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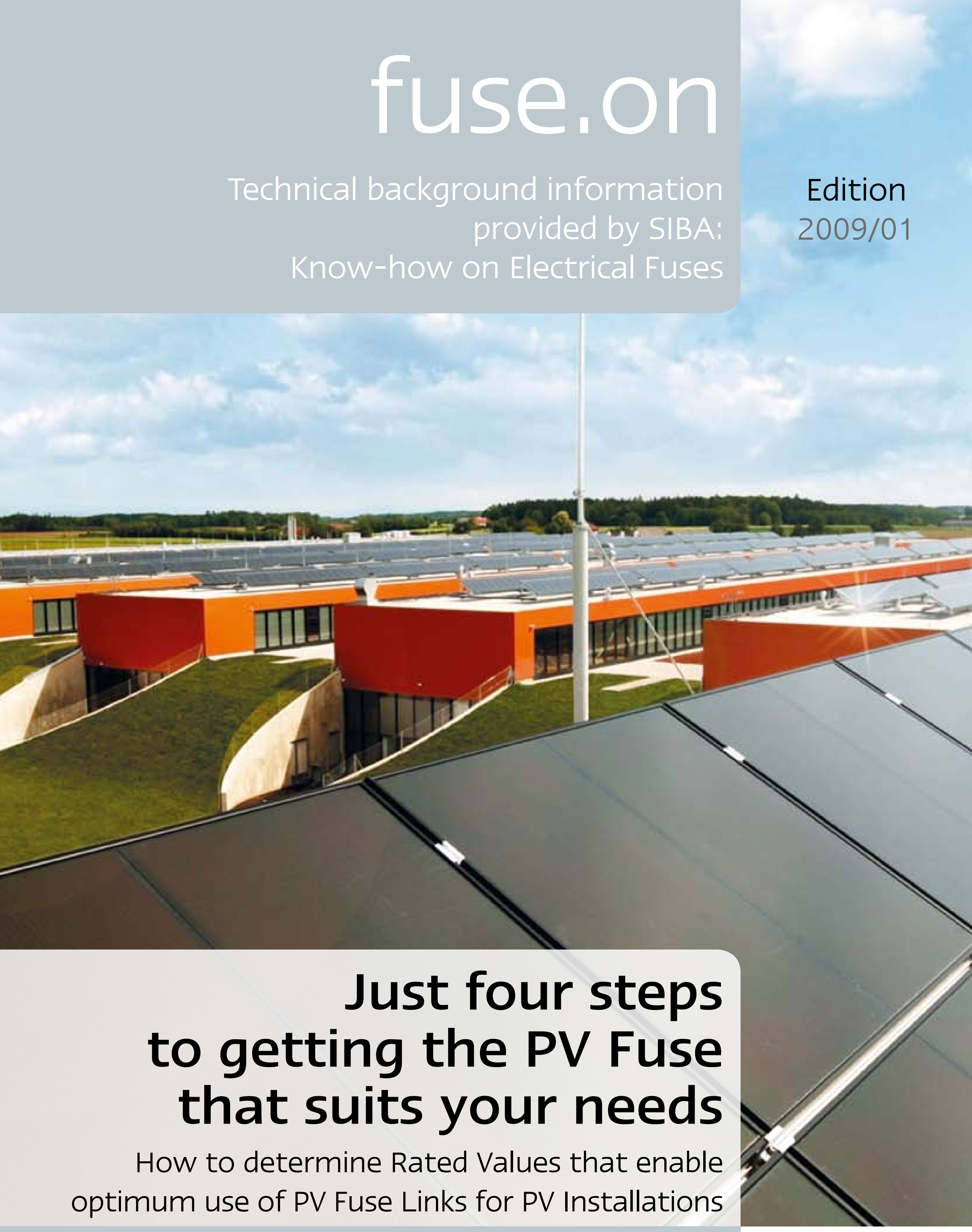

Just four steps to getting the PV Fuse that suits your needs

How to determine Rated Values that enable optimum use of PV Fuse Links for PV Installations

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Just four steps to getting a Fuse that suits your needs

How to determine Rated Values that enable optimum use of PV Fuse Links for PV Installations

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Given the thousands of PV installations already existing one should think that determining the rated data of fuses was everyday routine and part of an installation engineer's standard repertoire. When looking at the protection related recommendations given by the component manufacturers involved, however, it becomes obvious that this is not always the case. For example, the module manufacturer recommends a rated current of 20 A, the inverter manufacturer suggests 16 A, and the installation engineer, a 12 A fuse. While the one adjusts the fuse rated voltage depending on the installation's open circuit voltage under standard test conditions (STC), the other's basis is the maximum radiation occurring in Spain. So, which approach is the correct one? The present article is intended to provide every user with comprehensible criteria. That way, the best possible fuse for any type of installation can be chosen based on simply adjusting the installation or component related parameters.

The calculations shown here refer to data of available PV modules. As some installation related data in this form are encountered on a less frequent basis in practice, we have „modulated" them accordingly for the purposes of explaining limit cases. The installation chosen is a medium one with an overall capacity of 40 kW with eight strings connected in parallel. The reason is as follows: With smaller installations the short circuit currents to be expected are lower; therefore, any protection becomes reasonable only when the number of parallel strings is at least four.

Table 1 shows the data of the module. The values refer to the standard test conditions specifying an irradiance of 1000 W/m^2, a spectral distribution AM (air mass) of 1.5 and a temperature of 25 °C. Module voltage and module current are so called MPP values, i.e. values occurring at the „maximum power point", that have been recorded under optimum conditions.
Table 2 summarizes the actual installation related data. Further data are calculated in the relevant chapters.

Table 1: Data of the used PV Module	
Voltage at P_{MAX}	$U_{MPP\ MOD}$ = 29,2 V
Open circuit voltage	$U_{OC\ MOD}$ = 36,4 V
MPP current	I_{MPP} = 7,9 A
Short circuit current	$I_{SC\ MOD}$ = 8,7 A
Temp. coeff. of U_{OC}	0,36 %/°C
Temp. coeff. of I_{SC}	0,065 %/°C
Max. cell temp.	70 °C

Table 2: Installation related data	
Number of strings	N = 8
Number of modules/string	M = 22
Array voltage $U_{MPP\ MOD}$ x M	U_{ARRAY} = 642 V
String open circuit voltage $U_{OC\ MOD}$ x M	$U_{OC\ ARRAY}$ = 800 V
Temperature in junction box	60 °C
Lowest ambient air temperature	– 25 °C
Irradiance	1200 W/m^2

1 Determination of the Fuse Rated Voltage U_N

The voltage we took as a basis for the fuse link rated voltage was the string open circuit voltage. In order to obtain the actual highest value this voltage must be converted to the lowest possible ambient air temperature of the modules. Now it is the fuse test voltage U_P (and not the rated voltage) that must be higher than the maximum open circuit voltage of the string. One look in the data sheets of the desired fuse link is sufficient to know the value of the test voltage. In most cases (although not always) the fuse test voltage is 1.1 times the rated voltage.

Step 1

Determination of $U_{P\,MIN}$ at −25 °C, thus under conditions deviating by $\Delta\,\vartheta$ = 50 °C from the STC (+25 °C)

$U_{P\,MIN} \geq U_{OC\,ARRAY}$ x (1+ ($\Delta\,\vartheta$ x temp. coeff. of $U_{OC\,ARRAY}$))

$U_{P\,MIN} \geq$ 800 V x (1+ (50 x 0,0036)) = 945 V

In the case of an MPP current of 7.9 A and an open circuit voltage of 945 V, full range fuse links of the URZ 10 x 38 mm type **(Figure 1)** are chosen for string protection. Regarding this fuse type, the manufacturer's data sheets give a test voltage U_P of DC 1000 V and a rated voltage U_N of DC 900 V.

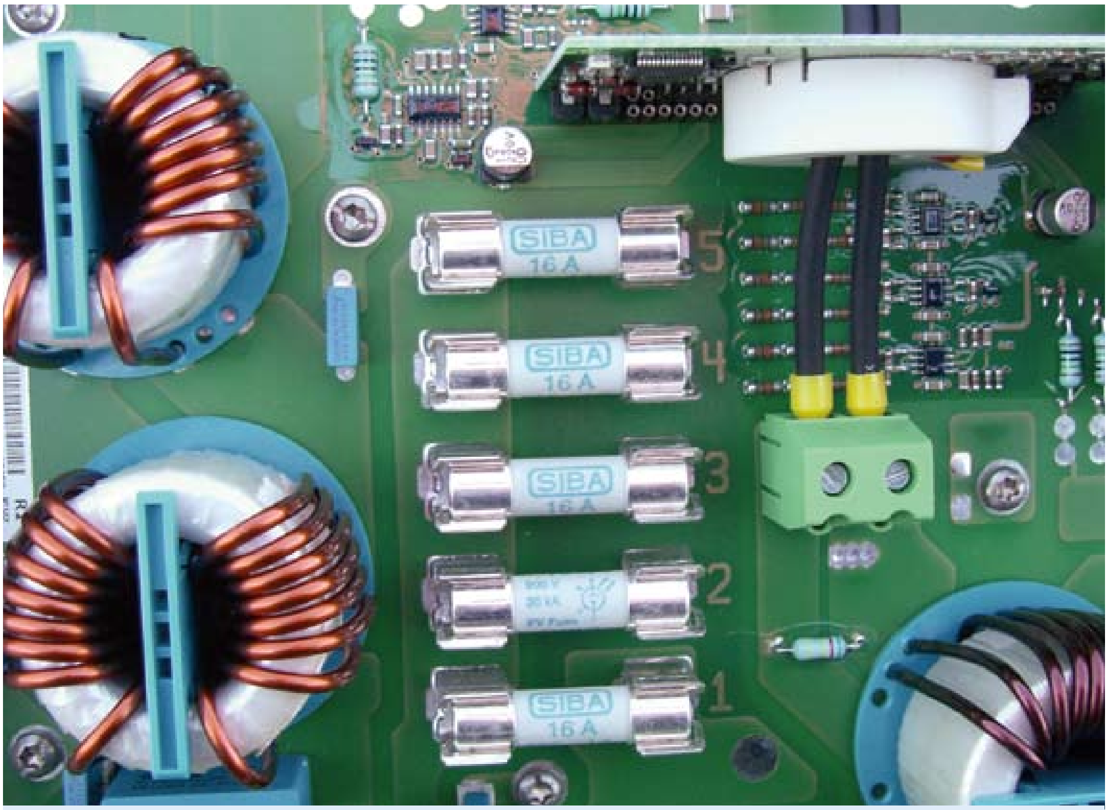

Figure 1: PV Fuses of the URZ Type Series

2 Determination of the Fuse Rated Current I_N

The standard test conditions (STC) apply to the fuse link as well but are not mentioned explicitely. For ambient air temperatures other than 25 °C, for operation under alternating load as well as for high numbers of fuse holders mounted beside each other, derating factors must be taken into account. These factors can be taken from the data sheets for the fuse link and the fuse holder. **Figure 2** shows the typical derating diagram for ambient air temperature: The factor that can be read off at 60 °C, for example, is 0.84. The alternating load factor for full range fuses in PV applications is 0.9. As the fuse holders are placed in groups of three fuses each, no further derating is required.

Ambient air temperature of 60 °C	K_{TH}= 0,84
Alternating load factor for full range fuse (PV fuse)	A2 = 0,9
Derating by high numbers of closed fuse-holders	K_{ZS} = 1 (because of groups of three fuses each)

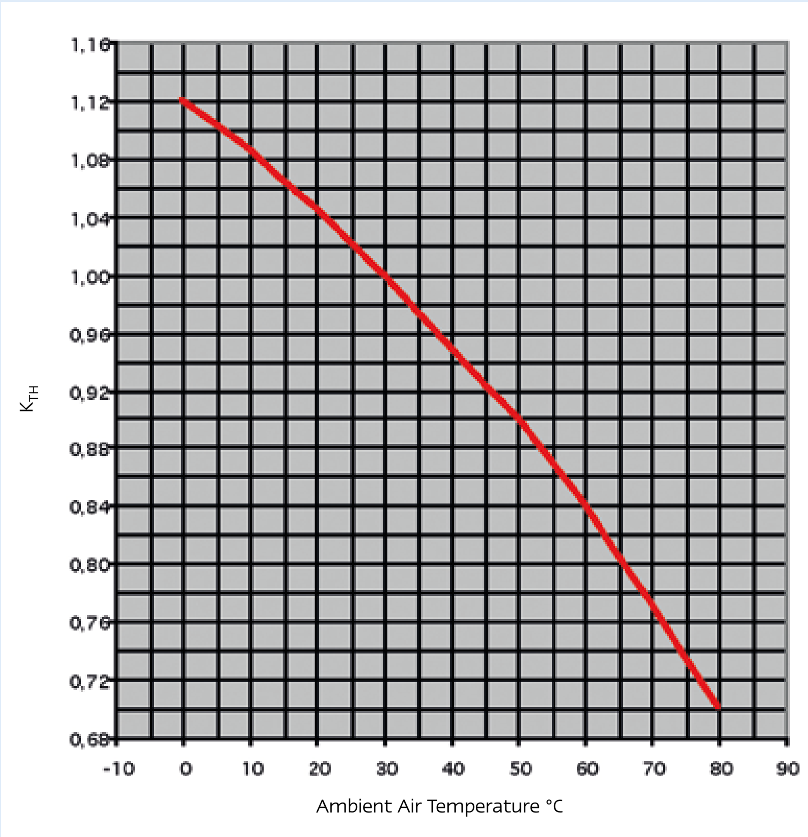

Figure 2: Temperature Derating

On the basis of the MPP current and the reduction factors we can calculate the lowest fuse rated current $I_{N\,MIN}$'.

Step 2

$I_{N\,MIN}' = I_{MPP} / K_{TH} / A2 / K_{ZS}$

$I_{N\,MIN}' = 7{,}9\text{ A} / 0{,}84 / 0{,}9 / 1 = 10{,}5\text{ A}$

chosen: I_N = 12 A (as the 1^{st} iteration step)

Now, the next higher rated current above 10.5 A is chosen from the series of possible rated currents for the respective fuse type, this value is 12 A. If applicable it must be checked whether this rated current meets the conditions for line protection of the string cables (in most cases the lines are rather oversized with the result that it is not necessary to take this aspect into consideration).

3 Testing and Iteration

In the next step we must reduce the chosen fuse rated current once more by the derating values ($I_{N\,RED}$); following this, the result must be higher than the module short circuit current $I_{SC\,MOD}$: after all, the fuses in the intact strings are not supposed to operate when there is a short circuit in the faulty string.

Step 3.1

$I_{N\,RED} = I_N \times K_{TH} \times A2 \times K_{ZS} = \mathbf{12\ A} \times 0{,}84 \times 0{,}9 \times 1 = 9{,}1\text{ A}$

Calculation of I_{SC} at 70 °C
(thus under conditions deviating by $\Delta\vartheta$ = 45 °C from the STC)

$I_{SC}' = I_{SC\,MOD} \times (1 + (\Delta\vartheta \times \text{temp. coeff. of } I_{SC\,STRING}))$
$I_{SC}' = I_{SC\,MOD} \times (1 + (45 \times 0{,}00065))$
$I_{SC}' = 9\text{ A}$

Allowance for max. irradiance to be assumed
I_{SC} at 1200 W/m²
$I_{SC} = 9 \times 1{,}2 = 10{,}8\text{ A}$

Requirement: $I_{N\,RED} > I_{SC}$
9,1 > 10,8 A

... not fulfilled; further iteration step required!

Step 3.2

Selection of the next higher rated current, here: 16 A

$I_{N\,RED} = I_N \times K_{TH} \times A2 \times K_{ZS} = \mathbf{16\ A} \times 0{,}84 \times 0{,}9 \times 1 = 12{,}1\text{ A}$

Calculation of I_{SC} at 70 °C
(thus under conditions deviating by $\Delta\vartheta$ = 45 °C from the STC) see above

Requirement: $I_{N\,RED} > I_{SC}$
12,1 A > 10,8 A

... fulfilled! The fuse rated current chosen is 16 A.

4 Optionally: Determination of the fuses' melting time

In a last step we check whether and after what time the chosen fuse link actually operates in the case of a short circuit. To do so, the string short circuit current is plotted both as the STC and the real maximum value in the fuse's time current diagram **(Figure 3)**.

String short circuit residual current $I_{SC\ STRING}'' = I_{SC\ MOD} \times (N-1)$	$I_{SC\ STRING}'' = 60{,}9$ A
Read off melting time t_S of 16 A fuse at $I_{SC\ STRING}''$ **(Figure 3)**	1,5 s

$I_{SC\ STRING}$ at 70 °C (thus under conditions deviating by $\Delta\vartheta = 45$ °C from the STC)
$I_{SC\ STRING}' = I_{SC\ STRING}'' \times (1 + (\Delta\vartheta \times \text{temp. coeff. of } I_{SC\ STRING}))$
$I_{SC\ STRING}' = I_{SC\ STRING}'' \times (1 + (45 \times 0{,}00065))$
$I_{SC\ STRING}' = 62{,}7$ A

Allowance for max. irradiance to be assumed
$I_{SC\ STRING}$ at 1200 W/m²
$I_{SC\ STRING} = 62{,}7 \times 1{,}2 = 75{,}2$ A

Read off melting time t_S of 16 A fuse at $I_{SC\ STRING}$ **(Figure 3)** 0,4 s

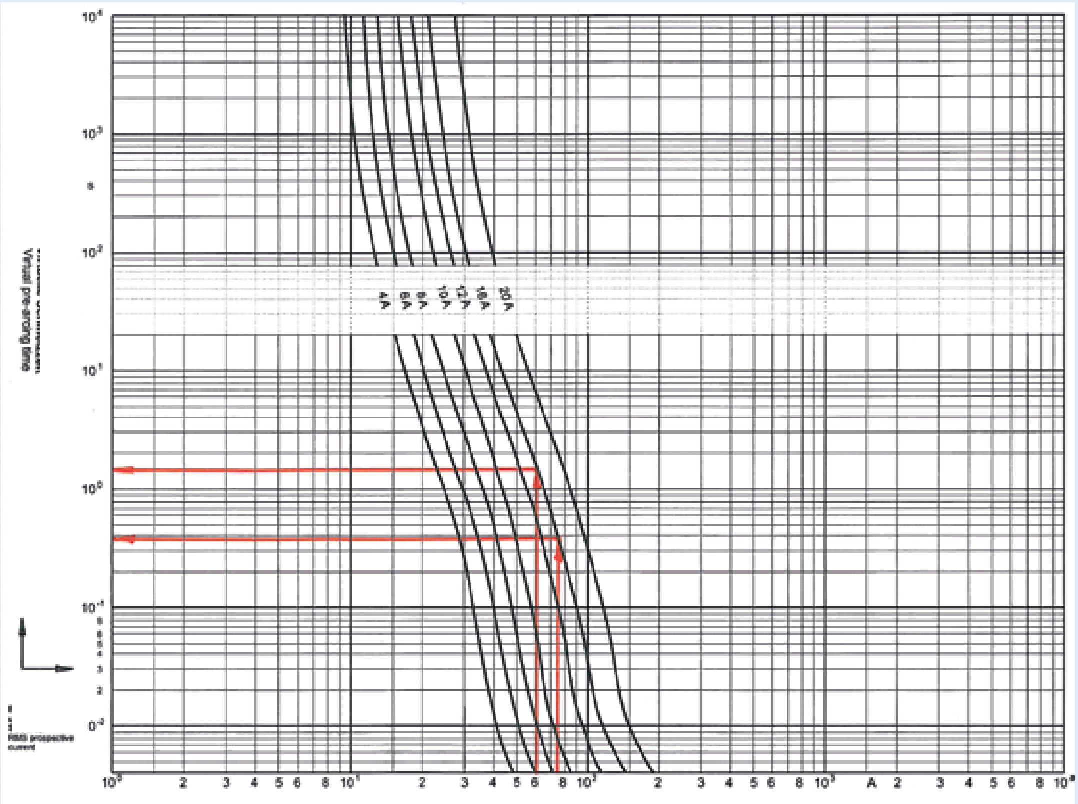

Figure 3: Time-Current Characteristics of the chosen PV Fuse

Result: A precise determination - and reliable empirical equations - in just four steps

DC 900 V full range fuse links with dimensions of 10 × 38 mm and a rated current of 16 A are able to both carry the continuous current of 7.9 A and to operate after approximately 0.4 s at a short circuit current of max. 75.2 A in the string. Fuse rated currents > 16 A are possible but require another calculation in accordance with the above scheme.

At first sight, this calculation of the most suitable fuse link seems quite complex; all in all, however, all the necessary information is gathered in just four steps. Furthermore, once the calculations have been performed for a certain type of installation or a certain region, it is possible to take the factors as a basis to facilitate one's future everyday work.

For example, the rated voltage can be calculated as follows, taking into consideration a lowest temperature of −25 °C and the corresponding temperature coefficient:

$$U_N \text{ resp. } U_{P\ Fuse} \geq U_{OC\ ARRAY} \times 1{,}2$$

When calculating the rated current, a temperature of 60 °C in the junction box and an alternating load factor of 0.9, as is typical of PV installations, as well as a maximum irradiance of 1200 W/m^2 can be assumed:

$$I_{N\ Fuse} \geq I_{SC\ MOD} \times 1{,}4$$

PV Standard Product Range by SIBA (DC Full Range)

Fuse Rated Voltage	Fuse Test Voltage	Product Group	Dimensions	Rated Current up to	Part no. e.g.	Approvals
V	V		mm or size	A		
400	400	GZ	6,3 x 32	8	70 065 26	-
600	600	URZ	10 x 38	30	50 225 26	UR pending
1000	1000	URZ	10 x 38	20	50 215 26	UR pending
900	1000	URZ	10 x 38	20	50 215 06	cURus
1100	1100	URZ	14 x 65	25	*50 235 26	UR pending
1100	1100	URZ	10/14 x 85	25	*50 238 26	UR pending
1500	1500	URZ	20 x 127	25	90 081 10	-
900/1000	900/1000	URM	NH1	160	20 556 20	-
1000	1100	URM	NH1	200	20 028 20	cURus
1000	1100	URM	NH3	400	20 031 20	UR pending

* 25 A = 1000 V

SIBA is constantly enlarging its product range geared at PV applications. One example of this are fuses for higher voltages that are as small as or even smaller than existing ones. We also supply tailor-made products for special requirements. Call us for the solution that is just right for you!

Disclaimer:
Fuse-links described in this document were developed to take over safety relevant functions as apart of a machine or complete installation. A safety-relevant system usually contains signalling devices, sensors, evaluation units and concepts for safe disconnection. The guarantee and responsibility of correct overall function lies with the manufacturer of the installation or machine. SIBA GmbH & Co. KG and their sales offices (in the following „SIBA") are not able to guarantee all features of a complete installation or machine, which was not designed by SIBA.
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Technologies and technical standards are being developed permanently. Therefore this brochure is only able to mirror the state of the art. This has to be considered when using the given information.

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