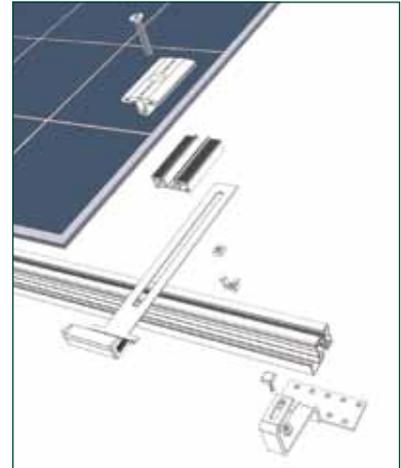


Mounting of thin-film modules

General information



Generally, there are no universally valid guidelines for the mounting of thin-film modules. As there are so many different thin-film module designs, it is impossible to create universally valid mounting instructions, a standardization of the mechanic details is not to be expected in the near future, either.

When thin-film modules are used, the installer in charge has to request the respective mounting instructions from the module manufacturer in writing as part of his **due diligence** and to observe these **mounting instructions** when planning the solar plant.

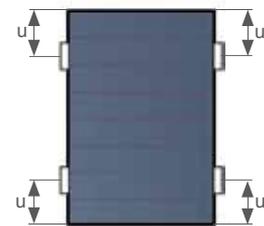
- Approval for the application of the intended clamp series
 - IEC-approval of the respective module including mechanical load test
 - Information on tested and certified distributed loads
 - General approval for punctiform support
 - Definite mounting instructions for the module
-
- If an installer installs thin-film modules without considering all the information mentioned above, he will have to assume the complete liability for the solar plant if any module damage occurs, and cannot just leave the handling of damage cases to the module producer.
 - Generally, not every thin-film module is suitable for punctiform clamp fastening! Due to the distributed loads and depending on the arrangement of the support points, there will be tensions in the glass. Thus, there must be a general approval for point fastening by the module producer and also for the admissible positions of the support points for a correct fastening.
 - The module must be generally suitable for the distributed loads that occur at the installation site. The installer has to compare the admissible distributed loads with the actual wind and snow loads at the installation site.
 - In this context, it has to be mentioned that many unframed modules are not tested. In many cases, there is not even an official data sheet for certain unframed modules, Quite often, such modules are not put to any mechanic loading tests according to IEC and thus may not withstand bigger mechanic loads.

1 Different kinds of mounting - technical details

With an approval according to IEC 61215, the modules are usually tested 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 tests with such heavy loads are not compulsory.

The test loads are only relevant for practical applications if the modules are installed on the roof exactly according to the testing conditions. Thus, the module producer has to specify the guidelines for the fastening of the modules on the roof.

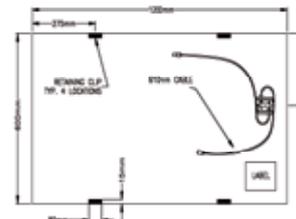
With framed modules, it is usually sufficient to specify the admissible areas of the module frames that can be used for placing the module clamps respectively the cross rails. The warranty of the module producer applies if the modules are fastened correctly and the usual local snow loads are below the test load (strictly speaking, the different cases of load interference of wind and snow have to be considered).



162mm/6.4inches ≤ u ≤ 393mm/15.5inches

Module mounting instruction
Example of a **framed** module

With unframed modules, the structural details of the different module laminates (double-glass; glass-EVA, glass - thin film, etc.) are decisive, so that the kind of fastening and the admissible kind of clamping (for example clamping distances, floating or fixed clamping, etc.) have to be defined exactly in detail. Only in this case, the real load conditions are comparable to the test conditions.



"center point of the clip shall be located between 250mm and 300mm"

Module mounting instruction
Example of an **unframed** module

2 Clamp designs

The two clamp designs Laminat Eco and Laminat Profi are intended for different requirements respectively different kinds of optimized thin-film module fastening:

Laminate Eco

The clamp design "Laminate Eco" is available for different module thicknesses (4, 6 and 8 mm). The module rests in the clamp with a suitable alignment (without strong pressing). With vertical mounting, the module has to be secured against sliding-off in a different manner (safety hook). The desired torque is about 15 Nm to 20 Nm.

The installer has to determine the suitable clamp design for the specific module thickness. In doing so, especially the thickness tolerances of the module have to be taken into account.

- As this design has a middle groove, the socket head screw can be equipped with a anti-theft device.
- The Eco laminate clamp is designed for guidance free of play, the laminate is not pressed (with accordant thickness)!
- The clamp has **no lower part**, the module rests on the EPDM rubber which in turn rests on the rail or the safety hook.
- As there is no lower part, the minimum width of the support rail has to be approved by the module manufacturer; On request, a lower support plate can be included in the scope of delivery.



Example test certificate

Laminate Profi

The clamp design „Laminate Profi“ is suitable for module thicknesses from 3 mm to 14 mm (end-to-end). **With this variable clamp design, reliable mounting depends mainly on the quality of the mounting.**

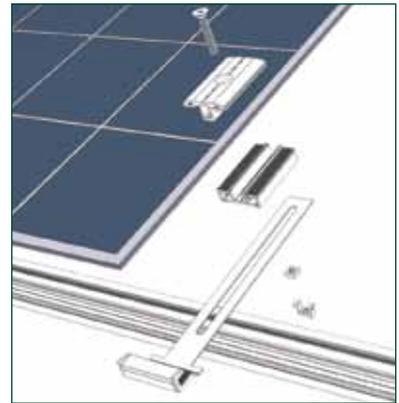
- The pressing of the module depends by 100 % on the tightening torque of the screw! Thus, the tightening torque and the admissible pressure force have to be agreed with the module manufacturer.
- The module only has direct contact to EPDM rubber, also at the front edge of the module. When mounting the modules, it has to be made sure that they are inserted into the clamps properly (see picture).
- When usual quality steel clamps are used, the modules are simply laid into them. In contrast, clamping using Laminate Profi clamps also safeguards resistance against wind suction.
- The middle clamp is suitable for modules from 3 to 14mm. The ends of the module rows are closed with end clamps which have been designed especially for that purpose. The clamps are generally available in two different designs for module insertion depths of 11mm or 15mm.



3 Anti-slip device

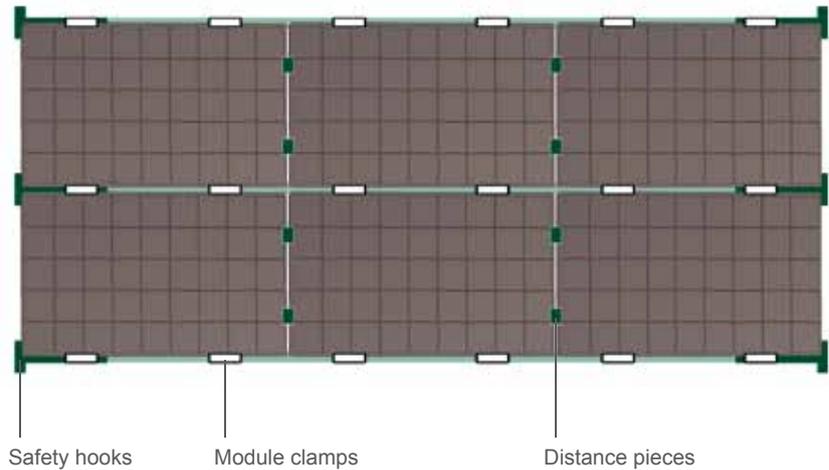
With all kinds of clamps for unframed modules, the modules cannot be secured against sliding-off simply by clamping. With vertical mounting, the module is mostly secured against sliding-off by means of so-called safety hooks.

It also has to be checked, if the clamping effect of the clamps is sufficient to prevent lateral shiftings (for example caused by wind forces). If necessary, the modules have to be additionally secured against lateral shiftings.



Example: Mounting with safety hooks

With horizontally arranged modules, thermal elongations of the profiles can make the modules move. In order to prevent this, module field sizes should not exceed 10m. We recommend securing the modules by means of distance pieces and safety hooks (see scheme).



4 Module clamping - characteristic data

With **framed** modules, it is mostly possible to bindingly define the clamping geometry and thus to create system-independent interfaces between the module and the mounting system. The definition of interfaces for unframed modules is much more difficult, as the coordination of mounting system and module is far more important in these cases and many parameters are decisive for a correct system dimensioning.

Like a check list, the present compilation is supposed to facilitate a good coordination of module and mounting system and to point out the most important aspects and guidelines.

Module thickness

The laminate clamp has to be chosen in such a manner that the clamping geometry is suitable for the module thickness. This is often the case with two-part module clamps (Laminate Profi, see Item 2). But there is also the disadvantage that the clamping of the module depends on the tightening torque of the screw which can lead to impermissible clamping conditions.

With one-part laminate clamps (Laminat Eco, see item 2) the mounting quality is virtually independent from the tightening torque of the screw, but for each module thickness, a specific clamp design is required. Clamps without screwed connections are a special case, here, there usually is the same geometry like with one-part screwed laminate clamps.

Thickness tolerance

When clamps for a specific module are selected, not only the nominal thickness but also the tolerances of the clamp and the module have to be taken into account.

Desired clamping (floating or slightly clamped)

Generally, the module should be completely surrounded by rubber when it is mounted and should have no contact to metal components, not even in case of deformations within the tolerances. Usually, UV-resistant EPDM-rubber has to be utilized. Depending on the kind of structural analysis of the glass module it has to be determined, if the module has to be clamped elastically (if so, what force is required), or if a defined "minimum distance" has to be maintained (floating support).

Tolerance for false clamp positions

Regarding support and clamping geometry, also slight malpositions of the clamps (deviation from the module alignment) that are caused by roof unevennesses have to be tolerated.

If such non-parallelisms are generally not acceptable for the module bearing,

- a) a testing procedure has to be determined which has to be bindingly observed by the installer.
- or b) a cross rail system has to be generally prescribed

Rubber hardness

The hardness of the rubber should be considered within the framework of the certification of the clamps.

Length of the clamps (clamping length)

The clamping length in relation to all other factors has to be defined by the module producer. Long clamping lengths lead to minimum surface pressure in the clamping area and low tensions. But at the same time, long clamping lengths impede module deformations and thus can lead to tension peaks. The optimum clamping length has to be determined on the basis of the structural analysis of the module.

Design of the upper clamping edge

A suitable "soft" design of the upper clamping edge of the module clamp can help to limit the tension peaks that arise when there are deformations.

Clamping depth for tensile loads (upper clamping depth)

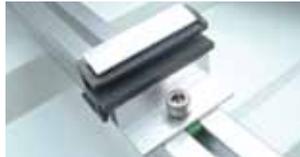
The clamping depth has to be defined. Big clamping depths limit the surface pressure and the tensions, but at the same time, they can reach into the active module area or cast a shadow on it.

Clamping depth and clamping length (lower support area)

Also in this case, the clamping depth has to be defined. Using an unsymmetric clamping rubber design on the lower side of the clamp possibly a bigger clamping length can be achieved than on the upper side. Regarding pressure loads, not only the rubber area directly beneath the module area is decisive, but also in the support area below, if one-part clamps are used. Thus, the minimum width of the cross beam has to be defined if one-part clamps are installed on the load-bearing profile at right angle.



Example of a one-part clamp with underlayment plate



Example of a one-part clamp at right angle to the load-bearing rail

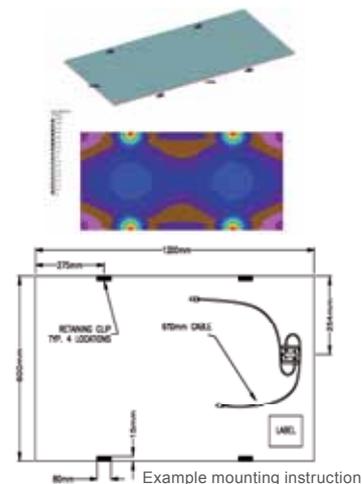
Clamping geometry - characteristic data

Rectangular modules are usually clamped in such a manner that the clamps are placed at the long sides of the module. Due to distributed load on the module (suction and/or pressure), there is a three-dimensional deformation and tension picture.

a) Bending line in direction of the module height

The optimum position of the clamps has to be determined in such a manner that an optimum deformation behaviour with **minimized tension peaks** will set in (according to the guidelines by the module producer). This can usually be done by calculation.

In addition to the optimum position, also the tolerance range of the clamping positions that has to be maintained has to be specified.

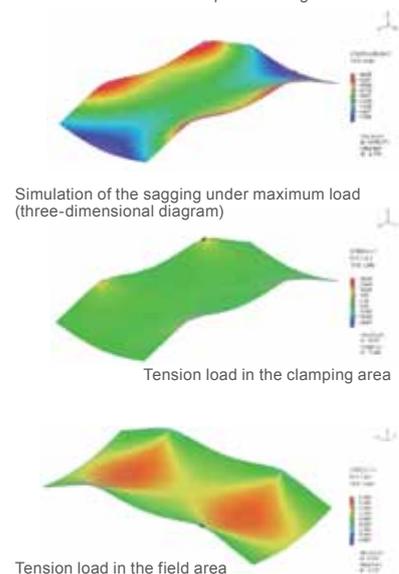


Example mounting instruction

b) Bending line in direction of the module width

The bending line in direction of the module width usually defines the maximum possible resp. reasonable module size with a determined glass thickness and a defined maximum load (please also see the section about module testing).

As the modules can only be supported at the module edges especially in case of suction load, there is a technological limit to the module size. A change of this maximum admissible module size with pre-determined distributed loads is only possible, when the glass thickness and/or the glass quality can be adjusted accordingly. For this reason, usually an economic maximum size of the modules is defined, even when the production costs of bigger modules are generally lower.

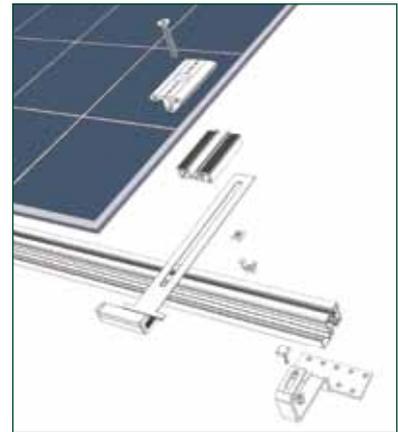


6 Clamping geometry - arrangement

Depending on the strength of the modules, several mounting cases are possible or can be ruled out.

- **Vertical without anti-slip device**
- **Vertical with anti-slip device**

If the module is installed vertically, usually an anti-skid device is required due to the downhill-slope forces. It has to be made sure that big distributed loads can arise at the front side of the modules. In case of very flat roofs, an anti-skid device is possibly not required (depending on the adjustment of clamp and module).

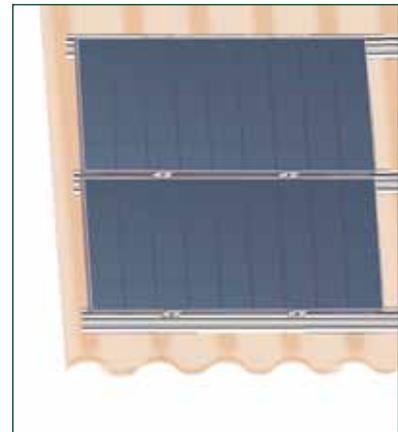


Vertical mounting of thin-film modules with anti-slip device

- **Horizontal without diagonal stabilization**

If the module is installed vertically, the module also works as an anti-slip device against slipping direction of the eaves. With this geometry it has to be checked, if lateral wind forces could shift the module in the clamp, or if this can also be ruled out because there is a sufficient clamping friction.

Possibly, only cross rail systems are possible to safeguard the parallelism of the clamping geometry.



Horizontal mounting of laminated modules

7 Special case: Linear support

Modules that are installed horizontally can also be supported linearly in purlin profiles, for example with open area plants. But most profiles actually have point supports, as the module rests only on the clamps without deformation. Under load by wind suction, the module is only supported by the clamps. Under strain by pressure loads, the module rests mainly in the clamps. With bigger deformations, the module might possibly rest on the girders, depending on the thickness of the clamps. It has to be sorted out whether or not a resting of the module on the beams can be tolerated or if the sagging of the module is smaller than the thickness of the clamp which impedes any resting module on metal. If required, more modules per clamp have to be used (even if this leads to an uninterrupted linear bearing); An exact structural simulation calculation has to be carried out in order to make sure that no stresses in the module are caused by deformations of the load-bearing system due to an overdimensioned clamping of the module (too many clamps).



Horizontal mounting of laminated (thin-film) modules

8 Example of module testing

Primarily, also the desired load level for the tests has to be defined. For example, possible maximum loads are 2400 Pa (compulsory according to IEC 61215) or 5400 Pa (optionally acc. to IEC). When defining the test load, also the future approval for different places of installation has to be taken into account.

Relevant technical standards are:

DIN EN 61215 (Testing of crystalline modules)

DIN EN 61646 (Testing of thin-film modules)

In the testing standards, no specific test method is prescribed. Some of the options are water bag, vacuum overpressure or vacuum suction. It cannot be taken for granted that unframed modules will gain exactly the same results with all test methods, thus the testing method for certifications should be defined.

Moreover it has to be made sure that the test procedure (loading from the front, loading from the back) and the test duration can have a decisive influence on the test result (please also see the section about failure criteria).



Example of a module loading test with vacuum suction (TÜV Rheinland)



Example of a module loading test with water bag (Schletter) (Preparation of the test set-up)



Example of a module loading test in an overpressure/underpressure test set-up (VDE)

9 Failure mechanisms of single-glass modules

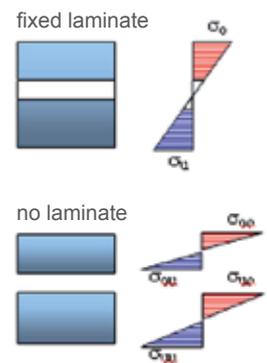
The strength of single-glass modules is usually limited by the strength of the glass plate in the specific clamping geometry. The load-bearing capacity is determined by the breakage limit and/or the limit of the maximum sagging of the glass module. But it has to be made sure in any case that the active layer of the module is not damaged by the maximum sagging that might occur. A verification by testing is basically only possible with a sufficient number of units under test and a check of the electric performance!

10 Failure mechanisms of double-glass modules

For technological reasons, double-glass modules have special structural characteristics:

Analogously to single-glass modules, the load-bearing capacity of double-glass modules is primarily determined by the specific fastening geometry. The second factor is the load-bearing capacity of the glass laminate; the following factors have to be taken into account:

- Besides the structural strains on the glass elements under load and with deformation of the module, also the deformations of the active layers of the module have to be considered.
- The minimum load-bearing capacity of the module laminate is the sum of all values of the individual glass plates utilized. This conservatively determined load-bearing capacity of the module can also be determined solely by calculation without experimental verification.
- Depending on the quality and the durability of the connecting intermediate layer, a glass laminate may also withstand much higher loads than the sum of the individual glass plates suggests. In certain circumstances, this increased load-bearing capacity can be verified by calculation. For the validations by tests, especially the test duration, the type of loading and the loading cycles have to be considered, as these might lead to a "gradual" failure of the laminate.
- A thermally pre-stressed lower glass plate has a positive effect on the load-bearing capacity of the glass laminate regarding pressure loads. But in this case it again has to be considered that with so-called "**substrate technology**" modules, the active layers are usually applied on the lower bearing plate using a thermal process, which eliminates the mechanical characteristics of the plate that were optimized by a previous thermal treatment. With "**superstrate technology**" modules, usually the upper plate is technologically treated, this can lead to an optimization of the mechanic characteristics of the lower plate and thus to an improvement of the mechanic characteristics of the whole module.



Example
Tension distribution in glass plates with laminate and without laminate