Arcing potential in fuses: missing standards for adequate testing of fuses in PV application

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1 INTRODUCTION

2 STANDARDS, DEFINITIONS AND REQUIREMENTS FOR FUSE-LINKS
   2.1 STANDARDS FOR LOW VOLTAGE FUSES
   2.2 DEFINITIONS FOR SEMICONDUCTER FUSE-LINKS
   2.3 GENERAL REQUIREMENTS FOR PV OVER CURRENT PROTECTION DEVICES MCBs OR FUSE-LINKS
   2.4 FIRST PV FUSE-LINK OF THE WORLD

3 PROBLEMS WITH FUSE-LINKS

4 CONCLUSION
Requirements for fusing in PV installations are more than confusing today.

There are no standards for PV fuse-links in grid connected PV systems without electrical storage.
Current PV standardization:

IEC 60364-7-712 (DIN VDE 0100-7102) Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems.

EN 50380:2003 Datasheet and nameplate information for photovoltaic modules.

IEC 61730-2 Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing.
These IEC/EN standards define no requirements to use fuse-links for overload device protection of PV modules.

The recommendation for fuse-links will be only an item coming from PV module manufacturer.
1 INTRODUCTION

Praxis today:

There are no clear instructions and type specification (type and operational class) from the module manufacturer’s to fit fuse-links into a string for module protection against reverse overload current.
1 INTRODUCTION

Do we have really a problem with reverse overload current?

The German committee DKE 373 for PV standardization stated clearly in their last 34th meeting in Frankfurt, on 14th September 2007:
- There is no relevant reverse current $I_r$ due to partial shading or full diffuse shading of a PV string or PV array.

- The risk for relevant reverse over current expected due to shorted bypass diodes or one earth fault (under single fault conditions in DC-IT- and/or protection class II installations) is negligible.
Arcing potential in fuses

2 STANDARDS, DEFINITIONS AND REQUIREMENTS

- There are existing standards for low voltage fuses.

- but there are some specific things to consider, using fuses in PV applications
2.1 STANDARDS FOR LOW VOLTAGE FUSES

International Standardization of low-voltage fuses

- IEC 60269-1:2006-11 Ed 4.0
  Low-voltage fuses - Part 1: General requirements

- EC 60269-2:2006-11 Ed. 3.0
  Low-voltage fuses - Part 2: Supplementary requirements for fuses for use by authorized persons (Fuses mainly for industrial applications)

- IEC 60269-3:2006-11 Ed. 3.0
  Low-voltage fuses - Part 3: Supplementary requirements for fuses for use by unskilled persons (Fuses mainly for household and similar applications)

- IEC 60269-4: 2006-11 Ed. 4.0
  Low-voltage fuses – Part 4: Supplementary requirements for fuse-links for protection of semiconductor devices
2.2 DEFINITIONS FOR SEMICONDUCTOR FUSE-LINKS

**Operational classes and function classes**

The operational class is the designation of the function class of a fuse-link in connection with the object to be protected.

- **gS operational class:**
  Full range semiconductor safety fuse for use in safety switching devices

- **gR operational class:**
  Full range semiconductor protection

- **aR operational class:**
  “Back-up” semiconductor protection

The function class means the ability of a fuse-link to carry specific currents without damage and to switch off over-currents within a certain range (breaking capacity range).

- **Function class g:** Full Range fuses
- **Function class a:** “Back-up” fuses
MCBs or fuse-links are selected according to rated voltage, rated current, breaking $I^2t$ value $I^2tA$ and varying load factor, taking into consideration other specified conditions (use of correction factors e.g. ambient temperature, conductor cross-section, construction angle and forced-air cooling).

Derating factor of a fuse-link

*MCB:
Magnetic circuit breaker

Ambient temperature °C
A MCB or fuse as an over current protecting device requires amperes to operate.

Current levels in electrical circuits in a utility grid (voltage source) above the over current rating of the device cause the over current device to open.

A PV DC installation without electrical storage is a "limited current source" with no short circuit power.

This makes the difference !!!

Why using semiconductor fuse-links for PV?

The requirements for fast semiconductor fuses with aR characteristic according VDE 0636-4 or IEC 60269-4 are very similar to the requirements for PV fuse-links e.g. DC voltage rating $U_n$, rated current $I_n$ and a partly match to $I^2t$ value for reverse over current protection.

Fuses are not so expensive like MCBs.
SIBA GmbH & Co. KG has developed a new fuse-link for use in photovoltaic equipments.

In the range of photovoltaic equipments the short circuit as well as overload protection requirements are steadily increasing. Today no-load voltages of DC 900 V are reached.

A 10 x 38 mm cylindrical fuse-link with rated currents of 4 A up to 20 A maximum has been developed, which corresponds to the requirements of modern PV equipments.

Comment:
These fuse-links are “DC Fuses (class gR for heavy duty application)” without VDE or IEC reference
There are problems with arcing due to the low arcing energy and aging during operation. Aging is also a potential risk for arcing during a long time of normal operating conditions.

The fuse-link (for power semiconductors operational class aR), Picture 1 was designed for a rated breaking capacity up to approx 3.5 times of the rated current.
3 PROBLEMS WITH FUSE-LINKS

Picture 1:
Failed fuse-link with following arcing due to insufficient fault current, derating due to high ambient and operation temperature or aging?

Arcing in PV DC-Arrays
Arcing potential in fuses

3 PROBLEMS WITH FUSE-LINKS

Picture 2:
Switch disconnector of the failed fuse-link
Arcing potential in fuses

3 PROBLEMS WITH FUSE-LINKS

Picture 3:
PV array junction box in operation
This PV array junction box with 8 fuses in “+” string cable and 8 fuses in “−” string cable was operating properly for 2 years in a multi megawatt PV power plant.
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3 PROBLEMS WITH FUSE-LINKS

Picture 4:
The day after without PV array junction box
Arcing potential in fuses

3 PROBLEMS WITH FUSE-LINKS

Picture 5:
PV generator junction box commissioning
Arcing potential in fuses

3 PROBLEMS WITH FUSE-LINKS

Picture 6:
A very nice standing arc

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3 PROBLEMS WITH FUSE-LINKS

Picture 7:
Bye bye junction box
If we have to install fuses in PV installations then we need a PV fuse standard for requirements and testing (e.g. arcing test) including fuse-holder.

Ask PV module manufacturers for the specification of the recommended fuse-link.
Use only approved PV-fuse-links if they are available.

Prefer fuse-less PV installations that’s the best solution because it is easy, very save and reliable.
Arcing potential in fuses

Backup 2

Arcing in PV DC-Arrays