fuse.on

SIBA technical background information:
Know-how on electrical fuses

Foto: fotolia/VioNet

Short circuit protection in PV systems

Requirements for photovoltaic fuses

Our Protection.
Your Benefit.

SIBA
Sicherungen | Fuses

Short circuit protection in PV systems

Requirements for photovoltaic fuses

By
Heinz-Ulrich Haas
Head of Research and Development
SIBA GmbH

1 The current standards

meet special photovoltaic criteria defined in IEC 60269-6 (DIN EN 60269-6 – VDE 0636-6) and UL 248-19. Both standards are relatively new; the international IEC standard was published at the end of 2010, while the United States' latest UL version came out in 2015. They lay out comparable fuse requirements and even give the same name to the operating class – "gPV". [1, 2]

Unlike standard fuses that only interrupt circuits under alternating current, these standards define fuses intended solely for direct current circuits in photovoltaic energy systems. They can interrupt the short circuits typically seen in PV systems; in other words, they interrupt fault currents that are even slightly higher than their rated current. Cycling capacity is writ large in these standards. The fuses have to withstand not only extreme thermal cycles, but complex current cycles as well. This requires the fuse and fuse element to be specially designed so they do not melt due to constant current cycling caused by passing clouds.

However, a tiny difference between the standards has kept the standardization world on its toes: The international IEC norm states that the gPV fuse must interrupt 1.45 times the rated current within 1 h ($I_n \leq 63$ A) under standard conditions, while the American UL standard sets the reference value at 1.35 times the rated current. The IEC takes this into account by definition. In a note, it states that, in actual use, the fuses easily interrupt 1.35 times the rated current in less than 2 h.

Standard-setters could have let this stand, but chose not to. Some members of the IEC are talking about setting 1.35 times the rated current as the reference value for the lowest breaking current for typical string fuses.

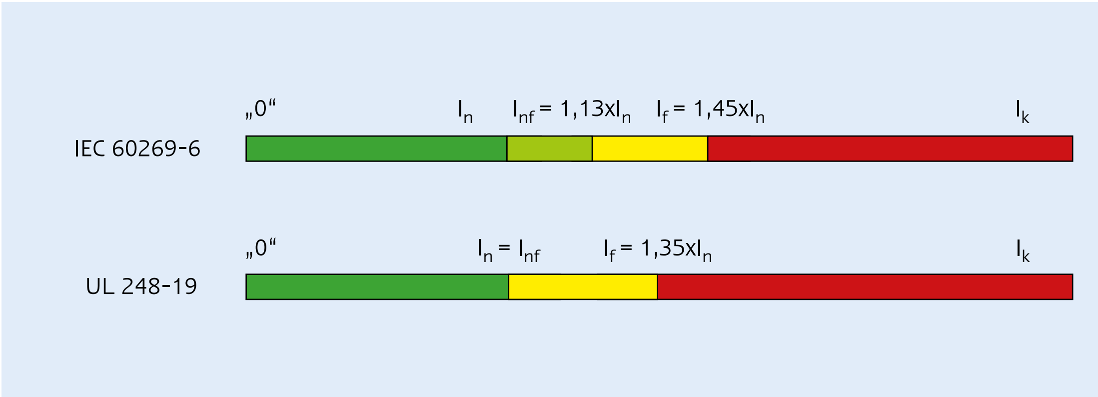


Figure 1: Working and breaking ranges for IEC- and UL-compliant gPV fuses

In other words, UL-listed PV fuses (and possibly faster IEC-listed fuses) may be slightly faster at a given rated current. They interrupt fault currents sooner – a feature that should be considered when designing the protection system. Figure 1 illustrates the difference.

The fuses operate more quickly because they have a higher internal resistance. This increases the amount of power dissipated by the fuse and raises the temperature of the fuse body ... which, obviously, no one wants in their PV system. However, this issue is also addressed by the standards in various protection recommendations.

2 What the standard recommends

It is fairly straightforward to select the rated current of the string fuse if you can link the fuse interrupting current to the panel fault current. When testing the panel's reverse current rating, the panel manufacturer determines the maximum rated current by running 135% of the rated current through the panel for 2 hours while ensuring that the panel does not ignite (DIN EN 61730-2). If you then install a fuse with the maximum current rating in the system, you can be sure that it will interrupt a fault current equal to 1.35 times the rated current in less than 2 hours. [3]

However, you can usually ensure better protection with a lower rated current. Annex BB of IEC 60269-6 recommends performing the calculations using the actual system fault current. Assuming an irradiance of 1200 Wm^{-2} and an ambient temperature of 45 °C, you can generally arrive at a lower rated current with 1.4 x I_{SC}.

UL 248-19-listed fuses are selected using 1.56 x I_{SC} in accordance with the National Electrical Code (NEC). This allows them to handle higher irradiance levels, higher ambient temperatures up to 40 °C and a lower continuous current of the UL fuses. The recommendation made in the future IEC 60269-6 should be similar.

Fuse standard	Lowest fuse current rating	SIBA fuse type 10 x 38 mm
IEC 60269-6	$I_n \geq 1{,}4 \times I_{SC}$	50 xxx 26
UL 248-19	$I_n \geq 1{,}56 \times I_{SC}$	50 xxx 28

Table 1: Lowest rated current I_n according to the current standard for string fuses

The sub-array fuse is responsible for protecting the conductors and PV panels from undesired reverse currents. The array fuse – the central fuse upstream of the inverter input – is intended to protect the PV conductors. The maximum rated current of the sub-array or array fuse is based on the allowed continuous current-carrying capacity of the PV conductors or cables (DIN VDE 0100-430). The IEC 62548 draft recommend a fuse current rating of 1.25 to 2.4 x I_{SC} for both applications. [4, 5]

The fuse voltage rating is based on the open circuit voltage of the panel string. It should be at least 1.2 times the open circuit voltage $U_{VO\ STC}$ at the lowest temperature of -25 °C.

3 What SIBA recommends

Since there were no recommendations in the standards in 2009, SIBA's fuse.on: Just four steps to getting the PV fuse that suits your needs described an extensive system for calculating fuse voltage and current ratings. It covered all the parameters that affect fuse rated values and has since been adopted in the field, albeit in a slightly modified form. [6]

$$U_n \geq U_{OC\ ARRAY} \times [1 + (\Delta\vartheta \times \text{TempKoeff of } U_{OC\ ARRAY})]$$

Where $U_{OC\ ARRAY}$ open circuit voltage of the string

Calculation of fuse voltage rating U_n

$$I_n \geq I_{SCmax} / K_{TH} / A2 / K_{ZS}$$

Where I_{SCmax}	max. panel fault current (for a given irradiance)
K_{TH}	Correction factor for ambient temperature
A2	Correction factor for cyclical load
K_{ZS}	Correction factor for holder grouping

Calculation of fuse current rating I_n

Frequently, higher levels of ambient temperature or irradiation power are to be considered. In these cases a more detailed calculation is necessary. Assuming a thermal radiation power of 1400 W/m^2 (contrarily to the standard data of 1000 W/ m^2) and an ambient temperature of 60°C (contrarily to the standard data of 25°C), this results in a fuse current rating as follows:

$$I_n \geq I_{SCmod} * 1{,}7$$

(at a modul short circiut current of 7,9 A the fuse current should be at least 16 A)

While the former calculation is used more often concerning string protection, the higher factor has been established choosing fuses for array and sub array protection. In this case the fuse carries, too, the protection of the conductors and has to be adjusted to the I_z of the wire.

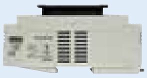
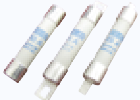
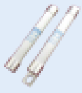
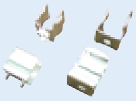
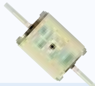
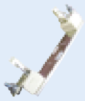
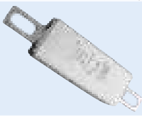
4 Why use PV fuses?

Properly designed PV fuses protect valuable solar energy systems. They monitor system components and require no maintenance for many years. They can differentiate, too: They interrupt circuits in response to short circuits – but ignore passing clouds. Has a cable deteriorated over time, or are damaged panels producing arcs? No problem. The fuses will quickly isolate damaged components within their zones of protection.

5 SIBA fuses according to IEC 602169-6 und UL 248-19 (UL2579)

Size	U_n (DC)	I_n-range	Article no.
10x38	1000 V	1-20 A	5021528
14x51	1000 V	10-32 A	5020426
14x65	1100 V	10-25 A	5023528
14x65	1500 V	10-30 A	5024028
10/14x85	1100 V	10-25 A	5023828
10/14x85	1500 V	10-30 A	5024328
10x85	1500	1-16 A	5011528
NH00	600V	35-160 A	2018928
NH1	1000 V	63-200 A	2055629
NH2	1000 V	200-250 A	2055729
NH3	1000 V	315-400 A	2056829
SQB-101	1000 V	100-300 A	2054428
SQB-102	1000 V	200-400 A	2054528
NH1XL	1100 V	50-200 A	2002828
NH3L	1100 V	200-500 A	2023128
NH1XL	1500 V	63-200 A	2004128
NH3L	1500 V	200-500 A	2024328
SQB 3-170	1500 V	200-500 A	2024528

Images see next page

SIze	Fuse-link	Fuse-holder
10x38		
14x51		
10/14x85		
10x85		
14x65		
14x100		
NH 00 DIN 80		
NH 1		
NH 2/NH 3		
NH 1 XL		
NH 3L		
SQB1 - 170		–
SQB2 - 170		–

6 Notice

The subject of this publication is closely related to the protection of battery circuits. Concerning the latter, SIBA has prepared an information flyer. You can obtain it for free (address see rear page, or click the download link in the pdf-version of this fuse.on).

7 Bibliography

[1] DIN EN 60269-6 (VDE 0636-6): 2011-11
Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems (IEC 60269-6:2010 + corrigendum Dec. 2010); German version: EN 60269-6:201

[2] UL 248-19 Standard for Safety - Fuses - Part 19: Photovoltaic Fuses (Nov. 2015)

[3] DIN EN 61730-2 (VDE 0126-30-2):2007-10;
Photovoltaic (PV) module – Safety qualification – Part 2: Requirements for testing (IEC 61730-2:2004, modified); German version EN 61730-2:2007

[4] IEC 62548
Design requirements for photovoltaic (PV) arrays (still 82/646/CDV:2011-04)

[5] DIN VDE 0100-430
Low voltage electrical installations, Part 4-43: Protection for safety – Protection against overcurrent, (IEC 60364-4-43: modified in 2008 + corrigendum in Oct. 2008, German adoption HD 60364-4-43: 2010)

[6] fuse.on
Just four steps to getting the PV fuse that suits your needs, Issue 01/2009, www.siba.de

SIBA Sicherungen | Fuses

Our protection.
Your benefit.

● **Headquarter:**
SIBA GmbH
Borker Straße 20-22
D-44534 Lünen
Tel.: +49 2306 7001 0
Fax: +49 2306 7001 10
info@siba.de
www.siba.de
● **Subsidiaries**

What sets SIBA apart

Specialists in fuses and fuse protection technology

Providing customers – their machinery and equipment and of course their personnel – with the highest possible level of protection. And we know that this is good for company profits too: production can continue without suffering lengthy disruptions because if anything untoward should happen our fuses will react immediately to prevent further damage.

Maintaining a global presence

For us ‚made in Germany' means ‚selling to the world'. With subsidiaries on every continent and sales partners in practically every country worldwide we can supply you with original SIBA fuses no matter where you are.

Photos: Lenfers | shutterstock/Monika Hunackova/GM

Staying close to our customers

Many of our products are the result of highly specialised requests from discerning clients. We therefore know our way around manufacturing and production, and our in-house R&D capabilities have also helped us face some of industry's major challenges – from digitisation and the DC factory through to e-mobility and the energy transition.

Stand 9/2021 - K0100431