FUSES FOR SOLAR (PV) APPLICATIONS

Photovoltaic, or 'PV' as it is also known, refers to the technology that converts light directly into electricity.

There is a rapidly growing need for solar energy in the world. This has created a dramatic growth in the development, manufacture and implementation of PV technology. Photovoltaic production has been doubling every two years, making it the world's fastest growing energy technology. At the end of 2007, it was estimated that the cumulative global production was 12,400 megawatts!

As the cost of coal-burning electricity rises, many governments have created financial incentives for solar generated electricity and this trend is predicted to continue around the world.

Electrical systems that convert the sun's energy into electricity are very reliable as long as they are protected properly. Any solar installation is vulnerable to fault currents or lightning strikes. Today, fuses and surge arrestors are the most effective ways of protecting the wiring and all the electrical equipment in a photovoltaic system.

But that protection must be designed, tested and adapted to the specific features of solar applications. Fuses protect the cables between the strings of modules from damage. The faulty circuits are then isolated and the system can keep on generating power.

The unique and specific nature of this protection has resulted in the creation of a whole new category of fuse products, known as Photovoltaic (PV) fuses.

OPERATING PRINCIPLE

PV powered systems consist of a number of strings connected in parallel, each string consisting of a number of modules (solar panels). The modules are connected in series to generate the DC voltage necessary for operation of the inverter, installed at the point of connection to the grid.

ARRAYS WITH 1–3 STRINGS OF MODULES

In this kind of system, the potential fault current is just barely higher than the operating current. In this case, a fuse is not required. Dimensioning the cables between the strings of modules to withstand the maximum fault current is enough to avoid any fire hazard.

ARRAYS WITH AT LEAST 4 STRINGS OF MODULES

In this kind of configuration, the fault current (which is still of much lower intensity than the short circuit current in classic grid supply systems) can reach a level that could cause heating and the damage of insulation. To ensure the best possible protection for the system and any people working on the equipment, each string of solar panels must be protected with a fuse on each pole (such systems are not grounded).

HOW TO CHOOSE THE CORRECT PV FUSE

When a fault occurs in a DC circuit, the absence of natural zero voltage makes the interruption of DC faults more difficult than the interruption of AC faults as only the fuse arc will force the current to decrease to zero.

The correct interruption depends on three parameters:

1. The value of the DC voltage
2. The value of the ratio L/R (time constant) of the fault path
3. The value of the fault current

Due to the unique requirement in PV systems of having to clear a very low level fault, it is important that a fuse with full range capability is used. This means that the fuse is designed for clearing overloads as well as short circuit faults and requires the use of a fuse with a **gR** characteristic. A fuse with an aR characteristic will not clear the low level faults that are potentially present in solar arrays.

In order to calculate the best fuse for a general recommendation, the following information is required:

- ✓ The array open circuit voltage (with the temperature coefficient)
- ✓ The lowest application temperature
- ✓ The ambiant temperature
- ✓ The MPP-current
- ✓ The short circuit current (with temperature coefficient of the short circuit current) of the string
- ✓ The number of parallel strings
- ✓ The max irradiance

General rule No.1

Taking the fact that the polarities **+** and **–** are never connected to the earth (neither one nor the other in photovoltaic equipment) into account, each chain of modules has to be fitted with two fuses: one fuse on the positive output and also one fuse on the negative output.

General rule No.2

The first rule has to be applied when the number of chains in parallel (N) is equal to or higher than 4. (for 1, 2, 3 parallel chains, the fusing is not necessary).

General rule No.3

The maximum DC operating voltage of the fuse must be higher than or equal to
1.20 x M x (Voc STC).

The 4 step calculation of how to choose the correct fuse for a PV power system

For example, say you would like to protect a 20kW generator…

From the datasheet of the module (STC-values):

Voltage at PMAX (Maximum Point of Power)	U_{MPP} = 29.2V
Open Circuit Voltage	U_{OC} = 36.4V
MPP-Current	I_{MPP} = 7.9A
Short Circuit Current	I_{SC} = 8.7A

From the datasheet of the generator (STC-values):

Number of strings N	N = 4
Number of modules per string	M = 22
MPP Array Voltage = U_{MPP} x M	U_{ARRAY} = 642V
Array-Open Circuit Voltage = $U_{OC\ MOD}$ x M	$U_{OC\ ARRAY}$ = 800V
Temperature inside junction box	60 °C

A. Evaluation of the fuse rated voltage

1. Calculation of the smallest fuse link test voltage:

$U_{P\ MIN}$ –25 °C (with temperature coefficient of U_{CO} = 0.36%/°C)

$U_{P\ MIN}$ >= $U_{OC\ ARRAY}$ x (1+ (25+25) x 0.0036) =945V taken: U_N = 900 V (U_P = 1000 V)

At an I_{MPP} – Current of 7.9A and an open circuit voltage of 945V for the string-protection should be using a full-range fuse (type gR) such as SIBA's 5021506 range.

B. Evaluation of the fuse rated current

2. Consideration of the fuse-link de-ratings:

Ambient temperature of 60 °C	0.84
Cycling factor for full-range fuse-links	0.9

De-rating of multiple encapsulated fuse-holders must possibly be considered.

3. Calculation:

Smallest fuse rating $I_{N\ MIN}$ = I_{MPP} / De-rating = 7.9 A / 0.84 / 0.9	10.5A
Next highest available fuse rating I_N chosen:	12A

4. Check:

Reduced fuse rating in the junction box	12A x 0.84 x 0.9 = 9.1A
Check, if the reduced fuse rating is > $I_{SC\ MOD}$	9.1 A > 8.7 A (OK!)
String short circuit current $I_{SC\ STRING}$ = I_{SC} x (N-1)	$I_{SC\ STRING''}$ = 26.1A
$I_{SC\ STRING}$ at 70 °C (with temp. coefficient of I_{SC} with 0.065%/°C)	
$I_{SC\ STRING'}$ = $I_{SC\ STRING''}$ x (1+ (70-25) x 0.00065))	$I_{SC\ STRING'}$ = 27A
Consideration of max. irradiance	
$I_{SC\ STRING'}$ at 1200 W/m²	$I_{SC\ STRING}$ =27x1.2 = 32.4A
Melting time t_s of the fuse rating 12A at $I_{SC\ STRING}$	30 s

Result:

In this case, SIBA's part number 5021506-12A fuse is the best choice. It is a full range fuse (type gR), has dimensions 10mm x 38mm, is rated at 900VDC with a rated current of 12A. This will carry the MPP current of 7.9A and will interrupt a string short circuit current of 32.4A in a time of about 30s. Fuse ratings above 12A are possible, but have to be calculated on the above scheme. Accordingly, the cable type and the cross section the maximum overload current I_Z has to be considered.

For further advice, please contact Fuseco and we will be happy to assist you with the best fuse selection solutions.

For detailed information on the fusing of solar systems, please refer to our Fuseco website: www.fuseco.com.au Navigate to the 'Tech Info' tab and scroll to the Solar (PV) section. Articles include:

PV Safety, Arcing & Fusing – Introduction & Background

PV Safety, Arcing & Fusing – PV Arcs & their properties

PV Safety, Arcing & Fusing - Arcs, what do we do?

Fusing of PV arrays (Nigel Wilmot)

WHAT MAKES PV FUSES DIFFERENT TO OTHER FUSES?

- Low level Fault Protection
  In Photovoltaic Equipment, fault currents can be only fractionally higher than system currents and the elimination of such low level overloads is a very challenging task for a fuse. This is the single biggest difference between PV fuses and all others and has taken many years of R&D to develop. The short circuit conditions associated with solar panels do not allow for sufficient current to open a standard fuse in a way that effectively isolates faulted photovoltaic strings.

- 1000VDC Capacity
  PV fuses are designed with a maximum 1000VDC operating voltage based on typical solar panel systems with L/R of 1ms and below. The development of sophisticated solar panel systems has accelerated the demand for high performance fuses.

- Superior Cycling Withstand
  PV fuses are tested in coordination with cycling conditions associated with solar panel system operation and environmental influences.

WHAT MAKES A SIBA PV FUSE DIFFERENT TO OTHER SOLAR FUSES?

- Very low Imin.
  The I_{min} is the minimum opening current of the fuse and this is the key to opening low level fault currents. This is especially true during times of low-light conditions.
  (eg. early morning, evening, fog, mist, cloudy or overcast conditions, etc.)
  During such times, the system is not producing a lot of current, however a short circuit can still occur, therefore a fuse with the lowest possible I_{min} is desirable.
  SIBA PV fuses have the lowest I_{min} of any PV fuses on the market!

- Expansive range
  Some brands have the 10x38mm PV cartridge fuses only. SIBA is the only brand to have developed a PV fuse offering consisting of 10x38mm, 14x51mm, NH style and even 6.3x32mm fuses. You can be sure that there is a fuse solution for your specific PV application.

- "Made in Germany" Quality
  SIBA is one of the rare remaining manufacturers who have not shifted their manufacturing to low cost labour markets. SIBA believe that it is impossible to manufacture to a consistent high quality standard unless the product is being built by highly trained people in a quality controlled environment. They are uncompromising in their quality so that you can have peace of mind.

- Vast experience with solar applications R&D
  Now that PV fuses are perceived as being an emerging market, other manufacturers are developing PV fuses to join 'the action'. However, SIBA have been building PV fuses and refining their technology for over 10 years! That is why their products are so advanced in comparison to the competition.

  This was very evident at the Intersolar exhibition at Munich in 2008 where the significant majority of exhibitors used SIBA PV fuses in their installations.

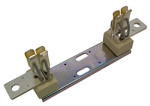
THE SOLAR (PV) RANGE *(DECEMBER 2008)*

Cylindrical

Visual	Part No.	Size	Mounting	Amp Ratings	Voltage
	5021506	10x38mm	Cylindrical	0.5 1 2 3.5 4 6 8 10 12 16 20	900VAC/DC
	5021606	10x38mm	PCB Pin	0.5 1 2 3.5 4 6 8 10 12 16 20	900VAC/DC
	5021706	10x38mm	Bolt-In	0.5 1 2 3.5 4 6 8 10 12 16 20	900VAC/DC
	5106304.DC	10x38mm	DIN Rail Holder 1P	32A	1000VDC
	5106304.2DC	10x38mm	DIN Rail Holder 2P	32A	1000VDC
	6101701.2	10x38mm	Screw Clip 10mm	-	-
	5806316	10x38mm	Solder Clip 10mm	-	-
	5020406	14x51mm	Cylindrical	4 6 8 10 16 25	900VAC/DC
	5020506	14x51mm	Bolt-In	4 6 8 10 12 16 20 25	900VAC/DC
	6100101.2	14x51mm	Screw Clip 14mm	50A	-
	5805806	14x51mm	Solder Clip 14mm	50A	-

THE SOLAR (PV) RANGE *(DECEMBER 2008)*

NH Style

Visual	Part No.	Size	Mounting	Amp Ratings	Voltage
	2002820	NH1	Size 1 NH Blade	35 50 63 80 100 125 160 200	900VAC/DC
	2102801	NH1	Fuse Base NH1	250A	1500VAC 1000VDC
	2003120	NH3	Size 3 NH Blade	50 100 125 160 200 250 315 350 400	900VAC/DC
	2103101	NH3	Fuse Base NH3	630A	1500VAC

Micro-switch available for NH1 and NH3 fuses

In Development
6.3x32mm
10x51mm
10x85mm
20x127mm

Please contact Fuseco or refer to our website *www.fuseco.com.au* for further information on PV fuses.

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