DETERMINATION OF FIRE SAFETY RISKS AT PV SYSTEMS AND DEVELOPMENT OF RISK MINIMIZATION MEASURES

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ABSTRACT: Since different discussions and research work in the recent past have contributed significantly to the entire aspect of fire risk and safety issues in photovoltaic systems, new challenges for the PV industry have evolved from these findings. With respect to other projects and joint working groups, a German 3-year research project, co-funded by the Federal Environment Ministry, started early 2011 to examine a wide range of fire related issues on photovoltaic products in order to support standardization groups, fire fighters, building authorities and component as well as module manufacturers regarding fire risks at PV systems. A broad view of the individual working packages, approaches and main goals will be given as very promising first results.

Keywords: Safety, BIPV, PV System, Reliability, Lifetime, Design

1 INTRODUCTION

As there are in general two substantial ways how PV components can be affected by fire, one has to differentiate between a fire resulting from a malfunction within the module or related components and an outer fire at or in a building influencing the integrity of the PV system.

Both cases require different safety measures that will be examined in the course of this 3-year research-project. Consequently, weaknesses within PV specific products, such as modules, j-boxes, cables, connectors, DC distribution boxes and inverters, will be evaluated, as these components are a possible source of increased fire risk.

Besides a detailed risk estimation with respect to the long-term perspective of modules, specifications will be defined for different concepts to enhance prevention measures and safety preservation of end users and fire brigades in cases of fire.

Enhanced safety measures and concepts for risk minimization will be developed and consequently presented within publications and to standardization groups.

The joint research project started in February 2011. Project webpage: www.pv-brandsicherheit.de.

2 MAIN GOALS OF THE PROJECT

2.1 Systematic risk evaluation of potential weaknesses within PV systems with regards to arcing risks

Fault electrical joints (e.g. soldering joints) within a module or system (connectors between modules, connections of strings and inverter etc.) may induce electric arcs due to the high currents and voltages. Basing on a research of different failure modes from the field/installed systems a correlation shall be achieved by identifying and evaluating the risks of fault contact joints with laboratory test.

On the basis of this risk analysis, measures shall be developed to ensure a permament quality of the electrical joints. The output will affect manufacturing, installation and inspection processes.

2.2 Identification of appropriate measures to ensure the avoidance of electric arcs and fire risks in PV systems

Precautionary fire protection consists of several individual aspects that need to be regarded. Whereas product and material specific issues are contributing to an integral fire protection, also technical devices for the detection and switch-off of electrical arcs need to be regarded. The project will determine requirements to also help to develop and qualify such devices.

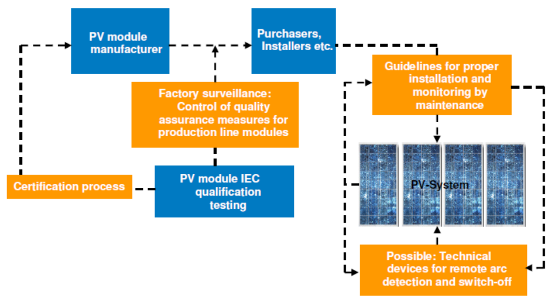


Figure 1: Risk minimization as network of different safety mechanisms.

2.3 Development of enhanced safety concepts for the fire protection of PV systems

As one of the centric goals, the risk minimization for rescue squads during the rescue or extinguish operation in a close distance to a PV system will be based on PV-application-wise safety concepts. The different concepts inhere either technical, constructional or administrative solutions. Requirements for lacking concepts will be worked out and adapted to system-wise measures.

3 RESULTS AND CURRENT WORK

3.1 Evaluation of single fire incidents

Based on press releases and information facilitated by insurance companies and technical experts, a first overview on cases where PV systems were the cause of fire or a hindrance to fire fighters was created.

Prominent cases involving injuries or important financial claims were researched individually in order to visualize the course of events and the mistakes and problems during these extreme incidents.

A systematic questionnaire was developed which aims to provide detailed insight into further incidents.

3.2 Determination of the electrical conductivity of extinguishing devices

VDE 0132 is stating safety distances for rescue squads avoiding the risk of electrocution when being close to power carrying parts while extinguishing a possibly damaged PV system during a rescue operation.

Different safety distances are listed for low and medium voltage applications when directing the extinguishing water jet towards or on the electrical conductor. The distances which have to be observed for low voltage (<1,5kV) are 1m for a spray jet and 5m for a full water jet [1].

In single test series employing different jet pipes, pipe adjustments, distances and extinguishing devices (water and foam), the electrical currents through an interconnection and resistance bridge were measured. The purpose of the tests was to estimate whether a dangerous current can run through the water jet which is touching an electrode from a distance with a potential of 1000V and carry it to a jet pipe, s. figure 2.

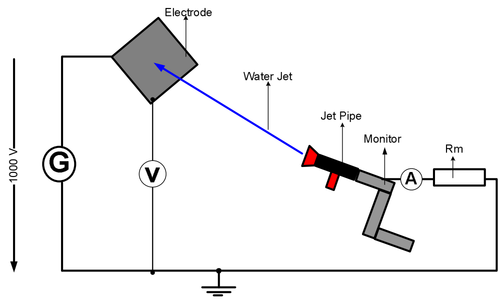


Figure 2: Principle est Set-up: Conductivity measurement, TÜV Rheinland 2011

To regard worst case scenarios, a load resistance in the range of realistic body impedances at 550 Ω (way: hand-hand, value 575 Ω of 5% of all people acc. to [2]) was applied to the interconnection to reproduce a person standing without any isolation connected to an earthed conducting material.

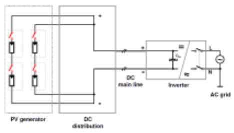
Figure 3: Testing conductivity of spray water jet at 1000V, TÜV Rheinland 2011

3.3 First evaluation on DC circuit breakers

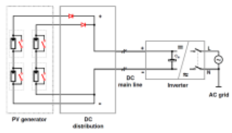
Recently, a surge of new prototypes and products that have the purpose of neutralizing potentially dangerous DC voltages in case of fire were presented by various business corporations.

In the course of the project, these developments were and will be monitored and categorized. The principles on which the devices are based have been presented and evaluated in a publication derived from this project.

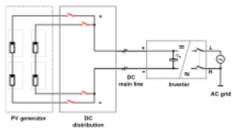
Circuit breakers on module level
Identified products: 2



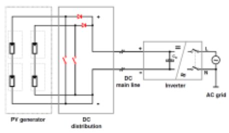
Short-Circuiters on module level
Identified products: 6



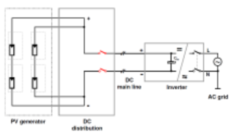
Circuit breakers on string level
Identified products: 3



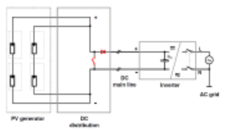
Short-Circuiters on string level
Identified products: -



Circuit breakers on DC main line
Identified products: 5



Short-Circuiters on DC main line
Identified products: 1



3.4 Testing: Fire behavior of PV modules as building components according to EN 13501-1

PV modules and their components are characterized e.g. by IEC 61730-1 in terms of flammability properties of polymeric materials. IEC 61730-2 defines as well as UL 1703 a fire test basing on a roofing application specific test method, UL 790.

For the integral compensation of building materials, which is a common way of PV assembling on a roof (BIPV), in Germany building authorities demand a construction products classification based on the German DIN 4102-1 or the European EN 13501-1.

For roofing applications, a flammability rating or classification with ‘E’ (acc. To EN 13501-1) is a minimal prerequisite.

The construction products classification according to this standard demands a defined flame which is applied under a 45° angle to the test specimen at the edges and surfaces.

Following the standard, it is allowed to test the material compound as installed on the building. The test specimen however has to be tested with the following dimensions:

- 90mm x 190mm (wxl), flaming at the edge
- 90mm x 230mm (wxl), flaming on surface

Using original full size modules, first exploratory analysis were carried out to estimate the flammability characteristics of both glass and backsheet characteristics.

Figure 4: Flammability Testing of PV-modules according to EN 13501-1

The integral testing series will be summarized and proposed as an applicable test method for PV modules.

4 SUMMARY

A three year integrated German research project on fire safety risks of PV systems is in line with a wide field of enhancing preventative measures on products side, during the installation and operation but also in the case of a damaged PV-system related to fire and the securing of rescue squads from electrical hazards.

The first results from individual work packages were achieved and summed up within this paper.

A detailed research on fire incidents on German PV installation was started to clearly estimate failures sources and evaluate the effect on surrounding materials and implication on a technical forecast by transferring these findings on accelerated testing methods for the laboratory.

Conductivity measurements on water jets and different jet pipes were carried out to support directly the basis of information of (fire) rescue squads.

As a part of medium-term applications from DC circuit-breakers, a first evaluation and characterization of such devices was conducted on the basis of available concepts or products.

In addition, flammability concerns play a certain role for the materials that are being used in PV-systems. Especially for integral products in the building shell similar requirements for the PV-systems in terms of flammability are demanded from the building authorities. Test series are developed to enable an applicable test method in the addition to material specific tests from the existing IEC standards.

5 CONCLUSIONS

The research project indicates fire safety risks with the goal to develop an integral fire safety concept for all PV applications, consisting of a strong variety of enhanced measures.

Results from the project are meant to be discussed and presented transparently to the industry as well as proposed for the definition of requirements in standardization committees.

The standardization of electrical risk-reduced joints at conducting materials as well as the proposal of requirements for technical devices such as arc detectors and DC circuit breakers is being to be solved and processed within this project. The output from these findings has a practical significance.

6 REFERENCES

[1] VDE 0132: 2008 – Firefighting and assistance in or near electrical installations

[2] VDE 0140-479-1: 2007 – Effects of curent on human beings and livestock – Part 1: General aspects

[3] IEC 61730: 2004 – Photovoltaic module safety qualification

[4] UL 1703: 2002 – Flat-plate photovoltaic modules and panels

[5] UL 790: 2004 – Standard test methods for fire tests of roof covering

[6] EN 13501-1: 2007 – Fire classification of construction products and building elements – part 1: classification using data from reaction to fire tests.

[7] DIN 4102-1: 1998 – Fire behavior of building materials and building components – part 1: Building materials, concepts, requirements and tests.

7 AKNOWLEDGMENTS

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