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

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Arcing potential in fuses

CONTENT

Arcing potential in fuses

1 INTRODUCTION

Requirements for fusing in PV installations are more then confusing today.

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

Arcing potential in fuses

1 INTRODUCTION

Current PV standardization:

IEC 60364-7-712 (DIN VDE 0100-712) 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.

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1 INTRODUCTION

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.

Arcing potential in fuses

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.

Arcing potential in fuses

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:

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1 INTRODUCTION

-There is no relevant reverse current *Ir* 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.

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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

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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

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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**

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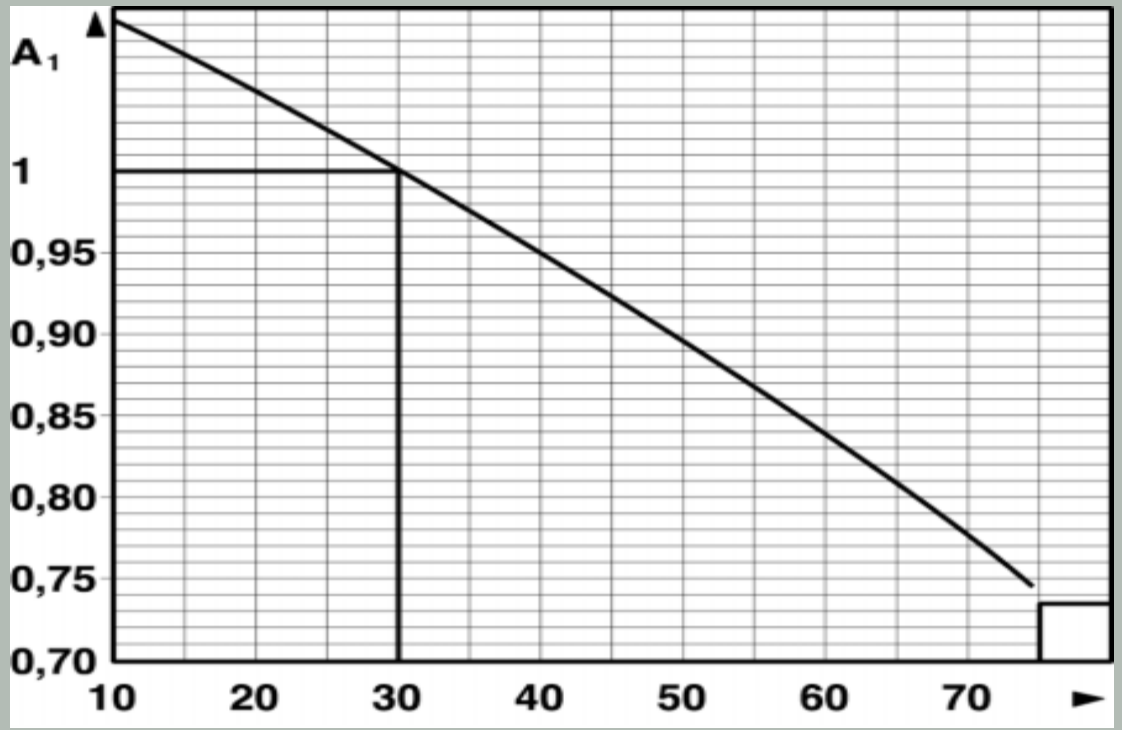
2.3 GENERAL REQUIREMENTS FOR PV OVER CURRENT PROTECTION DEVICES MCBs OR FUSE-LINKS

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



Ambient temperature °C

*MCB:

Magnetic circuit breaker

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2.3 GENERAL REQUIREMENTS FOR PV OVER CURRENT PROTECTION DEVICES MCBs OR FUSE-LINKS

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 *Un,* rated current *In* and a partly match to I^2t value for reverse over current protection.

Fuses are not so expensive like MCBs.

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2.4 FIRST PV FUSE-LINK OF THE WORLD

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

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3 PROBLEMS WITH FUSE-LINKS

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.

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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?

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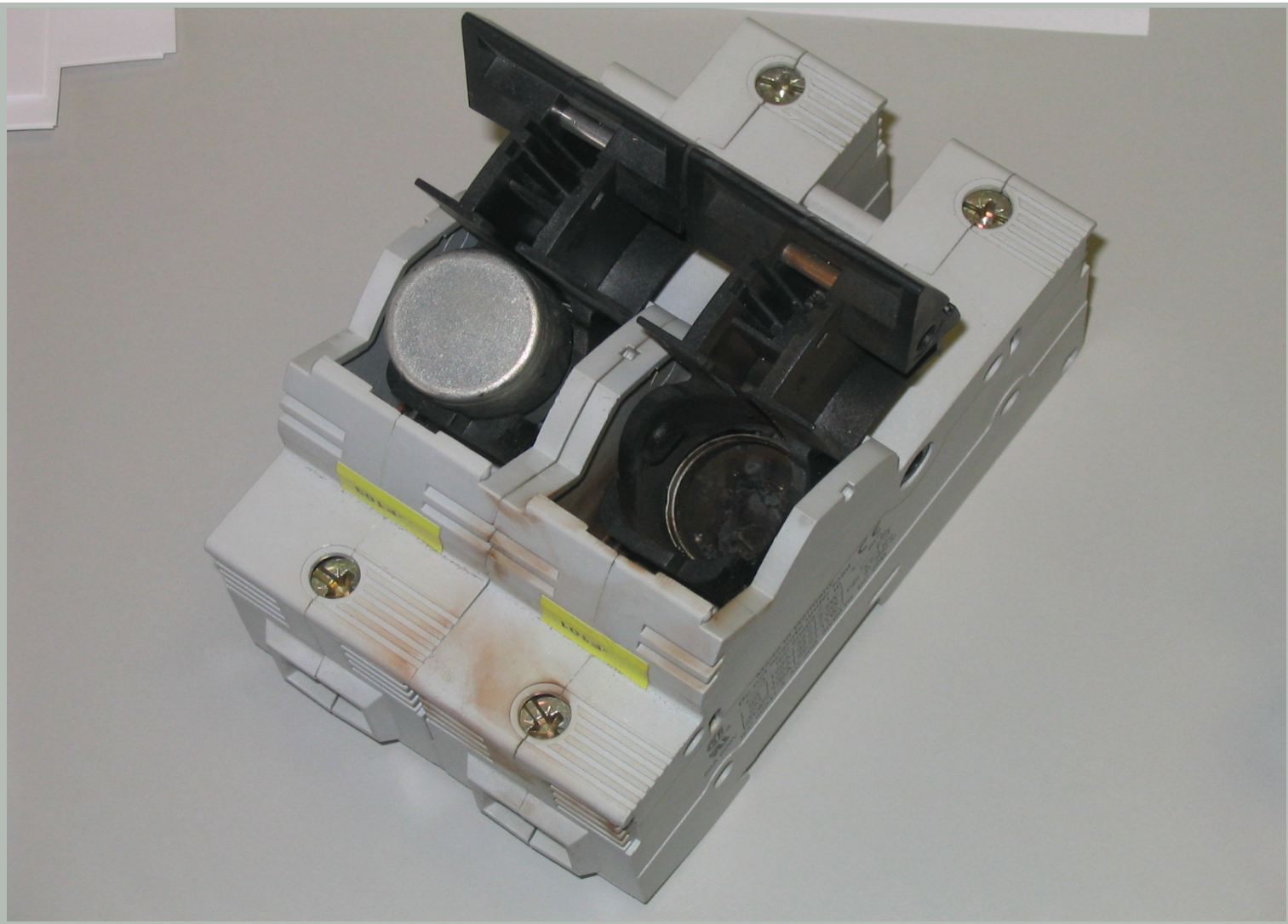
3 PROBLEMS WITH FUSE-LINKS



Picture 2:

Switch disconnector of the failed fuse-link

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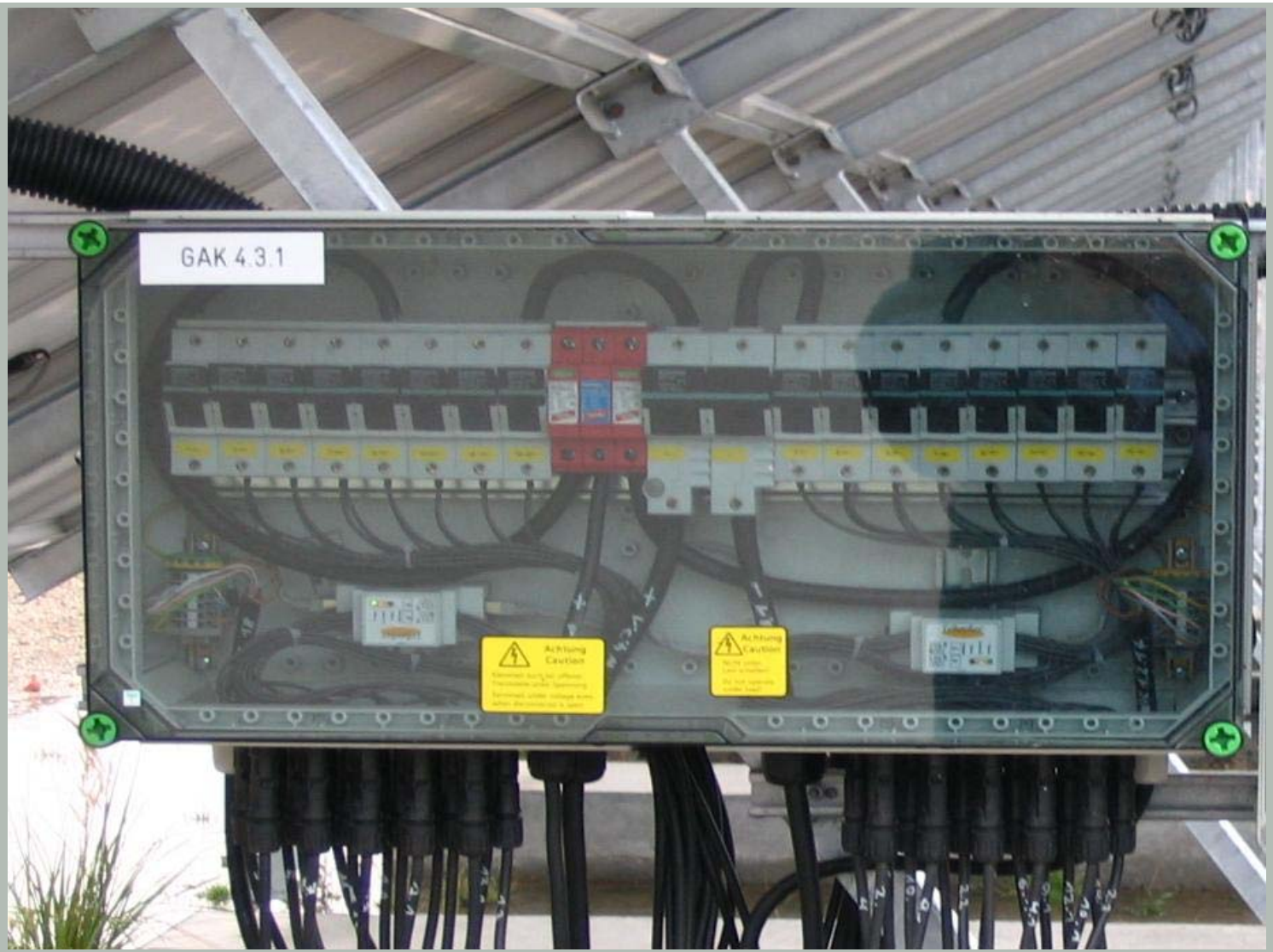
3 PROBLEMS WITH FUSE-LINKS



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

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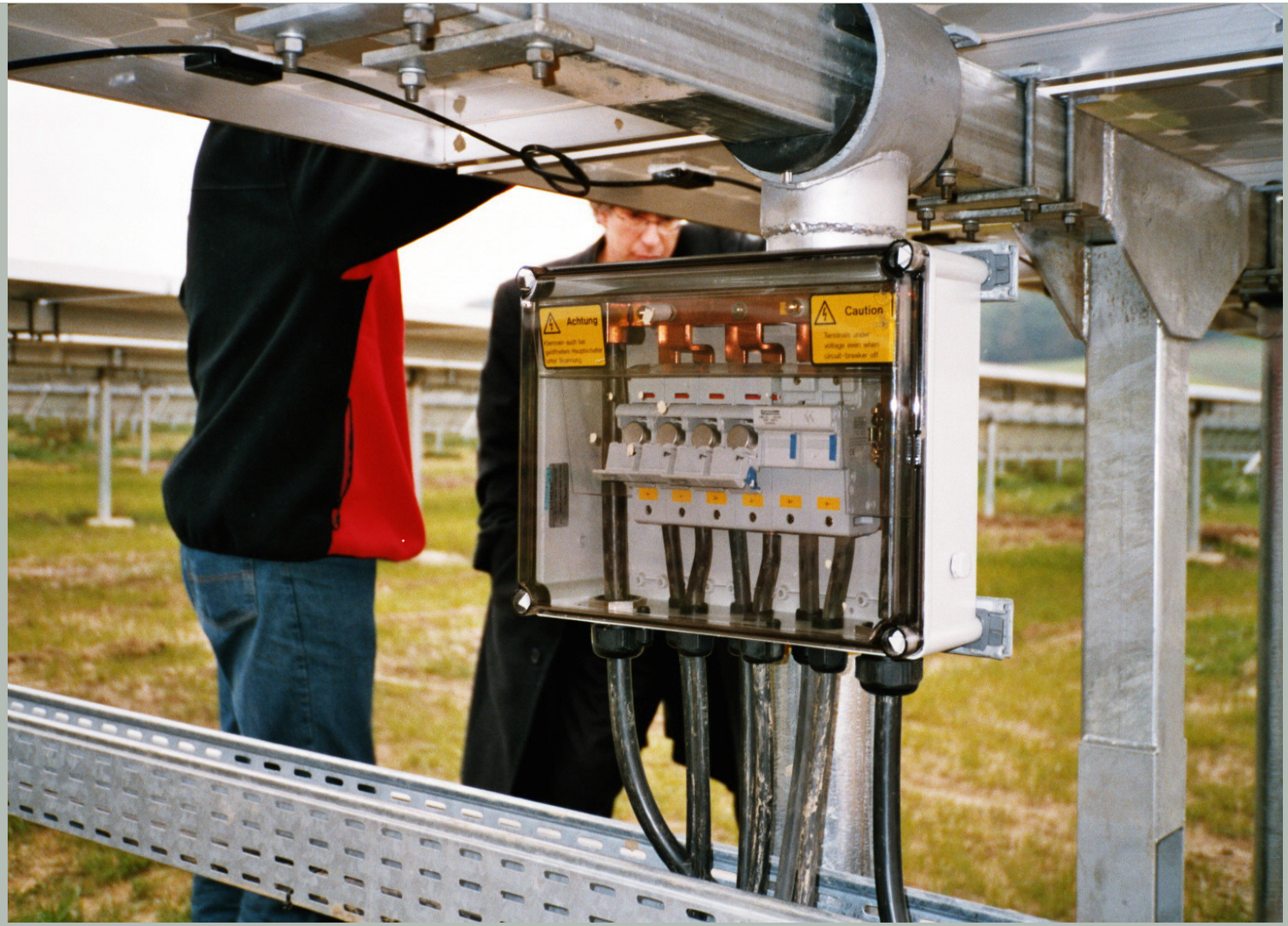
3 PROBLEMS WITH FUSE-LINKS



Picture 5:

PV generator junction box commissioning

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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

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4 Conclusion

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.

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4 Conclusion

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.

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Backup 2

SIEMENS