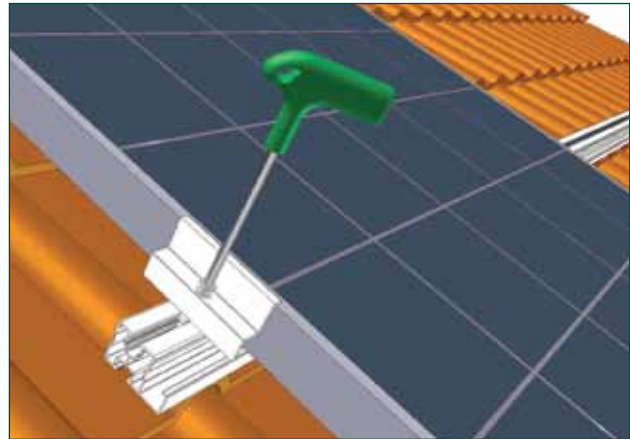


Module mounting

General information



As there are more and more photovoltaic plants, mounting details are getting ever more important besides electric parameters, warranty periods and durability. In the early days of photovoltaics, only small numbers of modules were installed on roofs, but now there are numerous mounting options for all kinds of roofs up to big-surface roofs of industrial buildings or installations in open areas. The increasing number of solar installations results in a certain statistical rise of damage cases. Thus, insurance companies are trying to gain more influence on the quality standards of solar plants.

Unfortunately, there are only very few electrical and mechanical standards that determine how the installer has to carry out an installation according to the norms. Only if there are exact specifications and standards, the installer can pass on the liability risk to the producer. This compilation is supposed to inform about unsolved problems and to pave the way for binding standards in the future.

1 Problems in today's module mounting: A few examples

Many producers still (as for autumn 2008) have no realistic concept of the fastening of modules to the substructure. By now, some module producers have taken action and have issued accordant mounting instructions, other producers are at least working on accordant instructions.

The following examples highlight some problems that have not been given much attention until now.

1.1 Module fastening

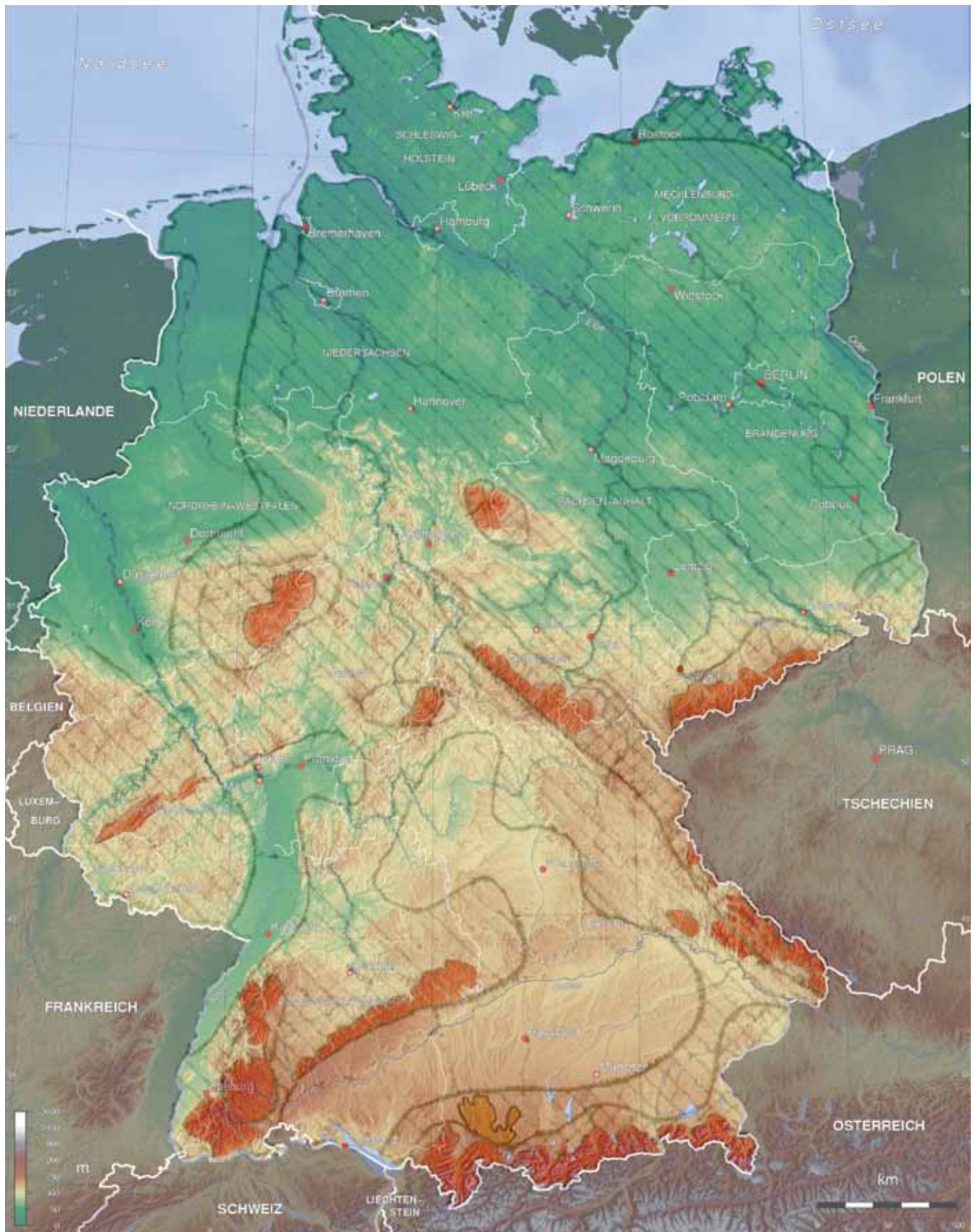
Most modules have holes at the back side that are intended for screwing the module to the substructure. In reality, these fastening holes cannot be used, because in case of numerous modules, they are simply not accessible when the modules are mounted. Moreover, mounting with many little screws at the lower side of the module is almost impossible on the roof and hardly affordable in view of the mounting time that would be required.

So the mounting holes are not utilized in virtually all mounting variants. Nevertheless, many module producers still refer to mounting holes as the only reliable kind of fastening. Thus, the installer virtually has to bear the complete liability risk when mounting.

1.2 Reliable distributed load onto the modules

With an approval according to IEC 61215, the modules are usually loaded with a distributed load of 2400 Pa (this corresponds to 2.40 kN/m² or ca. 240kg/m²). The fact that this distributed load is exceeded in areas with higher snow loads is often ignored. A higher test load of 5400 PA is possible within the framework of the IEC-test, but this is not legally prescribed.

The admissible load-bearing capacities of the modules (regardless of the mounting system that is used) is often ignored or exceeded when solar plants are installed. The following chart shows application limits for modules with a test value of 2400Pa.



Picture: Specially created limit snow load chart 2.4 kN/m^2

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(The areas marked in orange/red show an exceeding of the limit of 2.4 kN resp. 240 kg/m^2)

1.3 Admissible distributed loads with different kinds of mounting

The admissible loading onto the modules does not only depend on the approval of the individual module, but also depends on the kind of mounting and the mounting system. A verifiable load-bearing capacity of the module can only be assumed if the module is fastened or at least supported at the spots determined by the module producer.

With current support systems, usually the full load-bearing capacity of the module frame according to IEC is reached (an approximately ideal position of the cross beam is a precondition). With inlay systems, the load-bearing capacity of the module frame has to be reduced considerably.

1.4 Selling of mounting systems without consideration of specific local conditions

Different kinds of sales structures have been established in the PV-industry. Like the modules, the mounting systems are traded on multi-level distribution structures. In many cases, the installation site is not even known when the dimensioning is carried out. If you compare the different snow loads from 0.55 to 0.75 kN/m² (in normal regions in Germany) to the snow loads of 5 kN/m² in higher regions, you will instantly realize that these regional differences definitely should be considered. Especially with the implementation of the new DIN 1055, the differences between the assumable loads have further increased.

1.5 Earthing and potential equalization

According to the currently valid standards, there is no absolutely clear regulation whether or not module frames have to be earthed. However, according to the application guidelines by the module producers and the inverter producers, the earthing of the module frames is compulsory in almost 100% of the cases, which also makes it compulsory for the installer. Earthing can be carried out by means of accordant earthing lines or by means of alternatively suitable earthing module clamps or additional components. In most cases, it is not taken into account that there is no earthing of the modules in case of normal mounting due to the anodization of the module frames.

In practice, there often is no earthing of the module frames, which can lead to operational disturbances and even to danger to persons, especially if transformerless inverters are used.

- ➔ Earthing check
- ➔ Potential equalization

1.6 Lack of definitions of the areas of responsibility

In subparagraph 1.1, we already explained that there still are no feasible mounting instructions from the part of the module producers. Some module producers are starting to certify certain mounting systems in combination with their modules, but only very simple mounting cases are covered by such "combined certifications".

As the market is getting increasingly professional, unrestricted combinability of different mounting systems and different kinds of modules is required. The interfaces between module and mounting system have to be defined in agreements respectively in technical standards. If module producers limit their

approval to certain brands of mounting systems, the problem is not solved, as these mounting systems often are only applicable for very few kinds of roofs respectively mounting forms.

1.7 Mounting of laminated modules

Laminated modules have to be regarded as a special case. The kind of fixation for these modules is absolutely undefined in many cases or is left to the installer, who has to bear the liability risk in case of damage. It has to be explicitly stated that many unframed modules are not submitted individually to the IEC-testing, but often are declared as "standard modules sold without frames".

Basically, every producer has to give the installer exact guidelines for the fastening of laminated modules. These guidelines have to be met by the utilization of suitable mounting systems, but especially by a suitable kind of fastening.

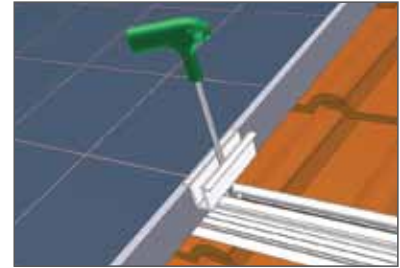
At the moment, the installer who installs laminated modules bears most of the liability risk due to the lack of binding guidelines.

Further examples for the danger of faulty dimensionings – especially regarding heavy loads - can be looked up under item 5.

➔ General information about laminate mounting

2 Mounting with module clamps

Mounting with so-called module clamps has become the most popular kind of mounting for the mounting of framed standard modules on different kinds of roofs and also for open area plants, even if this kind of mounting is not yet considered by many module producers when modules are certified (see also item 1.1). As a fastening with small screws at the fastening holes at the lower side of the modules usually is absolutely unfeasible, the kind of fastening mentioned above will further prevail and will have to be considered by all module producers.



For a standardization of this kind of fastening, the clamping of the modules should meet certain quality criteria:

- **Minimum length of the clamps**

Clamping leads to pressure on the module (glass and frame) that has to be distributed on a length as long as possible respectively on an area that is as big as possible. Otherwise, punctual tension peaks in the glass will arise that can lead to glass breakage. A clamp lengths of 100 mm has proven to be suitable.

- **Stiffness of the clamps**

The clamping pressure can only be distributed on the module, if the clamp has a sufficient stiffness. Aluminum wall thicknesses of 3 mm and high vertical bars (if possible) have proven to be efficient for longitudinal pressure distribution. Clamps that are too short or not stiff enough deform when they are mounted. Thus, they cannot safeguard a sufficient clamping force and lead to a considerable punctual load on the module in the area of the fastening screw.

- **Suitable end clamp shapes**

At the end of a module row, the module clamping is most important. End clamps made of aluminum profile with sharp-edged inner contour safeguard the best possible grip on the module frame. The pressure spot of the clamp on the load bearing profile must be outside of the bolted connection - the "balance" that is created like that results in an optimum clamping pressure.

- **Optimum clamp height**

The optimum clamp height is lower than the module frame height. Thus, only minimum thermal alternating loads arise due to the different expansion coefficients of the screw and the module frame.

- **No clamping with simple screws or plates**

If simple washers are used, pressure distribution is not possible. Thus, strong pressure is put on the module frame and possibly also on the module glass. Moreover, no sufficient clamping pressure is reached, as the washer will already bend through when low tightening torques are applied and thus the bolted connection is loosened.

- **Attention with screws in the aluminum duct**

In many cases, mounting systems are offered whose module clamp screws are directly screwed into the aluminum profiles that are corrugated accordingly. Flawless mounting can only be safeguarded if the tightening torque is controlled by 100%.

On the basis of our own tests with individual products (Schletter GmbH, 2003), we definitely cannot recommend this kind of bolted connection.

- **Screw locking**

Generally, a screw locking has to be provided for clamped connections.

- **Anti-theft device**

A theft-proof design of the screwed connections should be possible, if the customer wants that.

- **Materials of the clamped connection**

Screws and nuts made of high-grade steel have been tried and tested. Due to the danger of cold welding, no quality steel materials of the same kind should be combined. With constructional elements (for example insertion components made of aluminum, etc.), a sufficient torsional stiffness has to be safeguarded! If threads made of aluminum are used, mounting using a torque wrench is absolutely compulsory.

- **Possibilities to check the clamped connection**

If trapezoidal nuts are utilized, the correct position and grip of the screwed connection have to be controlled by all means. Thus, restraint-guided and thereby fault-tolerant components are preferable in the load-bearing profile.

- **Earthing clamps**

At least when inverters without transformers are utilized, middle clamps with potential connection should be optionally available.

- **Anti-skid devices**

So if a suitable module clamping is utilized, the mounting without any additional anti-skid device theoretically has been verified several times and has been proven in practice for several years. Additional anti-skid devices using hooks in the lower row or using screws in the module frame are optionally possible. Anti-skid devices are absolutely required for the clamping of unframed modules, as no sufficient clamping force can be transmitted due to the utilization of material-protecting rubber inlays.

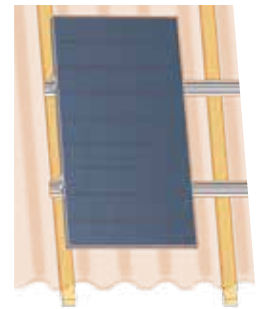
3 Comparison of current mounting forms: One-layer systems or cross rail systems

One-layer systems are most frequently used when standard modules are installed on different kinds of roofs and in open areas. But in some cases, cross rail systems can bring about advantages. But quite often, faulty dimensionings are created for cross rail systems.

The following comparison only refers to normal pitched roofs, because special constructions have to be used for special requirements that are not included in the following comparison.

3.1 One-layer systems - advantages

- Low costs
- Only little energy required
(If aluminum materials are used, minimum material consumption is to be desired)
- Reasonable arrangement of the fastening spots on the roof



3.2 Cross rail systems - advantages

- Better areal alignment on uneven roof constructions
- Optimization of the module fastening
- Universally applicable also on purlin roofs



3.3 Cross rail systems - frequent dimensioning errors

On pitched roofs, the connections to the roofs (roof hooks, hanger bolts, etc.) are generally the weak spot of the construction. So it has to be made sure by all means that the fastening elements are placed as close as possible to each other. The increased number of rails of the cross rail construction does not lead to a direct improvement of stability. In most cases, the fastening patterns respectively the rail distances are too big, so that far fewer fastening spots than required are installed.

In contrast, one-layer fastening systems mostly contain more fastening spots at comparatively little extra costs, and thus are suitable for bigger distributed loads.

The situation is often misjudged when the mounting is carried out. For example, an installer installs a cross rail system and checks the stability of the construction by punctual loading (in most cases using his own bodyweight). Because of the better load distribution, cross rail systems seem to be more stable in such punctual loading tests than one-layer systems. In practice, the loads that occur are always distributed loads (snow load, wind load). In view of these distributed loads, only a sufficiently high number of fastening spots is decisive at the end of the day..

With all dimensionings of one-layer systems, the number of fastening spots is higher than with comparable dimensionings of cross rail systems.

4 Comparison of today's kinds of mounting: Special form: inlay mounting

Due to visual advantages, inlay mounting of modules is preferred by many customers. But with this method of mounting, the structural characteristics (item 1.3) have to be considered by all means.

4.1 Inlay mounting - advantages

- Visually attractive due to a coherent module area
- Quick module mounting

4.2 Inlay mounting - disadvantages

- Painstaking alignment of the substructure
- Different systems are required for different module heights
- Due to impeded drain-off, the modules easily get dirty
- More rails are needed
- In many cases, there is only an insufficient structural connection to the roof

4.3 Inlay mounting - structural loading of the modules

Advantages and disadvantages of inlay mounting are more or less a matter of your personal point of view. The visual appearance may possibly justify the installation of a higher number of rails.

But the structural load on the module frame must never be ignored.



Scheme:
Support distances of the module frames
with inlay mounting



Scheme:
Support distances of the module frames
with support on cross beams

As already explained in 1.2 and 1.3, the mechanical load test according to the IEC standard is only conditionally relevant for practical applications.

With normal mounting on cross beams, the load in practical application and the test loads are almost identical. Only if there are bigger deviations of the cross beam positions from the ideal support distances, the load on the module frame is higher in practical applications than in the test.

With inlay mounting, the support positions vary significantly from the IEC-test conditions. In practice, the module frame is charged up to 500% more by distributed loads (wind loads, snow loads) than in IEC test conditions.

Strictly speaking, the application of an inlay system is only permissible in case of big distributed loads (snow loads), if the module has been certified for this kind of mounting. If modules that are certified according to IEC 61215 are installed in this manner, the module producer can deny all warranty claims due to the considerably higher loads on the module. **So if you want to use this kind of mounting, it is definitely recommendable to get an accordant approval by the module producer.**

5 Dimension information in case of big loads

In certain regions, special load parameters have to be taken into account. The new DIN 1055 differentiates between zones with different wind loads and also (like in the versions until now) regions with different snow loads. Especially regarding the snow loads, there are very big differences between regions with normal loads (for example 0.55 to 0.75 kN/m²) and higher loads (up to 5kN/m² in higher regions). Only if the mounting system and the building that provides the substructure are optimally synchronized, there will be economic and safe solutions.

The weakest link of the chain always limits the overall stability.
A few examples:

- **Roof hook layout on pitched roofs**

A pitched roof is structurally dimensioned as a unit. When a PV-plant is installed, the bearing capacity of distributed loads must be maintained, as the roof has to bear the load of the PV-plant in addition to the snow load. Especially with high loads, roof hooks have to be fixed to every rafter, as every rafter has to bear part of the load after mounting. If there are big distributed loads, it is not reasonable to save costs by mounting extra stable hooks to only every second rafter.

- **Roof hook layout on pitched roofs**

Every roof hook is only as stable as its fixation to the roof. Here also applies the following: It does not make sense to reduce the number of roof hooks, as each hook can only be fixed to the rafter with a limited number of screws.

- **Clamping components for sheet metal roofs**

Even the most stable clamp (standing seam clamp, Kalzip clamp, trapezoidal sheet metal clamp) can only transmit as much force as the roof can take at the respective spot. Thus, the stability of the fixation to the roof has to be checked first, especially in case of elevated photovoltaic installations.

- **One-layer systems or cross rail systems on pitched roofs**

Especially with high loads, cross rail systems are often preferred. But it is often ignored that roof hooks can be fixed to every rafter without problems when one-layer systems are installed. It is also possible, to load the rafters evenly by shifted mounting.

When cross rail systems are used, an evenly distributed loading of the roof can only be granted if a vertical rail can be placed on every rafter. But this is often not carried out for cost reasons.

- **Big plants on flat roofs of halls**

The mounting of big plants on buildings generally requires a check of the structural analysis of the building. But this approach has certain limits: How far does the check of the structural analysis go?

The load-transmitting connection of the fastening spots in the roof have to be checked in any case as well as the load-bearing capacity of the roof substructure in connection with the whole building structure. Strictly speaking, this is not the last interface either. In case of big flat roof plants, the elevation of the rows increases the wind impact on the roof considerable, as the roof is not flat anymore with a PV installation on it. In case of strong wind, a considerable horizontal pressure impacts the whole construction that has to be absorbed especially by the diagonal bracings of the building and reaches down to the foundations. In most cases, these far-reaching consequences are not considered.

- **Loading solutions for flat roofs**

This kind of fastening can go along with a potential "danger for life and limb" of third parties. PV-plants on flat roofs are often offered as loading solutions without any further planning and are also installed like that. This implies a maximum danger potential for the installer and liability claims that can possibly lead to bankruptcy or even criminal prosecution.

a) Being a specialized company, the installer has to dimension the loading according to all parameters (roof height, wind zone, terrain category, module size, etc.) in such a manner that uplifting, sliding and overturning can be absolutely ruled out. If this loading fails in a storm, third parties can be harmed by plant components falling off the roof.

b) The dimensioning of the loading according to item a) is only possible, if the flat roof definitely can bear this load plus the local snow load and the weight of the photovoltaic plant. It has to be taken into account that according to the guidelines of the new DIN 1055, quite often very high loadings are required to fasten a plant correctly.

The admissible punctual loads have to be taken into account in order to avoid damage to the roof cladding. Taking into account the maximum distributed loads is even more important, because the building structure might collapse if these maximum loads are exceeded.

Thus, the installer has to check on the basis of the structural analysis of the building, whether or not the roof structure can bear the additional load of a PV plant and especially the loading required for the fastening of the PV plant.

Especially after the serious weather events in the winter of 2005/2006, the importance of the dimensioning criteria should be clear to anybody.

c) The continuation permit for existing buildings is another important item after the amendment of the DIN1055. According to the new standard, a location in the south of Bavaria can now have a snow load of 1.6kN/m^2 instead of 1.2kN/m^2 until now. A hall that was buildt in Germany before the amendment of the standard with a load-bearing capacity of 1.4kN still is covered by the continuation permit regulations, but if an expert company installs a photovoltaic plant, the new loading guidelines apply for the structural analysis, and the continuation permit for the buidling is not valid anymore if new facilities are installed.

➔ General information about flat roof mounting

These examples are supposed to show that there is no "overall solution of fastening technology" that can replace a thorough dimensioning by a mounting system producer.

The increasing professionalism of the market requires also a specialization of the producers and qualified advice for the installers to safeguard the mounting quality of the plants in the long run.

6 Load assumptions

Special load assumptions for the mounting of solar plants on buildings do not yet exist at all. The usual "load assumptions for buildings" according to DIN 1055 were revised in 2005, but regarding solar plant constructions, the structural engineer in charge still has too much room for interpretations. Especially the superimposed loads for open area plants without roof perforation are difficult to determine. Moreover, there are no comparable load assumptions for wind and snow loads for all European countries, which makes free trade with fastening systems more difficult.

7 Types of mounting for laminated modules

➔ General information about laminate mounting

8 Summary

The present compilation surely shows some deficiencies in the mounting of photovoltaic plants and thermal solar plants until now. But at the same time, it is supposed to be a basis for debates in order to eliminate these deficiencies in the long run. In cooperation of the mounting system producers with the certifying institutes (for example TÜV, RAL, VDE, etc.) as well as in the accordant work committees (for example RAL association, DGS, BSW, etc.), useable load assumptions and separations of competences and liabilities between the producers of modules and mounting systems have to be found.

It must be the aim of all common efforts to further improve the mounting quality in the long run, to reduce the liability risk for the installer as far as possible and especially to maintain the high level of acceptance of solar plants in the public opinion.