These ratings impact the selection of tests to be performed according to this standard. For integrated AFPEs correlations between the AFPE ratings and product ratings are described.		P
5.2	**PCE integrated AFPEs and AFDs**	See below.	P
5.2.1	**Rated and limiting values**		P
5.2.1.1	**Rated channel current**		P
	The maximum rated detection current of a channel.	See AFCI configuration table.	P
5.2.1.2	**Maximum current per input port**		P
	The maximum rated current an input port can carry. For PCE the maximum current per input port corresponds to the maximum MPP current of the related input port. This current may be limited by a power conversion stage or a terminal rating.	20A	P
5.2.1.3	**Rated interruption current**		P
	The maximum rated dc currents the PCE is able to interrupt. NOTE For PCE integrated AFPE the maximum rated interruption current typically corresponds to the IpA of the PCE. Although for inverters interruption may be provided by the ac bridge or on the ac side, the current is defined by IpA.	20A	P
5.2.1.4	**Other ratings**		P
	Other ratings of the AFPE or AFD correspond to the input characteristics of the PCE according to IEC 62109-1.	Specified according to IEC 62109-1.	P
5.3	**Stand-alone AFPEs and AFDs**	Not stand-alone AFPEs.	N/A
5.3.1	**Rated and limiting values**		N/A
5..3.1.1	General		N/A
	Rated values are assigned by the manufacturer. They shall be stated in accordance with IEC 60947-1, however it may not be necessary to establish all of the rated values listed.		N/A
5.3.1.2	**Rated voltages**		N/A
5.3.1.2.1	**Rated operational voltage (*Ue*)**		N/A
	Subclause 4.3.1.1 of IEC 60947-1 applies.		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
5.3.1.2.2	**Rated insulation voltage (*U*i)**		N/A
	Subclause 4.3.1.2 of IEC 60947-1 applies.		N/A
5.3.1.2.3	**Rated impulse withstand voltage (*U*imp)**		N/A
	Subclause 4.3.1.3 of IEC 60947-1 applies.		N/A
5.3.1.3	**Currents**		N/A
	AFPE is defined by the following currents.		N/A
5.3.1.3.1	**Rated channel current**		N/A
	The maximum rated detection current of a channel.		N/A
5.3.1.3.2	**Maximum current per input port**		N/A
	The maximum rated current an input port can carry. This current may be limited by a terminal rating.		N/A
5.3.1.3.3	**Rated interruption current**		N/A
	The maximum rated dc currents the AFI is able to interrupt, usually corresponding to the breaking current as described in IEC 60947-1 subclause 2.5.11.		N/A
5.3.1.4	**Rated duty**		N/A
	Subclause 4.3.4 of IEC 60947-3 applies		N/A
	NOTE In most cases AFPEs either fall under clause 4.3.4.1, eight-hour duty or under 4.3.4.2, uninterrupted duty		N/A
5.3.2	**Utilization category**		N/A
	Standalone AFPEs shall be rated either DC-PV1 or DC-PV2 according to IEC 60947-3. NOTE Selection depends on the location in the system.		N/A
6	**Product information**		P
6.1	**General**		P
	AFPEs and AFDs may be designed in many different ways. Table 2 defines a classification of various products. It shall be used to distinguish the different designs by indicating the different parameters, separated by '-'. **Table 2 – Combined classification of AFPEs and AFDs** Protection coverage (according to 4.2): – Full coverage (F) – Partial coverage (P) Method of implementation (according to 4.3): – Integrated (I) – Stand-alone (S) – Distributed (D) Functionality (according to 4.4): – AFPE – AFD Monitored strings (according to 4.5): Number of strings Input ports (according to 4.6): Number of input ports Monitored channels (according to 4.7): Number of monitored channels NOTE Following Table 2, an integrated AFPE providing full coverage for 4 monitored strings with 1 input port and one monitored channel will be characterized by F-I-AFPE-4-1-1. The documentation of the product shall include information how to install the equipment correctly to comply with the provided classification.	See AFCI configuration table.	P

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Clause	Requirement – Test	Result – Remark	Verdict
6.2	**PCE integrated devices**		P
	IEC 62109-1 applies with the following additions. In addition to the product information relevant according to IEC 62109-1 clause 5, the following information shall be provided. – Protection coverage (F for “full” or P for “partial”) – Method of implementation (D for ‘distributed’ or I for fully integrated systems) – Maximum number of strings per input or input port (derived from number of channels and maximum number of monitored strings per channel) – Reconnection method – Functionality (AFD, AFPE) In addition to the marking and documentation requirements described in IEC 62109-1:2010, 5.1, Table 3 requirements apply. **Table 3 – Marking and documentation requirements** Marking or information item / Visible on product when installed / In a manual a Classification according to Table 2 x x b Reconnection method x	Marked on the product and specified in the manual.	P
6.3	**Standalone devices**	Not stand-alone AFPEs.	N/A
6.3.1	**Nature of information**		N/A
	Subclause 5.1 of IEC 60947-1 applies as appropriate for a particular design with the following additions. – Protection coverage (F for “full” or P for “partial”) – Method of implementation (D for ‘distributed’ or S for stand alone device) – Maximum number of strings per input or input port (derived from number of channels and maximum number of monitored strings per channel) – Reconnection method		N/A
	– Functionality (AFD, AFPE) – Rated interruption current (where applicable) – Reconnection method • Type of reconnection. If more than one type can be selected, indication for the preset (or default) method shall be given • Procedure for manual reconnection (if applicable) • Procedure for remote manual reconnection (if applicable) • Time settings for automatic reconnection (if not configurable) – Information regarding compatibility with specific PCE models and other components according to subclauses 8.3 and 9.2.10.		N/A
6.3.2	**Marking**		N/A
	Subclause 5.2 of IEC 60947-1 applies as appropriate for characteristics defined in Table 4		N/A

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	Table 4 – Requirements for documentation, marking and position of marking Marking or information item / Position of the marking or information: Visible on product when installed / On the product / In a leaflet a Classification according to Table 2: x / x / x b Rated current: x / x / x c Maximum number of strings per input or input port: / x / x d Orientation: / x / x e Reconnection method: / / x f Information regarding compatibility: / / x		
6.3.3	**Instructions for installation, operation and maintenance**		N/A
	Subclause 5.3 of IEC 60947-1 applies.		N/A
7	**Normal service, mounting and transport conditions**		P
7.1	**PCE integrated AFPEs**		P
	For PCE integrated AFPEs the normal service, mounting and transport conditions of IEC 62109-1 apply. In case a manual test function is incorporated, the frequency of manual operation shall be stated.	Specified in manual.	P
7.2	**Stand-alone AFPEs**		N/A
	Clause 6 of IEC 60947-1 applies with the following addition. Unless otherwise stated by the manufacturer, the equipment is intended for installation under environmental conditions of pollution degree 3. [SOURCE: IEC 60947-3] In case a manual test function is incorporated, the frequency of manual operation shall be stated.	Not stand-alone AFPEs.	N/A
8	**Construction and performance requirements**		P
8.1	**General requirements for PCE integrated AFDs/AFPEs and Stand-alone AFDs/AFPEs**		P
	This general part defines requirements which are identical for PCE integrated AFDs/AFPEs and Stand-alone AFDs/AFPEs. Additional requirements are included in 8.2 and 8.3.		P
8.1.1	**General**		P
	This clause defines requirements which are identical for PCE integrated AFDs/AFPEs and stand-alone AFDs/AFPEs. Additional specific requirements are included in 8.2 and 8.3.		P
8.1.2	**Construction requirements**		P
8.1.2.1	**Annunciator of arc fault events**		P
	AFDs and AFPEs shall be provided with an annunciator (local or remote) that provides a visual indication that the device has operated when an arc fault is detected. Where the reconnection is required to be performed manually, this indication shall not reset automatically. This applies to manual reconnection, remote manual reconnection and also in case automatic	Fault indication light provided on the product and visual fault indication provided in APP.	P

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	reconnection after the fifth interruption within a 24 h period.		
8.1.2.2	**Programmable circuit components**		P
	Any circuit that employs a programmable circuit component shall comply with IEC 61508, IEC 60730-1:2013, Annex H or IEC 62109-1:2010, Annex B.	Functional safety assessment according to IEC 60730-1 was performed for arc fault protection function. See functional safety assessment for details.	P
8.1.3	**Operation in case of series arc fault event**		P
	The AFD shall detect the arc within 2,5 s or before the arc energy exceeds 750 J, whichever occurs first.	Not AFD.	N/A
	The AFPE shall detect the arc and interrupt it within 2,5 s or before the arc energy exceeds 750 J, whichever occurs first.	See test result on the following pages in the report.	P
	If the AFPE can extinguish the arc before exceeding 200 J and within 2,5 s, then annunciation of an arc detection is not required. Those events are not considered disconnection and therefore reconnection requirements according to 8.1.4 do not apply. The arc energy is measured during testing for the arc itself. The DUT is not required to measure the arc energy, neither during testing nor in field operation. Annunciation of arcs below 200 J are not required for technical reasons but can provide useful information for the operator to raise his attention and should be provided where possible.	Annunciation of an arc detection is provided.	P
8.1.4	**Reconnection capability of AFPE**		P
8.1.4.1	**General**		P
	After detecting an arc the circuits shall remain interrupted even in case of loss of power supply. For restart the following restart methods apply.		P
8.1.4.2	**Manual reconnection**		P
	To restart the AFPE and close circuits a manual procedure is required (button or external signal, triggered by manual operation on-site). This manual procedure requirement shall be maintained after loss of supply power to the AFPE. NOTE The intended use for manual restart is where the operator prefers a system inspection before reconnection.	Reconnection could be operated manually in the APP on-site.	P
8.1.4.3	**Remote manual reconnection**		N/A
	To restart the AFPE and close circuits a manual procedure is required (button or external signal, triggered by manual operation on-site or remote activation). This manual procedure requirement shall be maintained after loss of supply power to the AFPE. NOTE The intended use is where a PV system is under supervision via remote control and the opera-	Not available.	N/A

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Clause	Requirement – Test	Result – Remark	Verdict
	tor prefers to check the system remotely before reconnection.		
8.1.4.4	**Automatic reconnection**		P
	Adjustable automatic reconnection times are allowed for compliance with local installation standards or owner/operator preferences, provided that a minimum reconnection delay is ensured. In case the reconnection times are adjustable, this shall be done via adjustable setup parameters or manual switches (e.g. rotary switches). NOTE The intended use for adjustable settings is to allow more sensitive arc fault detection where deemed appropriate, and to enable system checks to differentiate between nuisance tripping and real arcs.	Automatic reconnection is provided.	P
	To restart the AFPE no manual procedure is required if a minimum interruption time of 5 min is ensured before continuing operation of the array.	Minimum interruption time is 5mins	P
	When interrupting the fifth time within a 24 h period, the AFPE is only allowed to be reset manually according to 8.1.4.2 or 8.1.4.3 before the AFPE does reconnect. Afterwards the AFPE may return to automatic reconnection mode.		P
8.1.5	**Self-test function**		P
	AFDs and AFPEs shall be provided with a manual or an automatically initiated test function or both that allows for regular checks of the arc detection circuit.		P
	The test function shall: – simulate an arc such that the arc detection circuit or software is caused to detect the simulated arc, or	By simulating an arc signal.	P
	– perform another safety check routine such that a fault in the arc detection circuit or software is detected.		N/A
	The manual test function shall allow for periodic testing of the device by manual means that does not require the use of a tool or key. For an AFD a successful test shall be indicated after manual initiation.		P
	An AFD or AFPE may be provided with a means to actuate the test remotely. If such a feature is provided, a remote visual indication of the results of the test and the means for remote manual reset shall be provided.		P
	The automatic test function shall be performed before starting operation and at least once in a 24 h period.		P
	During automatic testing the AFPE is not required to interrupt.		P
	In case of manual test, the AFPE shall interrupt.		P
	In case a malfunction of the AFD or AFPE is detected during the test, the AFD shall indicate the result and the AFPE shall interrupt and indicate the result according to 8.1.2.1.		P

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Clause	Requirement – Test	Result – Remark	Verdict
8.2	**PCE integrated AFDs and AFPEs**		P
	For PCE integrated AFDs and AFPEs, the normal service, mounting and transport conditions of IEC 62109-1 with the additional requirements defined under 8.1 apply.		P
8.3	**Stand-alone AFDs and AFPEs**	Not stand-alone AFPEs.	N/A
	Stand-alone AFDs and AFPEs shall comply with 7.1 of IEC 60947-1 in addition to the requirements described below and in 8.1 Stand-alone AFPEs shall also comply with 7.1 of IEC 60947-3. AFDs and AFPEs shall be compatible with the PCE and their power line communication devices. AFD and AFPE functionality shall not be compromised by the PCE or power line communication.		N/A
9	**Tests**		P
9.1	**General**		P
	The tests defined in this section are broadly applicable to all AFD and AFPE devices. Additional specific requirements apply as follows: - Stand-alone AFDs and AFPEs: Clause 8 of IEC 60947-1.	Not stand-alone AFPE.	N/A
	- Stand-alone AFPEs: IEC 60947-3.	Not stand-alone AFPE.	N/A
	- PCE integrated devices: Clause 4 of IEC 62109-1.	See attached table 9.1 for thermal test. For single fault tests and other tests, see functional safety report and IEC 62109 report for details.	P
9.2	**Series arc fault test**		P
9.2.1	**General**	See below.	P
	The general test set up consist of 6 major elements: • Arc generator • DC source • Decoupling network • Impedance network • Device under test (DUT) • Load.		P
	The AFD and AFPE may be used within different array topologies. To ensure that detection is achieved in all application cases defined by the manufacturer, different test scenarios shall be applied. The major distinctions are related to: – single string case; – parallel string case; – single channel case; – multi-channel case; – single module case.		P
	Accordingly, the AFD and AFPE shall be tested for		P

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	all applicable scenarios following the procedures described below. Annex A provides illustrative examples for setting up the different test cases. NOTE 1 This document can be applied to systems including overcurrent protection devices and blocking diodes.		
	The detection capability of stand-alone devices shall not be compromised by expected internal or external interference. Therefore, the compliance of stand-alone and distributed AFPEs and AFDs to this document shall only apply to the combination of the specific PCE models with which the devices have been tested. NOTE 2 Switch mode PCEs generate electromagnetic noise during operation. Experience has shown that the detection of arcs can be affected by this interference. NOTE 3 Nuisance tripping is not a safety issue but rather a quality concern for AFD and AFPE. Simulating cloud movement of e.g. 300 W/m²/s based on Clause B.3 of IEC 62891:2020 and startup/shutdown tests according to Clause B.4 of IEC 62891:2020 may help to reveal device susceptibilities to nuisance tripping in actual installations.	Not stand-alone or distributed AFPE.	N/A
9.2.2	**Arc generator**	Complied.	P
	The arc generator shall consist of tungsten alloy ball-ring electrodes and a movable slide as illustrated in Figure 1 and Figure 2. The test is initiated with the electrodes in contact with each other (shorted) and then separated at a controlled rate to the specified gaps defined in Table 5. The positive pole of the test circuit shall be connected to the ring of the assembly shown in Figure 1.		P
	Special care shall be taken to a correct positioning of the electrodes to each other in order to achieve a contact area over the full circumference.		P
	Figure 2 defines the relevant dimensions for the electrodes. Parts of the drawing where no dimensions or requirements are defined are considered not to influence the outcome of the test. For these locations individual design and dimensions are allowed for supporting mounting means like brackets or screws.		P

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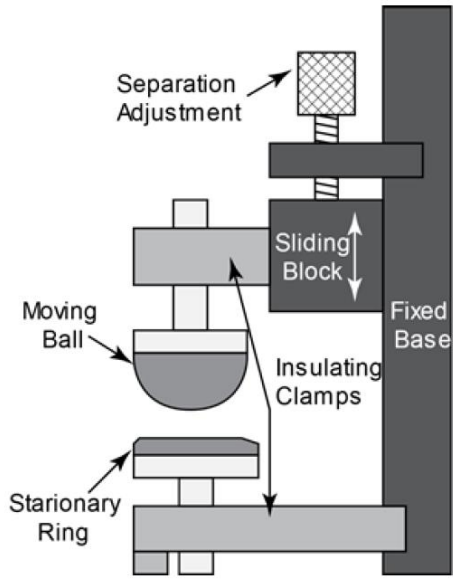

Figure 1- Schematic of the arc generator (as derived from UL 1699 B)

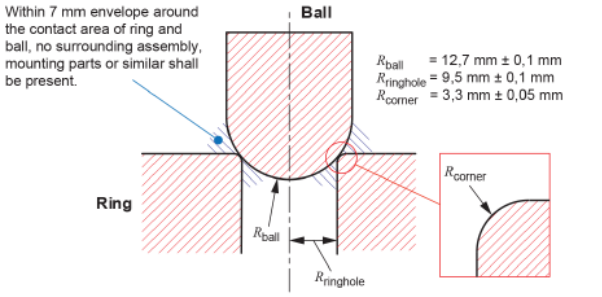

Figure 2 – Dimensions of arc generator electrodes

9.2.3	**DC source**		P
9.2.3.1	**General**		P
	The source required for testing shall consist of a DC power source, either: – a constant voltage source with additional resistance to simulate PV specific IV-characteristics, or		N/A
	– a PV simulator. Since a PV simulator may produce unwanted tripping or may inhibit the AFPE from detecting arcing, reference tests should be made using a suitable array of PV modules when deemed necessary.		P
9..2.3.2	**Constant voltage source**		N/A
	Where tests are specified to be conducted at maximum power, the DC source shall be adjusted for its Maximum Power Point (MPP) as follows: a) The constant voltage of the supply shall correspond to the VOC as defined in Table 5. b) The current limitation of the source shall be set to 1,1 times the Impp value given in Table 5. c) Rtot shown in Table 5 shall be used to calculate		N/A

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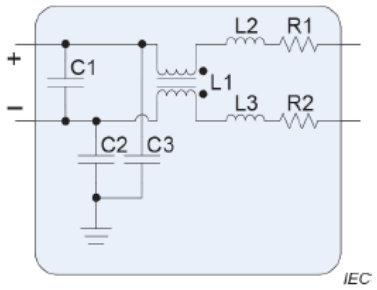
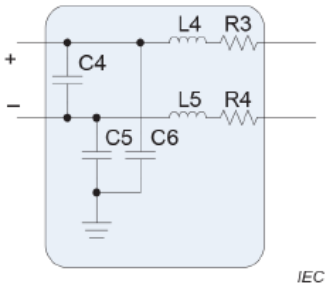
Clause	Requirement – Test	Result – Remark	Verdict
	R1 and R2 (see 9.2.3.4) following the formula R1 = R2 = Rtot / 2 × k – R3. Where k represents the number of decoupling or PV-networks used within one string. E.g. two half strings k = 2, full string k = 1.		
9.2.3.3	**PV simulator**		P
	Where tests are specified to be conducted at maximum power, the PV simulator shall be adjusted for its Maximum Power Point (MPP) as described in Table 5, with the short circuit current value set to 1,1 times the Impp value. For all tests using a PV simulator, the resistance values R1 = R2 = 0.		P
9.2.3.4	**Decoupling network**		P
	The network decouples the source and the DUT to avoid potential influence on the test. It shall be designed according to the topology shown in Figure 3. The parameters for the respective components shall be calculated according to Annex B.  **Figure 3 – DC source decoupling network**		P
9.2.4	**Array line impedance network**		P
	The DUT shall be connected to the DC source and the arc generator using a network which accounts for the various line impedances found in different array configurations. The general layout of the network is shown in Figure 4. The parameters of the components of the line impedance network for the specific application cases are further specified in Annex B.  **Figure 4 – Array line impedance network** NOTE The array line impedance network is parame-		P

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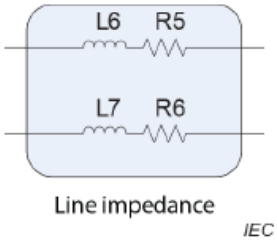
Clause	Requirement – Test	Result – Remark	Verdict
	terized to reflect typical PV field installations. Nevertheless, the array impedances depend on numerous factors such as module technology, length and routing of the DC cabling, etc. A robust AFD may be achieved by in-field arc fault tests in many different PV installations or by recording DC and high frequency noise signals during field tests and replaying them later on a DUT.		
9.2.5	**Line Impedance**		N/A
	Cabling between a PV string combiner or dc/dc converter and an inverter is not covered by the array line impedance network and shall be simulated by an additional line impedance (Figure 5).  **Figure 5 – Line impedance network** The parameters of the components of the line impedance are specified in Annex B	Not used.	N/A
9.2.6	**Test procedure**	Considered.	P
	Table 5 lists all arcing test conditions. The applicable test conditions shall be selected based on the DUT ratings and the test configurations. The maximum rated current per input port I_{pA} is used to select suitable tests. The I_{pA} is defined either by the maximum input current of the DUT or the maximum input current per channel or the current at maximum power point of the PCE or a single input stage of the PCE.		P
	In the situation where the classification is partial coverage, the maximum arc current cannot directly be referred to the I_{pA}. In this case the arcing current needs to be selected according to the sub string currents. As an example, use 15 A as illustrated in Figure 6b).		N/A
	Table 5 – Arcing test conditions Test # | Minimum I_{arc} A* | I_{mpp} A | Sep. rate mm/s | V_{mpp} V | V_{OC} V | R_{tot} Ω | Gap mm 1 | 2,5 | 3,0 | 2,5 | 312,0 | 480,0 | 56,0 | 0,8 2 | 7,0 | 8,0 | 5,0 | 318,0 | 490,0 | 21,0 | 0,8 3 | 14,0 | 16,0 | 5,0 | 318,0 | 490,0 | 11,0 | 1,1 4 | 7,0 | 8,5 | 5,0 | 607,0 | 810,0 | 24,0 | 2,5 5 | 0,9 × I_{pA} | I_{pA} | 5,0 | 318,0 | 490,0 | $(V_{OC} - V_{mpp}) / I_{pA}$ | 2,5 * Values given shall provide an indication of currents that likely occur. The actual value depends on several factors. Tests 1 to 5 shall be performed as follows: For testing purposes, the applicable number of full string models defined in B.1.2 shall be connected in parallel. Alternatively, a full string model and a parallel string model may be used, where n in the parallel		P

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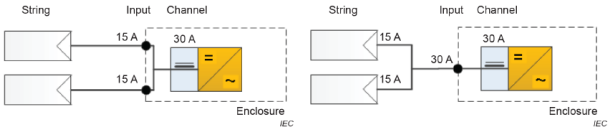
Clause	Requirement – Test	Result – Remark	Verdict
	string model is defined by the input port current divided by 10 A. The value of n shall be rounded up to the nearest integral value. If the DUT is not able to operate at 318 V, the closest possible voltage shall be used. See also Note 4 in B.1.2.		
	Test 1: This test shall be applied to all DUTs. In case there is an uncertainty whether a low current arc was extinguished by the AFPE or by an inadequate test setup, the test setup including the DC source settings shall be reviewed and the result of the review shall be documented. NOTE 1 This test is intended to address low currents at which arcs become possible to form.		P
	Test 2: This test shall be applied where the maximum rated current per input port of the DUT is 8 A or higher.		P
	Test 3: This test shall be applied where the maximum rated current per input port of the DUT is 16 A or higher.	Max. current per input port is 20A.	P
	Test 4: This test shall be applied where the maximum input voltage of the DUT is 810 V or higher.		N/A
	Test 5: This test shall be applied where the maximum rated sensing current of a single channel of the DUT is 24 A or higher and where the maximum arcing current is not limited by the input ratings of the DUT to less than 24 A (see Figure 6). Test 5 is intended especially for detecting arcs on the main cable of systems where the parallel connection of PV strings is external to the device or equipment enclosure.  a) maximum arc current limited by max. input current b) maximum arc current not limited **Figure 6 – Limitation input current**	No parallel strings.	N/A
	For tests 1 through 3 and 5 the following applies: If the maximum rated voltage of the DUT is less than the value for V_{OC} in Table 5, V_{OC} shall be replaced by the maximum rated voltage of the DUT, and V_{mpp} shall be replaced by 0.65 times the maximum rated voltage.		P
	For tests 1 through 5 the following applies: If the minimum V_{mpp} of the DUT is higher than the value for V_{mpp} in Table 5, V_{mpp} shall be replaced by the minimum V_{mpp} of the DUT. V_{OC} is then calculated by V_{mpp} divided by 0.65.		P
	For configurations with parallel modules or strings the current for the parallel strings in the parallel test setup shall be calculated as follows:		P

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Clause	Requirement – Test	Result – Remark	Verdict
	Test 1: I_{T1} = (n-1) × 3 A		
	In case the calculated current of the parallel non-arcing strings I_{T1} plus 3 A is higher than the maximum arcing current of the DUT, the parallel non-arcing current shall be reduced such that the total current matches the input of the DUT. NOTE 2 As an example, for n = 6 the calculation will result in 15 A as parallel current. The total current, including the arc current of 3 A, will be 18 A. The input current of the DUT is limited by ratings to a maximum of 15 A, which is equal to the maximum arcing current. In this case the parallel current for test 1 will be reduced to 12 A.		P
	Test 2: $I_{T2} = I_{ch}$ – 8 A for input setup I_{T2} = (m-1) × I_{input} for output setup For DUTs with multiple inputs per Channel the calculated parallel current for Test 1 and 2 shall be divided between the inputs according to the product classification (see Clause 4) and with respect to the maximum input current limits per input port. Refer to Annex C for examples for applying the parallel current and its distribution over several inputs. where n is the number of strings per channel. m is the number of input ports per channel. I_{ch} is the maximum current per channel. I_{input} is the maximum current per input port. I_{T1} or I_{T2} is the current of the parallel non-arcing strings. NOTE 3 For detailed definition of input, output and parallel setup refer to Annex B and Annex D.		P
	For test 3 and test 5 the currents from the DC sources can be differentiated according to the number of represented strings per DC source.		P
	Test 4 is not required to be tested with parallel test configurations.		N/A
	For string output test configurations (Figure B.16 to Figure B.18) the following applies: • Where constant voltages are present in the output circuit the tests shall be performed using the arc current values defined in Table 5. • The maximum output current of the DC/DC converter is considered the maximum input current of the DUT for selection of applicable test according to Table 5.	Not DC/DC converter	N/A
	For module level input test setups (Figure B.11 to Figure B.15) the maximum input current of the DC/DC converter is considered the maximum input current of the DUT for the purpose of selecting the applicable tests from Table 5.	Not module level.	N/A

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Clause	Requirement – Test	Result – Remark	Verdict
	The arc generator shall be positioned as shown in the applicable figures in Annex B.		P
	In general, the arc generator shall be positioned close to the PV terminal (positive or negative) of the DUT that creates the most severe condition. If more than one PV module can be connected in series to the DUT input, an additional test shall be performed with the arc generator in the middle of the series connected modules.	Be positioned close to the positive PV terminal and in the middle of the series connected modules.	P
	As two different values of parameter C4 are defined in Table B.2 each test (arc-gap and current combination) results in two test runs. Testing may be reduced to the worst-case scenario. To determine the worst-case scenario five measurements at each of the two values for C4 shall be conducted with selected test setups. The capacitor value resulting in the highest average detection time shall represent the worst case.	Two different values of parameter C4 verified.	P
	Each test run shall be performed two times.		P
	For multi-channel devices each channel shall be tested according to the single channel setups. Where the same hardware and software modules are used for each channel, the number of tests may be reduced as follows: Test one channel according to the full set of applicable tests required for one channel. Test the remaining channels only with the most adverse arc location determined in the original tests, evaluated according to highest average arc energy or longest detection time.		P
9.2.7	**Arc energy and response time measurement**		P
	The voltage across the arc gap, the arc duration, and the current through the arc shall be measured and recorded. These measurements are then used to calculate the total energy generated by the arc prior to detection or interruption. For arc duration measurements, - The arc period for AFPEs begins when the arc voltage reaches 10 V and ends when the arc current falls below 250 mA. - The arc period for AFDs begins when the arc voltage reaches 10 V and ends at the indication of an arc event.	Tested, see test data on the following pages.	P
9.2.8	**Self-test function**		P
9.2.8.1	**General**		P
	The test function of the AFD or AFPE is required to demonstrate the operational readiness of the AFD or AFPE during operation. Two cases shall be evaluated here, ‘test function without malfunction of the AFD or AFPE’ and ‘test function with malfunction of the AFD or AFPE’. The first case defines the normal operation of the DUT where ‘test function with malfunction of the AFD or AFPE’ defines a		P

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Clause	Requirement – Test	Result – Remark	Verdict
	case which has to be constructed by manipulation of the device.		
9.2.8.2	**Test function without malfunction of the AFD or AFPE**	Tested	P
	For an AFPE providing a manual test function, the test shall be initiated and the interruption shall be verified.		P
	For an AFD providing a manual test function, the test shall be initiated and the indication of the successful test shall be verified.	Not AFD	N/A
9.2.8.3	**Test function with malfunction of the AFD or AFPE**		P
9.2.8.3.1	**Detection malfunction**	Tested.	P
	A fault shall be introduced into the AFD or AFPE in a way to cause a malfunction of the detection mechanism. The test function shall be initiated and the malfunction of the detection mechanism shall be indicated.		P
9.2.8.3.2	**Automatic test function before starting operation**	Tested.	P
	The AFD or AFPE shall be modified in a way to cause a malfunction of the AFD or AFPE detection. The operation of the AFD or AFPE shall be initiated and the indication of a malfunction shall be verified.		P
9.2.8.3.3	**Automatic test function during operation**	Tested.	P
	A fault shall be introduced into the AFD or AFPE in a way to cause a malfunction of the detection mechanism during operation. It shall be verified that the AFD or AFPE indicates a malfunction within 25 h. NOTE The pass/fail criteria of 25 h allows for tolerances on the 24 h timer.		P
9.2.9	**Reconnection test**		P
9.2.9.1	**Manual reconnection**	Tested.	P
	After arc-fault interruption, the AFPE shall neither reconnect automatically nor shall remote reconnection be possible. Compliance shall be demonstrated by tripping the AFPE three times.		P
9.2.9.2	**Remote manual reconnection**	Not available.	N/A
	After arc-fault interruption, the AFPE shall not reconnect automatically. Compliance shall be demonstrated by tripping the AFPE three times.		N/A
9.2.9.3	**Automatic reconnection**	Tested.	P
	After arc-fault interruption, the AFPE shall reconnect automatically within the limitations described in 8.1.4.4. Compliance shall be demonstrated by tripping the		P

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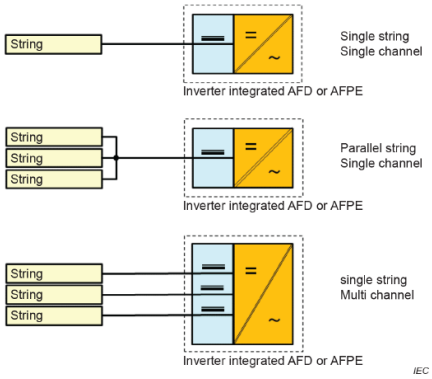
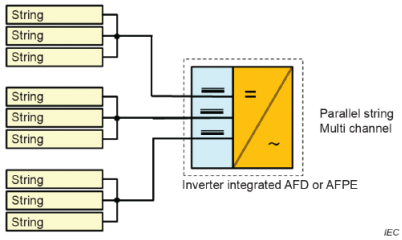
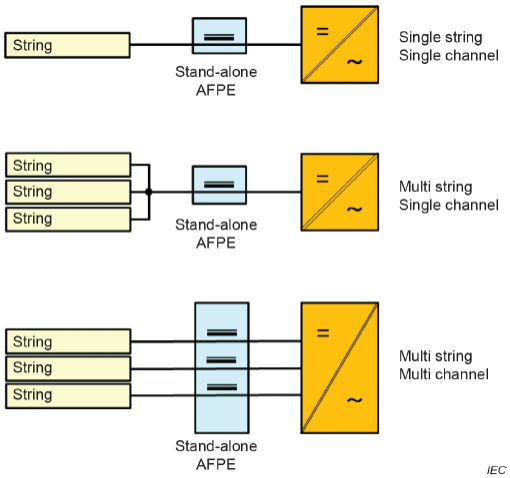
Clause	Requirement – Test	Result – Remark	Verdict
	AFPE at least five times within a 24 h period to demonstrate the manual reconnection state.		
Annex A (informative)	**String and channel examples**		P
A.1	**General**		P
	The following schematics illustrate the range of string and channel examples of AFPEs and AFDs, see Figure A.1, Figure A.2, Figure A.3, Figure A.4, Figure A.5 and Figure A.6.		P
A.2	**PCE integrated AFDs and AFPEs**		P
	 **Figure A.1 – Schematic of string setting of PCE integrated AFDs and AFPEs**  **Figure A.2 – Schematic of parallel setting of PCE integrated AFDs and AFPEs**		P
A.3	**Standalone AFPEs**	Not stand-alone AFPEs.	N/A
	 **Figure A.3 – Schematic of string setting of stand-alone AFPEs**		N/A

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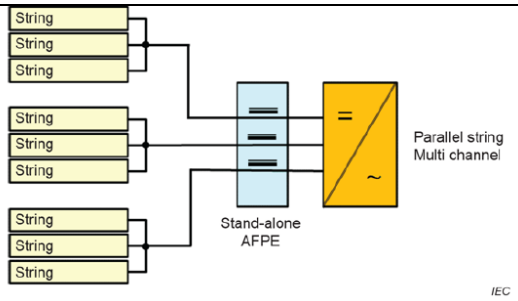
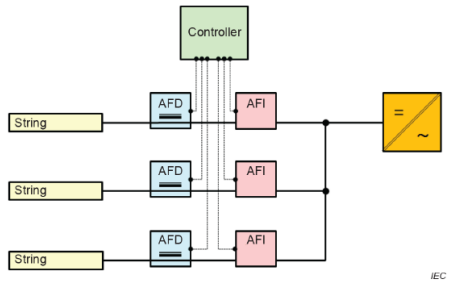
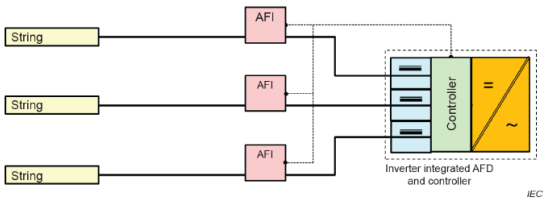
Clause	Requirement – Test	Result – Remark	Verdict
	 **Figure A.4 – Schematic of parallel setting of stand-alone AFPEs**		
A.4	**Distributed AFPEs**	Not distributed AFPEs	N/A
	 **Figure A.5 – Schematic of single string, single channel distributed AFPEs**  **Figure A.6 – Schematic of single string, single channel (Inverter integrated AFD and controller)**		N/A
Annex B (normative)	**Test setups following different application cases**		P
B.1	**General**	See below.	P
B.1.1	**Overview**		P
	This annex gives an overview of the different test setups for AFPE and provides guidance for selecting the appropriate test setups based on the equipment classifications. Subclause B.1.2 defines the PV source models that are used in the different test setups. Clauses B.2, B.3 and B.4 define test setups for typical application cases for string inverter, micro-inverter and DC/DC converter-based systems. Clause B.5 mainly defines setups for systems where AFPE is integrated within combiner boxes or where strings are otherwise combined external to the AFPE devices. Clauses B.4 and B.5 differentiate between input and output setups. This differentiation is not necessarily related to the location of the AFD or		P

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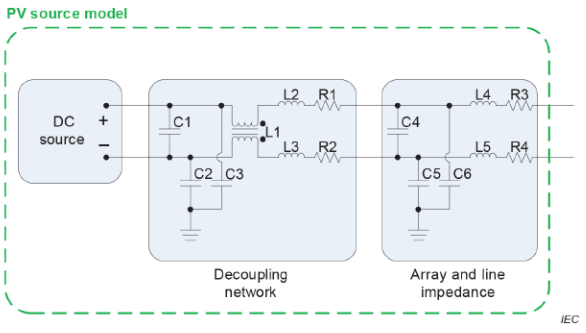
Clause	Requirement – Test	Result – Remark	Verdict
	AFPE within the system. Instead, it refers to the transition point were DC/DC conversion or parallel connection leads to different arcing scenarios. For Clause B.4 the transition point for input and output is the DC/DC converter, for Clause B.5 the transition point is the combiner.		
	Test setups according to Clause B.2 (Figure B.3, Figure B.4 and Figure B.5) shall be performed for AFPE with method of implementation classified as I for: – Inverter integrated AFPE, except micro-inverters – Stand-alone AFPE with one input port per channel. NOTE Stand-alone AFPEs with more than one input port are covered by test setups defined in Clause B.5.		P
	Test setups according to Clause B.3 (Figure B.6, Figure B.7, Figure B.8, Figure B.9 and Figure B.10) shall be performed for AFPE with system integration classified as I for: – Micro-inverter integrated AFPE.	Not micro-inverter	N/A
	Test setups according to Clause B.4 (Figure B.11, Figure B.12, Figure B.13, Figure B.14, Figure B.15, Figure B.16, Figure B.17 and Figure B.18) shall be performed for AFPE with system integration classified as I or D for: – AFPE for DC-DC converter systems.	Not DC-DC converter	N/A
	Test setups according to Clause B.5 (Figure B.19, Figure B.20, Figure B.21, Figure B.22 and Figure B.23) shall be performed for AFPE with system integration classified as S for: – AFPE integrated in combiner boxes – Stand-alone AFPE with more than one input port per channel.	Not in combiner boxes or Stand-alone AFPE	N/A
B.1.2	**PV source models**	Considered.	P
	 **Figure B.1 – PV source model** The PV source model represents the combination of DC source, decoupling network and array and line impedance (see Figure B.1). Depending on the application and the test setup, four different PV source models are defined with the respective parameter values for the LRC components in Table B.1 and Table B.2: (1) Half string model. (2) Full string model. (3) Module based model.		P

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Clause	Requirement – Test	Result – Remark	Verdict

	(4) Parallel string model.		
	In the following test setups placeholders for the PV source model are indicated with the respective numbers of the required PV source model. They are used in Clauses B.2, B.3, B.4 and B.5 in different settings in order to reflect the different application cases.		P

Table B.1 – General LRC component parameters

Parameter	Value	Comment
	(All test setups)	
C1	Min. 20 µF	Value shall dominate the output capacity of the DC source
C2, C3	22 nF	
L1	12 mH	Common Mode (CM)-Filter, minimal DC flux
L2, L3	Min. 60 µH	Saturation at high currents or frequencies shall be avoided
R1, R2	$(R_{Tot} / 2 \times k) - R3$	*k*: Number of decoupling networks
L6, L7	30 µH	Air core; values for line impedance defined in 9.2.5
R5, R6	0,4 Ω	Wire resistance; values for line impedance defined in 9.2.5

Table B.2 – LCR component parameters for different module configurations

Parameter	Half string	Full string	Module level	Parallel strings	Comment
C4	300 nF and 20 µF	150 nF and 10 µF	1,5 µF and 100 µF	150 nF × (*n*-1) and 10 µF × (*n*-1)	See note 3
C5, C6	0,5 nF	1 nF	100 pF	1 nF × (*n*-1)	
L4, L5	25 µH	50 µH	3 µH	50 µH / (*n*-1)	Saturation at high currents or frequencies shall be avoided, L4 + L5: approximately 0,75 µH / m approximately 4 µH / module
R3, R4	Max. 0,5 Ω	Max. 1 Ω	Max. 0,5 Ω	Max. 1 Ω	

	Nominal component parameters of resistors and inductances shall be within a 10 % range of the values demanded in Table B.1 and Table B.2. Nominal component parameters of capacitors shall be within a 20% range of the demanded values. The parameter values are critical over a wide frequency range. The nominal value of all inductances shall be measured at 10 kHz and shall not decrease by more than 40 % at 300 kHz NOTE 1 The n in the parallel strings column equals the maximum number of parallel strings that can be connected to one channel of the DUT. As an example, if there are a total of 8 strings being monitored by a single AFPE, a series arc fault test with a parallel string setup has to be conducted and n-1 would equal 7. NOTE 2 Connecting several half string or full string models including DC source, decoupling network and array line impedance network in parallel will also form a parallel string model. NOTE 3 Two values are given for C4 to represent different framing and module technologies, whereby no combination of different frame and module technologies needs to be tested. Depending on the AFD one of these values may pose a worst-case scenario. NOTE 4 The parameters for the full string column in Table B.2 represent a string with 10 modules with approximately 10 A. Using the same parameters for significantly higher currents leads to a mismatch with respect to the realistic impedances of typical strings. This also applies to the parallel string.		P

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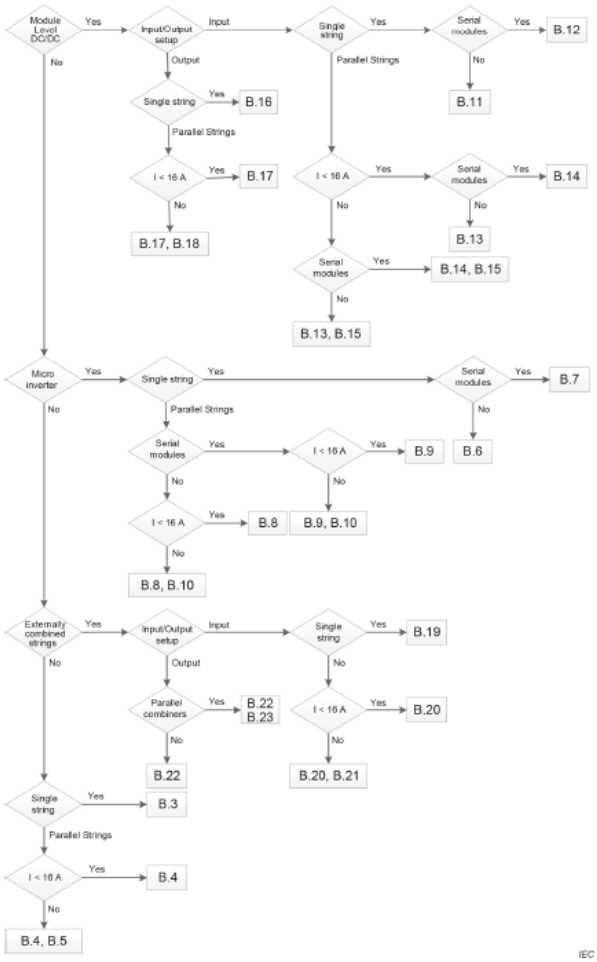
Clause	Requirement – Test	Result – Remark	Verdict
	NOTE 5 Resistors with high stray inductances may reduce arcing signals at high frequencies more than intended by the parameter setting of Table B.2. NOTE 6 The parameters for the full string column in Table B.2 represent a total conductor length of 80 m.		
B.1.3	**Flow chart for test selection**		P
	The applicable test cases relevant for testing shall be selected according to the flow chart in Figure B.2. All possible configurations shall be taken into account to find all required test setups. As a result, it may be necessary to go through the flow chart several times.  **Figure B.2 – Flow chart to select applicable test cases**		P
B.2	**Application String inverter**	Test 1, 2, 3 applied.	P

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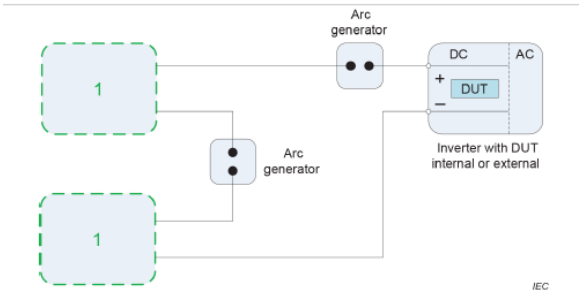
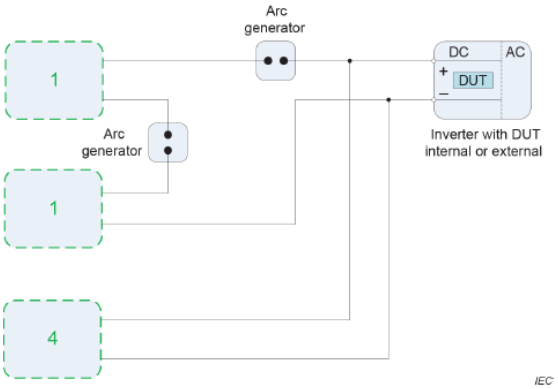
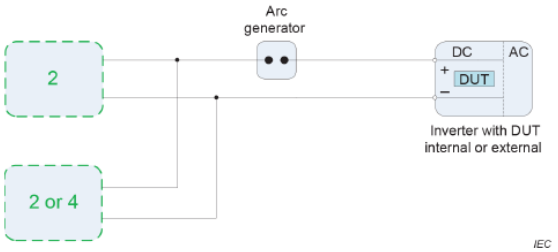
Clause	Requirement – Test	Result – Remark	Verdict
	 **Figure B.3 – Single string test setup (tests 1, 2, 4)**  **Figure B.4 – Parallel string test setup (tests 1 and 2)**  **Figure B.5 – Parallel string test setup (tests 3 and 5)**		P
B.3	**Application Micro inverter**	Not micro inverter	N/A

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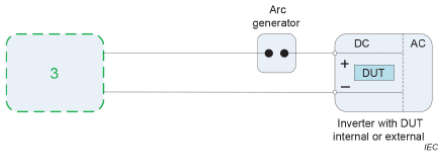
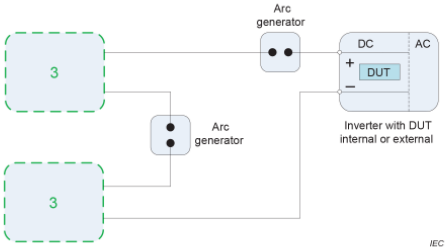
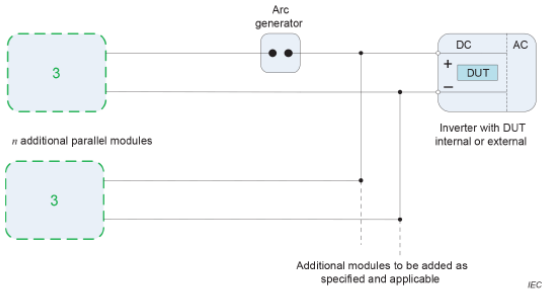
Clause	Requirement – Test	Result – Remark	Verdict
	 **Figure B.6 – Single string test setup (tests 1 and 2)**  **Figure B.7 – Single string test setup (tests 1 and 2) – series modules**  **Figure B.8 – Parallel string test setup (tests 1 and 2)**		N/A

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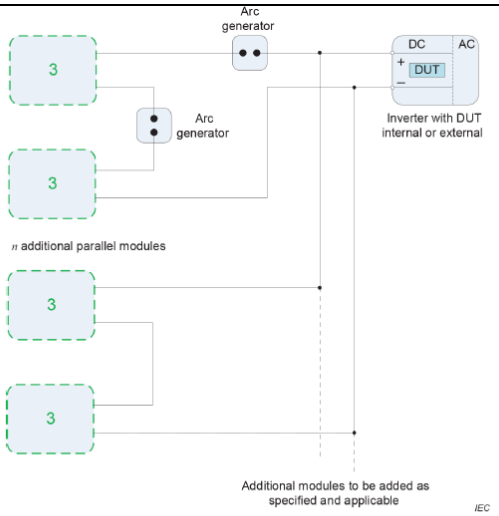
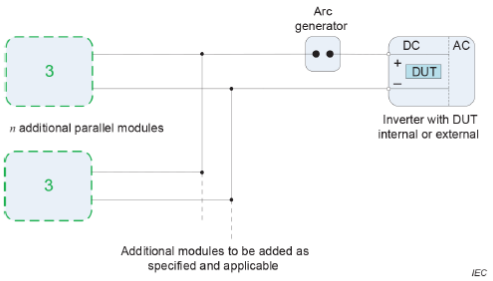
Clause	Requirement – Test	Result – Remark	Verdict
	 **Figure B.9 – Parallel string test setup (tests 1 and 2) – series modules**  **Figure B.10 – Parallel string test setup (tests 3 and 5)**		
B.4	**Application module level DC/DC conversion**	Not module level DC/DC conversion.	N/A
B.4.1	**Input setups**		N/A

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Clause	Requirement – Test	Result – Remark	Verdict
			N/A

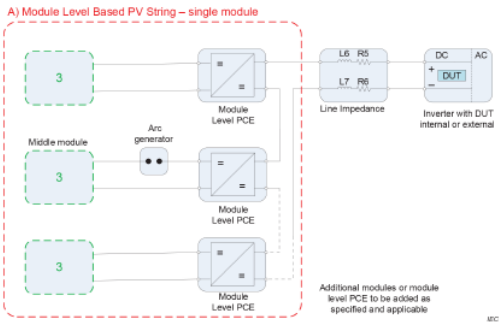

Figure B.11 – Single string test setup (tests 1, 2, 4)

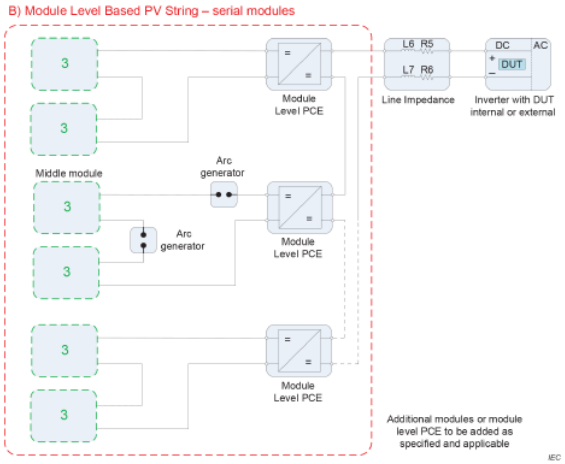

Figure B.12 – Single string test setup (tests 1, 2, 4) – series modules

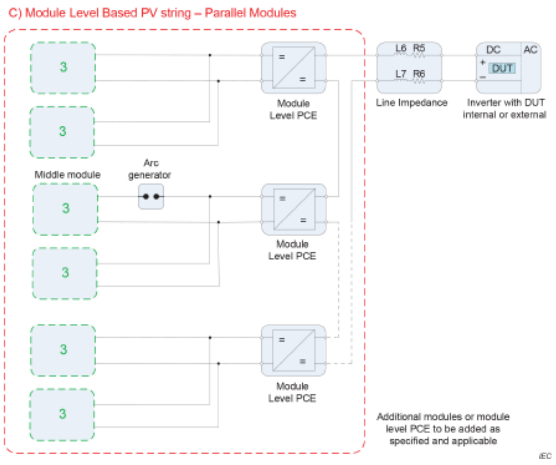

Figure B.13 – Parallel string test setup (tests 1 and 2)

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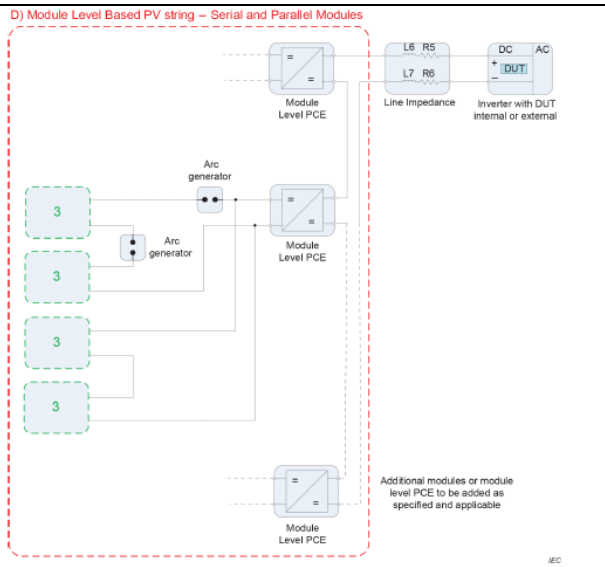
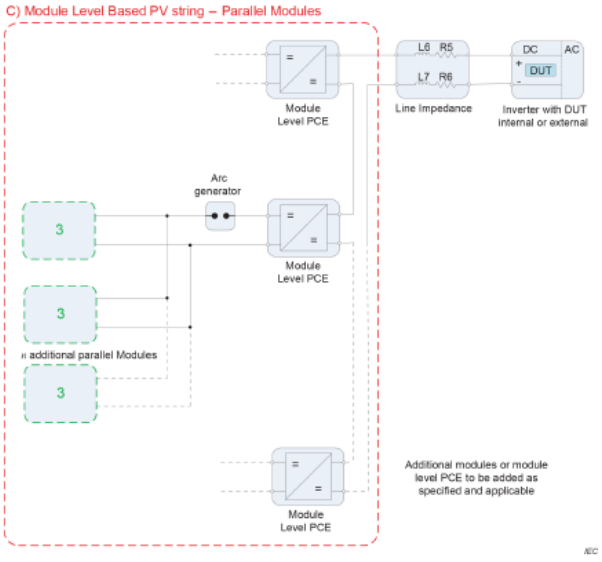
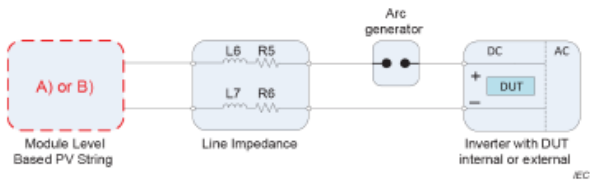
Clause	Requirement – Test	Result – Remark	Verdict
	 Figure B.14 – Parallel string test setup (tests 1 and 2)  Figure B.15 – Parallel string test setup (tests 3 and 5)		
B.4.2	**Output setups**		N/A
	 Figure B.16 – Single string test setup (tests 1, 2, 4)		N/A

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Clause	Requirement – Test	Result – Remark	Verdict

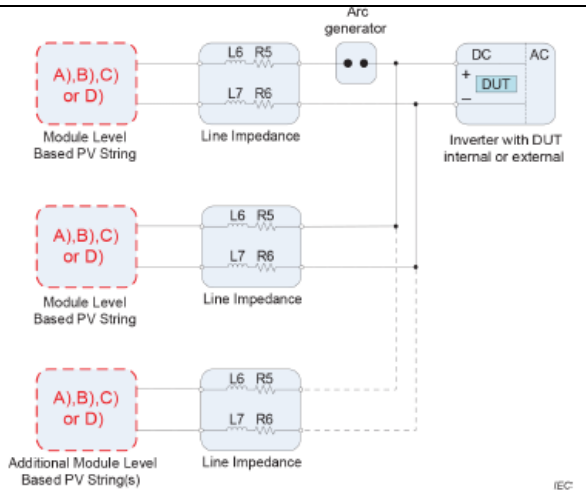

Figure B.17 – Parallel string test setup (tests 1 and 2)

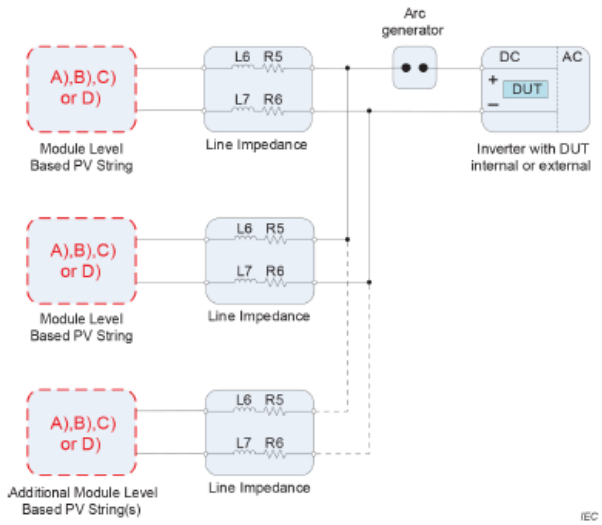

Figure B.18 – Parallel string test setup (tests 3 and 5)

B.5	**Application external combined strings**	Not external combined strings.	N/A
B.5.1	**Input setups**		N/A

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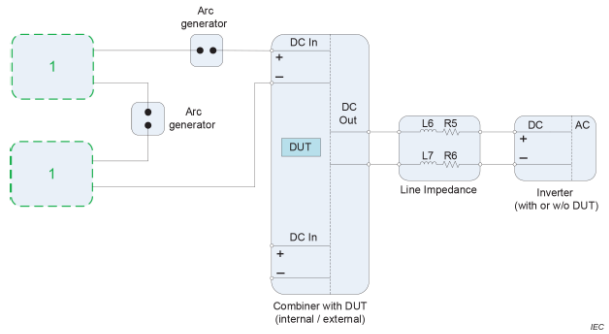
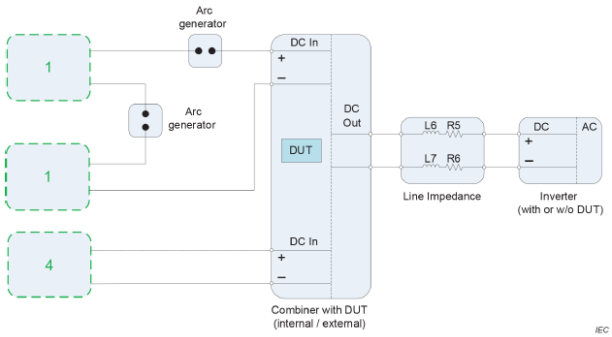
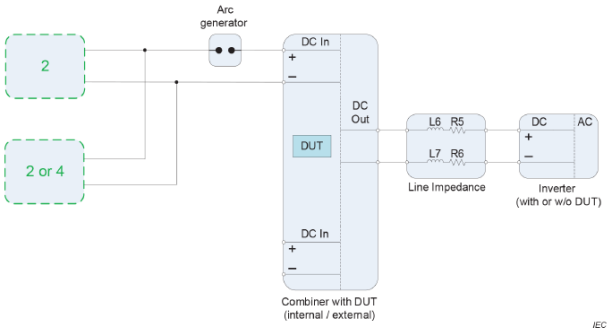
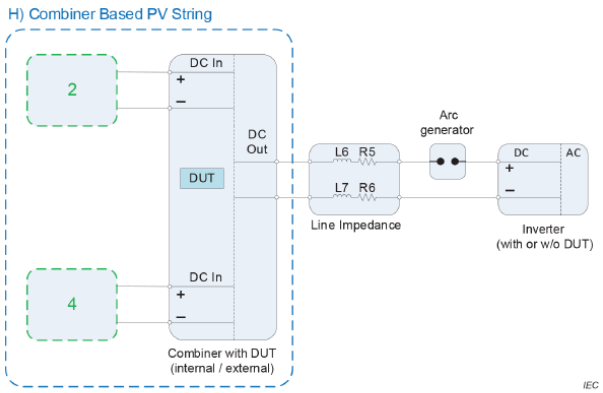
Clause	Requirement – Test	Result – Remark	Verdict
	 **Figure B.19 – Single string test setup (tests 1, 2, 4)**  **Figure B.20 – Parallel string test setup (tests 1 and 2)**  **Figure B.21 – Parallel string test setup (tests 3 and 5)**		N/A
B.5.2	**Output setups**		N/A
	 **Figure B.22 – Single string test setup (test 1 and 2)**		N/A

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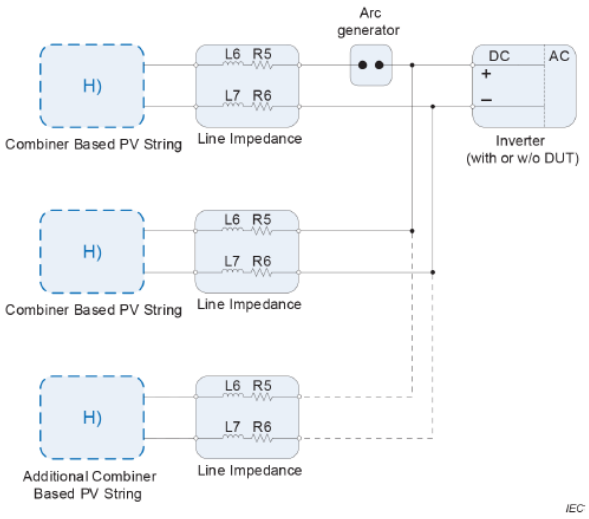
Clause	Requirement – Test	Result – Remark	Verdict
	 **Figure B.23 – Parallel string test setup (tests 3 and 5)** NOTE For the DUT position in Figure B.23 refer to Figure B.22, where the combiner-based PV string H) is defined. Typically for the application externally combined strings the DUT is located in the combiner.		
Annex C (informative)	**Application examples**		P
C.1	General	See below test overview table.	P
C.2	Example 1: String inverter with integrated AFPE (F-I-AFPE)		P
C.3	Example 2: Module level inverter with integrated AFPE (F-I-AFPE)	Not module level inverter	N/A
C.4	Example 3: External AFPE (P-S-AFPE)	Not external AFPE	N/A
C.5	Example 4: Module level DC-DC converter system with AFPE integrated (F-I-AFPE)	Not module level DC-DC converter	N/A
C.6	Example 5: String inverter with multiple Inputs (F-I-AFPE)		P
C.7	Example 6: String inverter with multiple Inputs (F-I-AFPE)		P
C.8	Example 7: String inverter with multiple Inputs (F-I-AFPE)		P

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Clause	Requirement – Test	Result – Remark	Verdict

9.1	TABLE: Thermal testing (tested with model GW6K-DNS-G40)		P
	test voltage (V)	See below	—
	t1 (°C)	--	—
	t2 (°C)	--	—

Supplied Voltage:	Vpv=200V dc., Vgrid=198 Vac, Poutput=max, ambient=45°C, 50Hz	Vpv=200Vdc, Vgrid=264V ac, Poutput=Pderating, ambient=60°C, 50Hz	Vpv=500V dc, Vgrid=264 Vac, Poutput= Pderating, ambient=60, 60Hz	Vpv=500V dc, Vgrid=198 Vac, Poutput=max, ambient=45°C, 50Hz	--
Maximum temperature T of part/at:	T_{max} @ ambient 45 (°C)	T_{max} @ ambient 60 (°C)	T_{max} @ ambient 60 (°C)	T_{max} @ ambient 45 (°C)	Max. temperature limit (°C)
PV connector	57.79	67.31	64.09	52.48	105
PV input cable	47.83	59.96	58.59	44.99	105
AFCI current sensor	88.34	91.20	85.65	82.14	105
AFCI PCB base	83.37	87.31	82.01	77.40	130
GRID Relay	83.39	83.38	82.83	83.78	85
INV Relay	82.58	83.82	82.02	82.95	85
DSP U15	93.93	96.72	91.57	88.34	105
DSP PCB base	88.51	91.34	87.21	83.88	130
ARM U303	89.89	92.25	88.23	85.38	105
Ambient	45.43	60.08	60.06	45.36	--
Note: N/A					

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Clause	Requirement – Test	Result – Remark	Verdict

Annex C	Overview of the respective tests are conducted on model GW6K-DNS-G40						
Channel number	Test number	*I*arc A	$I_{parallel}$ *A*	*I*mpp A	*V*mpp V	Test setup	Number of tests
1	1.0.1 (single)	2.5	N/A	3.0	312	Figure B.3	8
	1.0.2 (single)	7.0	N/A	8.0	318	Figure B.3	8
	1.0.3 (single)	14.0	N/A	16.0	318	Figure B.3	8
	1.1.1 (parallel)	2.5	3.0	3.0	312	Figure B.4	8
	1.1.2 (parallel)	7.0	20	8.0	318	Figure B.4	8
	1.1.3 (parallel)	14.0	20	16.0	318	Figure B.4	8
Note: Tests to be conducted two times with two different arc generator locations and with two different values of C4, therefore, number of tests is 8.							

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Clause	Requirement – Test	Result – Remark	Verdict

9.2.7		Arc energy and response time measurement							P
Channel No.	Test No.	Location	C4 (F)	Test Voltage (cross arc gap)/V	Test current (through arc)/A	Arc dura-tion/ms	Energy /J	Trip <2.5s J<750J	Off/Standby current <250mA
1	1 (single)	1	20uF	29.85	3.575	1010	105.86	PASS	PASS
			20uF	29.10	3.646	960	100.00	PASS	PASS
			300nF	30.51	3.597	980	105.66	PASS	PASS
			300nF	30.12	3.581	1020	108.01	PASS	PASS
		2	20uF	28.12	3.552	1010	99.02	PASS	PASS
			20uF	29.16	3.563	1000	101.76	PASS	PASS
			300nF	27.57	3.561	1010	96.68	PASS	PASS
			300nF	28.99	3.651	990	102.73	PASS	PASS
	2 (single)	1	20uF	26.07	8.391	830	181.25	PASS	PASS
			20uF	25.46	8.308	840	176.95	PASS	PASS
			300nF	25.75	8.429	830	178.91	PASS	PASS
			300nF	25.90	8.446	830	181.45	PASS	PASS
		2	20uF	26.06	8.465	840	184.96	PASS	PASS
			20uF	25.36	8.418	860	183.01	PASS	PASS
			300nF	25.98	8.076	880	183.40	PASS	PASS
			300nF	25.31	8.380	830	175.59	PASS	PASS
	3 (single)	1	20uF	23.94	14.537	860	298.05	PASS	PASS
			20uF	24.49	14.169	880	303.13	PASS	PASS
			300nF	24.36	14.289	830	283.59	PASS	PASS
			300nF	24.73	14.513	870	310.16	PASS	PASS
		2	20uF	23.85	14.558	860	297.27	PASS	PASS
			20uF	24.71	14.351	850	298.44	PASS	PASS
			300nF	24.32	14.197	860	295.70	PASS	PASS
			300nF	23.94	14.288	870	296.09	PASS	PASS
	1 (parallel)	1	20uF	30.19	3.558	1000	105.08	PASS	PASS
			20uF	28.69	3.535	960	95.51	PASS	PASS
			300nF	29.65	3.624	970	102.54	PASS	PASS
			300nF	28.38	3.592	1000	100.20	PASS	PASS
		2	20uF	28.25	3.543	1010	99.02	PASS	PASS
			20uF	30.22	3.592	990	105.27	PASS	PASS
			300nF	30.07	3.535	950	98.83	PASS	PASS

IEC 63027			
Clause	Requirement – Test	Result – Remark	Verdict

9.2.7		Arc energy and response time measurement							P
Channel No.	Test No.	Location	C4 (F)	Test Voltage (cross arc gap)/V	Test current (through arc)/A	Arc dura-tion/ms	Energy /J	Trip <2.5s J<750J	Off/Standby current <250mA
			300nF	27.88	3.655	990	98.83	PASS	PASS
	2 (parallel)	1	20uF	26.65	7.231	620	114.26	PASS	PASS
			20uF	23.90	8.021	910	171.09	PASS	PASS
			300nF	25.56	8.410	850	182.42	PASS	PASS
			300nF	24.31	8.432	870	177.54	PASS	PASS
		2	20uF	25.48	8.378	910	193.95	PASS	PASS
			20uF	25.08	8.414	840	176.76	PASS	PASS
			300nF	24.73	8.449	830	173.05	PASS	PASS
			300nF	26.02	8.387	840	183.01	PASS	PASS
	3 (parallel)	1	20uF	26.99	15.657	850	358.59	PASS	PASS
			20uF	27.45	15.658	910	390.63	PASS	PASS
			300nF	28.01	15.836	840	372.66	PASS	PASS
			300nF	25.02	15.978	830	332.03	PASS	PASS
		2	20uF	25.01	15.549	870	337.89	PASS	PASS
			20uF	24.74	16.10	910	362.11	PASS	PASS
			300nF	24.74	15.936	920	362.50	PASS	PASS
			300nF	24.73	16.097	880	350.39	PASS	PASS
Note: N/A									

-- End of report --