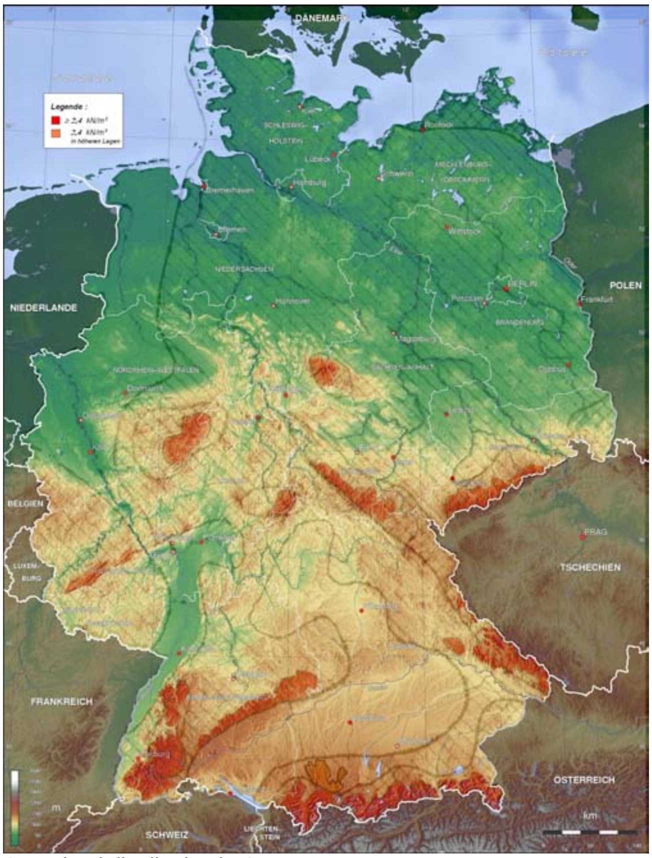
Introduction

In the winter of 2006/2007 rather extreme snow loads occurred in many places of Southern Germany, which in many cases led to building damage, in some cases even to collapses with the most severe consequences. So it was unavoidable that photovoltaic plants mounted in these regions were affected, too. In many cases the damage was due to loads „beyond the norms“, if you will, but also plants were damaged, which were only exposed to maximum snow loads within the norms, as posterior evaluations have shown.

The evaluation of the damage symptoms of these cases has to be the basis for constructive counter-measures, in order to further improve the quality of photovoltaic plants in the future. To make sure that constructive further developments can become part of future product cycles, the efficiency of such counter-measures has to be proven and controlled by adequate testing procedures.

Especially the introduction of the new engineering standards concerning load assumptions at buildings (wind loads acc. to DIN 1055, part 4 (03/2005) and Eurocode 1 (06/2002), snow loads acc. to DIN 1055, part 5 (06/2005)) reflects the empirical values of the last years.
So, for example, in many areas of Southern Germany much higher snow load values have to be considered. Furthermore a special load approach for snow accumulations at the lower edge of the roof has been introduced, which has to be considered in static calculations.



Snow load distribution in Germany

In the course of the testing of the stability of photovoltaic plants according to the valid norms (IEC 61215, IEC61646) this snow accumulation related load concentration has not been considered up to now. A first schematic approach in this matter is done by the RAL-Solar Association with the RAL GZ 966.

This present compilation is a suggestion for a future module test for a realistic proof of stability of modules following RAL GZ 966.

1 Evaluation of module damage – mechanism of failure

In the winter of 2006/2007 rather extreme snow loads occurred in many places of Southern Germany, which in many cases led to building damage, in some cases even to collapses with the most severe consequences. So it was unavoidable that photovoltaic plants mounted in these regions were affected, too. In many cases the damage was due to loads „beyond the norms", if you will, but also plants were damaged, which were only exposed to maximum snow loads within the norms, as posterior evaluations have shown.

The evaluation of the damage pictures of these cases has to be the basis for constructive counter-measures, in order to further improve the quality of photovoltaic plants in the future. To make sure that constructive further developments can become part of future product cycles, the efficiency of such counter-measures has to be proven and controlled by adequate testing procedures.

In all cases of damage primarily the lower module rows were affected. In these lower rows in most cases the lower parts of the module frames had come off the laminate and were pushed outwards (respectively downwards in direction of the eaves) by the snow and ice load. In many cases the laminate was broken and deformed. Combined with the reports about the weather events the following damage scenario unfolds:
Big snow loads; the laminates bend through. The module areas are affected most by the snow accumulations. Due to the bending through of the laminate the lower module rail offers an even bigger contact surface for loads in direction of the roof inclination; in turn the laminate loses more and more stability due to the deformation of the module frame. Because of periods with higher temperature during the day the lowest layer of snow partially melts and freezes to ice again during the night. In combination with further snowfalls a layer of extraordinarily high density comes into being. In addition to that, the complete layer can move downwards almost frictionless on the surface of the modules, but at the same time the module frames are frozen in a form-closed manner. As a consequence of that, the complete downhill-slope force burdens the lower parts of the module frames, and thereby causes the known damage scenario. Mostly affected are modules with relatively unstable frame profiles and / or modules, whose module frames are not connected in a sufficiently stable manner with the laminate.

2 Damage symptoms - Examples

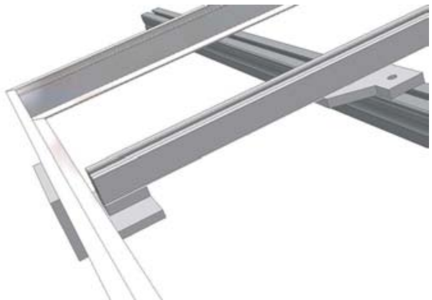
3 Counter - measures

The aim of further developments must be to rule out the described kinds of damage.
As these extreme load conditions do not arise in all regions, but statistically only in a few regions, different options are available.

a) Structural strengthening of all module series for the arising extreme loads.

b) Structural strengthening of specific module series for the arising extreme loads and the selection of the modules according to regionally arising snow loads.

c) Renouncement of the general structural strengthening of modules; Application of additional external measures in critical regions, for example by taking additional measures concerning the substructure.
(see example picture).



In each of the three cases the efficiency of the according counter-measure has to be proven within the framework of an extension of the corresponding module tests (for example acc. to IEC 61215). Until now, mechanical tests of modules have only been carried out in horizontal position and with evenly distributed loads. The testing procedure that is presented here is supposed to additionally or also alternatively simulate the following loading scenarios in a realistic manner:

1. **Snow accumulations on the lower module area simulated by a close to reality loading distribution onto the module area.**

2. **The downhill-slope force of the complete ice and snow layer burdening the modules is put on the module frame as an additional load on the lower module frame.**

4 Test procedure in addition to RAL GZ 966

The basic idea for the testing of modules in diagonal assembly and with a realistic load distribution originates from the RAL-Solar research group. From the evaluations of the damage symptoms of winter 2005/2006 in this committee possibilities to grant and control counter – measures against the occurred damage symptoms were discussed. The original schematically drafted load approach with „sand bags“ still has weak points, which are supposed to be circumvented with the test assembly presented here.

- The form of the sand bags influences the test result (no optimum reproducibility)
- The sand bags only put very insufficient load on the lower module frame.
- If the sand bags are put on glass, there will be static friction. However, a minimum frictional coefficient is realistic (melting ice on glass).
- When sand bags are used the transition from static friction to sliding friction depends on many external parameters (Material of the sand bags, glass surface, air moisture, coated surface layers) etc.. Therefore the test results would only be insufficiently reproducible.

The present test procedure adapts the basic schematic approach and completes it to a scientifically reproducible test procedure, which practically cannot be influenced by external boundary parameters.

GÜTE- UND PRÜFBESTIMMUNGEN RAL GZ 966:

Novellierungsvorschlag der Bestimmungen für die qualitative Differenzierung von Photovoltaikmodulen zur öffentlichen Diskussion

In der Fassung der Güte- und Prüfbestimmungen RAL GZ 966 vom Mai 2006 wird im Bereich Qualitätsanforderungen für Photovoltaik-Module auf die IEC 61215 Bezug genommen. Diese beinhaltet Tests für Umweltlasten, die durch Schnee, Wind, Strahlung, Temperaturunterschiede, Feuchte, Frost und Hagel auf Photovoltaikmodule wirken.

Im Rahmen der Mitgliederversammlung der Gütegemeinschaft Solarenergieanlagen wurde eine Novelle dieses Bereiches der RAL GZ 966 durch die Einführung erweiterter Testverfahren beschlossen, die den Marktteilnehmern eine bessere qualitative Differenzierung von Photovoltaikmodulen ermöglicht.

Die Testbestimmungen gemäß IEC 61215 sehen vor, dass 6 PV-Module in 3 Pfaden auf Umweltlasten getestet werden. Zur besseren qualitativen Differenzierung der Module bringt die Gütegemeinschaft folgenden Vorschlag in die öffentliche Diskussion ein:

Analog zu dem Aufbau der IP Schutzart für elektrische Gehäuse soll ein System geschaffen werden, welches die Anforderungen verschiedener Umweltlastklassen auf Module für jedermann transparent durch zwei Ziffern kennzeichnet.

RAL-Umweltlastgrad:

RAL 1 3
[erste Ziffer, zweite Ziffer]

Die erste Ziffer symbolisiert hierbei den Umweltlastgrad für Temperatur-, Feuchte- und Frosttests. Die Skala reicht von 1 bis 7.

Die zweite Ziffer symbolisiert den mechanischen Lastgrad während der Modultests. Sie reicht ebenfalls von 1 bis 7.

Damit sich das System nahtlos in die bestehenden Regelungen einfügt, entspricht ein RAL 11 Modul exakt dem IEC 61215 Lasttest in der normalen (2,4 kN/m²) und ein RAL 13 Modul in der erweiterten (5,4 kN/m²) Ausführung.

Die folgenden Tabellen geben Auskunft über die Klassifizierung der Anforderungen nach dem RAL-Umweltlastgrad in beiden Ziffern.

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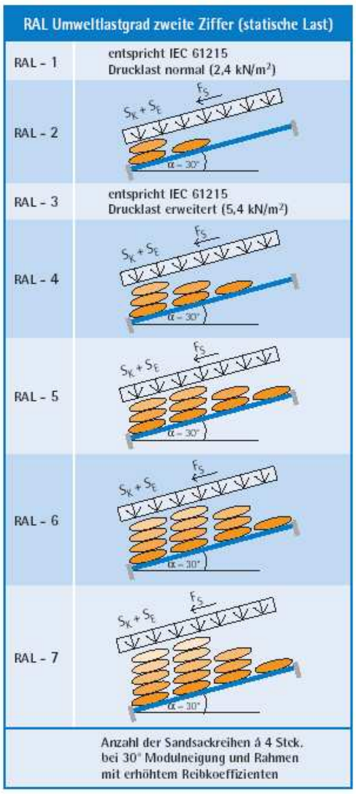
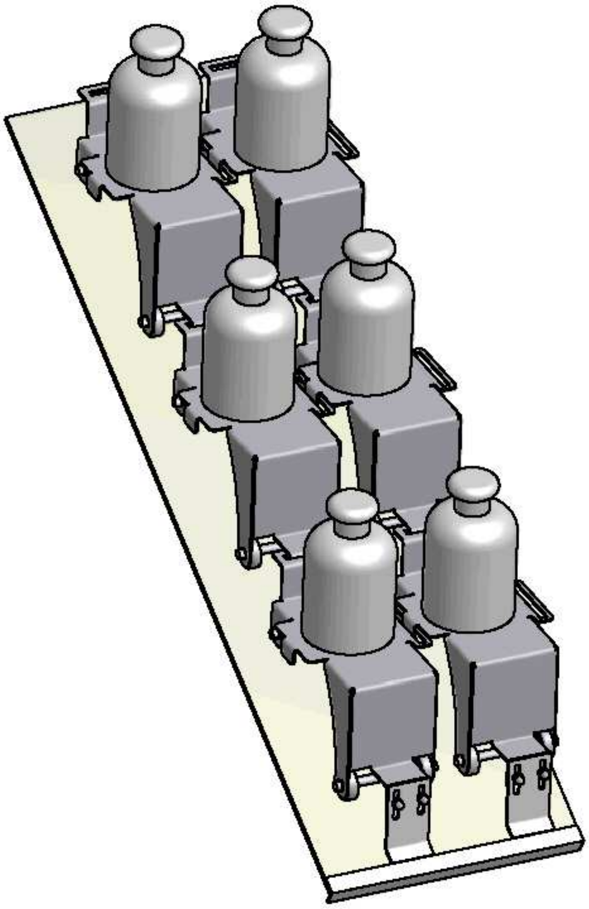


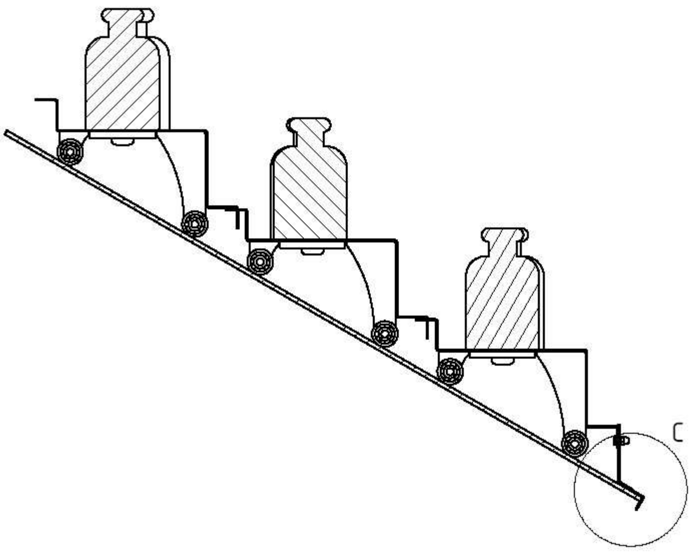
RAL Umweltlastgrad erste Ziffer (UV-Strahlung, Temperatur, Feuchte, Frost, Mechanik, Hagel, Zug und Kriechstrom)									
	RAL - 1	RAL - 1	RAL - 1	RAL - 2	RAL - 3	RAL - 4	RAL - 5	RAL - 6	RAL - 7
	IEC 61215 Standard entspricht RAL - 1						Automotive Minimum	Automotive Standard	Automotive Heady Duty
Anzahl Module	2	2	2	mindestens 1	mindestens 1	mindestens 1	mindestens 1	mindestens 1	mindestens 1
UV-Vorkonditionierung	15 kWh	-	-	15 kWh	15 kWh	15 kWh	15 kWh	15 kWh	15 kWh
thermische Belastung	50 Zyklen -40° bis +85°C	200 Zyklen -40° bis +85°C		50 Zyklen -40° bis +85°C	100 Zyklen -40° bis +85°C	200 Zyklen -40° bis +85°C	500 Zyklen -40° bis +85°C	1.000 Zyklen -40° bis +85°C	1.500 Zyklen -40° bis +85°C
Feuchte/Wärme Prüfung	-	-	1.000h +85°C und 85% Feuchte	1.000h +85°C und 85% Feuchte	1.000h +85°C und 100% Feuchte	1.000h +85°C und 100% Feuchte	1.000h +85°C und 100% Feuchte	1.000h +85°C und 100% Feuchte	1.000h +85°C und 100% Feuchte
Luftfeuchte/Frost Prüfung	10 Zyklen -40° bis 85°C bei 85% Feuchte	-		10 Zyklen -40°bis 85°C bei 85% Feuchte	50 Zyklen -40° bis 85°C bei 100% Feuchte	100 Zyklen -40° bis 85°C bei 100% Feuchte	500 Zyklen -40° bis 85°C bei 100% Feuchte	1.000 Zyklen -40° bis 85°C bei 100% Feuchte	1.500 Zyklen -40° bis 85°C bei 100% Feuchte
Mechanische Last	-	-	IEC 61215 Druck-Zug mit 2,4 kN/m²	IEC 61215 Druck-Zug mit 2,4 kN/m² + siehe RAL Ziffer 2	IEC 61215 Druck-Zug mit 2,4 kN/m² + siehe RAL Ziffer 2	IEC 61215 Druck-Zug mit 2,4 kN/m² + siehe RAL Ziffer 2	IEC 61215 Druck-Zug mit 2,4 kN/m² + siehe RAL Ziffer 2	IEC 61215 Druck-Zug mit 2,4 kN/m² + siehe RAL Ziffer 2	IEC 61215 Druck-Zug mit 2,4 kN/m² + siehe RAL Ziffer 2
Hageltest	-	-	Eiskugel 25mm mit 23m/s auf 11 Stellen	Eiskugel 25mm mit 23m/s auf 11 Stellen	Eiskugel 25mm mit 23m/s auf 11 Stellen	Eiskugel 25mm mit 23m/s auf 11 Stellen	Eiskugel 25mm mit 23m/s auf 11 Stellen	Eiskugel 25mm mit 23m/s auf 11 Stellen	Eiskugel 25mm mit 23m/s auf 11 Stellen
Festigkeit Anschlüsse	40 N Zug, Drehmoment	-		40 N Zug, Drehmoment	40 N Zug, Drehmoment	40 N Zug, Drehmoment	40 N Zug, Drehmoment	40 N Zug, Drehmoment	40 N Zug, Drehmoment
Kriechstromprüfung unter Benässung	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys	500 V oder Umax, sys

RAL Umweltlastgrad zweite Ziffer (statische Last)								
Umwelt-lastklasse	Schneelast Sk	Gesamtlast bei 30° =Sk+Se (b=1m)	Höhengrenze (m) von Module mit 30° Neigung laut Schneelastkarte DIN 1055					Resultierende Hangab-triebslast auf Rahmen Fs
			Zone 1	Zone 1a	Zone 2	Zone 2a	Zone 3	
RAL - 1	1,97 kN/m²	2,40 kN/m²	ok	700	575	500	425	keine, da IEC 61215 normal (2,4 kN/m²)
RAL - 2	2,32 kN/m²	3,00 kN/m²	ok	800	675	575	525	0,93 kN/m
RAL - 3	3,50 kN/m²	5,40 kN/m²	ok	ok	850	725	625	keine, da IEC 61215 erweitert (5,4 kN/m²)
RAL - 4	3,75 kN/m²	6,00 kN/m²	ok	ok	900	750	675	1,50 kN/m
RAL - 5	4,89 kN/m²	9,00 kN/m²	ok	ok	1.075	925	825	1,95 kN/m
RAL - 6	5,86 kN/m²	12,00 kN/m²	ok	ok	1.175	1.025	900	2,34 kN/m
RAL - 7	6,72 kN/m²	15,00 kN/m²	ok	ok	ok	1.125	1.000	2,69 kN/m

Suggestion for a classification into load classes according to RAL GZ 966

5 Schematic picture of the test assembly





6 Explanations on the test procedure

In the suggested procedure the module, in addition to the horizontal load that was applied up to now, is elevated in the representative position with an inclination of 30 degrees and fitted with an arrangement of loosely connected movable load holders. The individual movable load holders are loaded with load units in any desired pattern, in order to gradually simulate the loading. This test assembly has the following characteristics, respectively advantages:

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- The accumulations of snow loads acc. to DIN 1055, part 5 (06/2005) can be variably simulated without big effort.
- By an adequate arrangement of the weight units any load onto the modules can be simulated. Thereby a module can be gradually loaded and so can be classified into different load categories acc. to the suggestion of the RAL – committee, without having to change the test setup.
- The small size of the load holders and their individual movability within the arrangement allow a realistic and a sufficiently accurate distributed loading of the test loads within the pattern.
- The movable test load holders are so narrow that the force applied on the lower module frame is divided up into a sufficient number of partial vectors, and thereby the real load is simulated in the best possible way.
- The practically frictionless mounting above the ball bearing simulates in an optimum manner the worst case of downhill-slope force, like it also arises in reality in case of melting ice layers, for example.
- The practically frictionless mounting above the ball-bearing grants optimum reproducibility of the test results and the independence from interfering test parameters like static friction, material influences, the condition of the surface, air moisture, etc..
- The load application from the modules onto the frames takes place at certain connection spots and simulates the real worst case of a frame frozen into an ice-layer.
- The suggested testing procedure is cost-efficient and therefore is also suitable for pretests by the producers parallel to the development process or for example also for the testing of modules of more or less unknown origin by installation companies.

7 Summing up and further proceeding

In the interest of a further professionalisation of the market for photovoltaic plants new, respectively extended testing procedures for all components have to be worked out in order to minimize as far as possible, respectively avoid any risk of failure in future applications. To achieve this goal it takes an open dialogue between module producers, testing institutes, producers of mounting systems and especially installers. The associations should play the role of an intermediator here.

The present suggestion for a module testing procedure has been worked out by the mounting system producer Schlettter GmbH on the basis of the „quality and testing regulations RAL GZ 966“, which also form the basis for a future classification of the modules into different load classes. Therefore, a joint patent is to be applied for for the elaborated test procedure.
The other market participants, from module producers to installers, are free to use these suggestions as a basis for a further development of the module geometrics.