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Photovoltaics

MegaSlate® – *Solar roof system*

Planning guide and assembly instructions for installers

For distribution after training by Swiss Solar Systems AG

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1 Planning and layout

1.1 General observations

This planning guide is intended for experienced solar installers or individuals who have been trained by 3S. Furthermore, photovoltaic installations may only be connected to the public electricity grid by licensed electricians. The relevant SEV regulations and "Photovoltaic energy-producing installations" provisional safety regulations, available from SEV must also be observed. The SWISSOLAR Brochure "Photvoltaics - electricity from the sun", containing interesting literature references is also recommended reading material. In Germany, the VDE regulations, in particular VDE0100T712, the VDE guidelines (connection of installations in parallel to the network) and the BGV professional association accident protection regulations.

The electrical voltages at solar installations connected to the grid are usually life-threatening! Improper installation can also result in fire.

Swiss Solar Systems AG disclaims all liability for damages caused by inadequate planning or installation by inappropriately-trained staff.

1.2 Potential applications and certifications

In principle, MegaSlate® can be installed on any roof with a minimum slope of 20º and facing east or west via southerly. It can occupy entire roof surfaces or just a portion of the roof surface, meaning that there are an almost unlimited number of potential configurations.
Roofs with a slope of less than 20° should be assessed individually. As far as possible, roofs should not lie in the shadow of trees, neighbouring buildings or other objects on the roof itself, otherwise performance will be correspondingly reduced.
MegaSlate® is available in standard sizes. Nevertheless, in combination with complementary tailor-made sizes any roof can be covered completely. The following standard modules are available (as of October 2006):

- 131.6 cm horizontal by 97.5 cm vertical (approx. 82.5 cm exposed), monocrystalline Si cells, 155 W_p
- 131.6 cm horizontal by 97.5 cm vertical (approx. 82.5 cm exposed), polycrystalline Si cells, 136 W_p
- 60 cm horizontal by 120 cm vertical (115 cm exposed): CIS module, 60 W_p (by Würth Solar)

The modules are shingled to the roof with a 5 cm overlap (CIS modules) or 15 cm overlap (crystalline cells). It may be necessary to plan for the use of dummy elements for optimum aesthetic value.

Roof surface is suitable for MegaSlate® if it:
- is oriented towards the easterly, southerly or westerly sectors
- remains as shadow-free as possible for most of the day
- consists of large, exposed and contiguous roof surfaces
- Has a slope of at least 20°

The MegaSlate PV roof system has certification from TÜV Rheinland (June 2003) for PV elements with single-layer safety glass and PV elements with the aforementioned CIS thin-film cells. According to this certification, the system components are considered 100% recyclable, and the MegaSlate® roof is also suitable for zones with elevated snow load and rainproof (the use of a sarking membrane is recommended). The system lifespan is expected to exceed 30 years.

1.3 Requirements for the sub-roof and batten construction

A correctly laid MegaSlate® roof is well back-ventilated and has thin, covered ventilation slits running from below to above. Therefore it is breathable and as rainproof as possible. A rainproof sub-roof is recommended depending on the use and exposure of the building/roof.
The substructure consists of a traditional well dried wood batten structure (battens and counter-battens), a specific supportive construction of vertically arranged water-channelling sections to seal the photovoltaic elements in the horizontal direction, and hooks to retain the photovoltaic elements. An appropriate sub-roof to prevent a falling person from breaking through must be used if it will be necessary to walk on the roof for servicing purposes (see section 3.6: Instructions for walking on the roof).
If possible, the counter-battens must be at least 50 mm high to guarantee adequate back-ventilation. The batten has a cross-section of at least 30 x 120 mm CIS: 30 x 100 mm). The vertical batten distance corresponds to the vertical exposed height of the PV elements. The batten layer must be planar and should be carefully levelled if needs be. In accordance with the regulations the battens and counter-battens must be fixed to the sub-roof or rafters. Figure 1 shows the specifications for batten structure for modules with crystalline cells (15cm overlap). Further specifications are given in chapter 2.1.

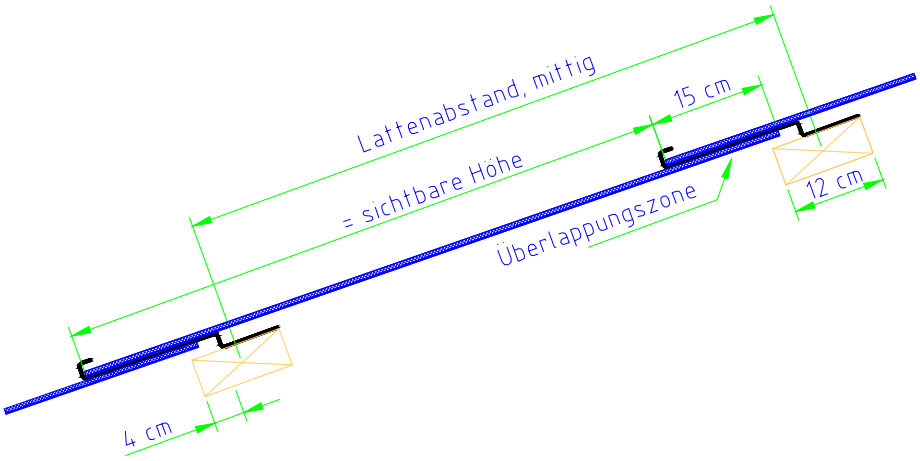


Figure 1 Side view of module and battens

1.4 Expected annual output

The annual output of a MegaSlate® installation depends firstly on its geographical location and local weather conditions, and secondly on its slope and any shadows cast on the installation.
From an optimally-situated installation (southerly facing, slope of about 30° to 35°) and installed performance of 1kWp (approx. 9 m^2), around 850 to 900 kWh per year can be expected in Switzerland. This corresponds to around 100 kWh per square metre of roof surface per year. Around 70% of this is generated during the summer half-year, and 30% in the winter half-year.
Using computer software and a comprehensive climate database, 3S can calculate expected annual output from a specific planned installation of a MegaSlate® roof in a specific location with good accuracy.

1.5 Layout

1.5.1 Geometric layout

Firstly the carrying capacity of the roof must be checked. To plan a roof with MegaSlate®, an exact plan (for example at 1:50 scale) of the roof surface to be covered, in normal projection or side view, incorporating all items that protrude through the roof surface such as mansards, skylights, chimneys and vent pipes, needs to be produced by the responsible individual (principal, expert planner) Areas which are expected to be in shadow should be marked as clearly as possible with their respective expected daylight hours (estimate). Furthermore, roof slopes and directions (deviation from southerly) should be determined and indicated. The dimensions of the roof surface will be derived from this plan and the sections required will be determined.
If the roof surface is not to be fully covered with photovoltaic elements, it is recommended that the area which is covered with photovoltaics remains as straight and compact as possible to minimise the edge contact length.

Once the size of the area to be covered has been determined, dimensioning of the PV elements can be carried out by the planner with the aid of the „MegaSlate_Systemauslegung.xls“ Excel file, (delivered with installation instructions.) The general conditions need to be observed, cf. example in figure 2 and instructions in the system layout program:

1. Ideally an even number of strings (cell rows) should be used.
2. In terms of production technology it is better if these run lengthwise along the module, but this is not a strict requirement.
3. The module should not exceed about 1.4 m (horizontal) by 1.3 m (vertical).
4. When dimensioning the PV elements, a vertical overlap according to figure 1 (5 cm or 15 cm) should be allowed for, and the minimal edge displacements (cell to glass border, min. 2 cm) need to be adhered to.

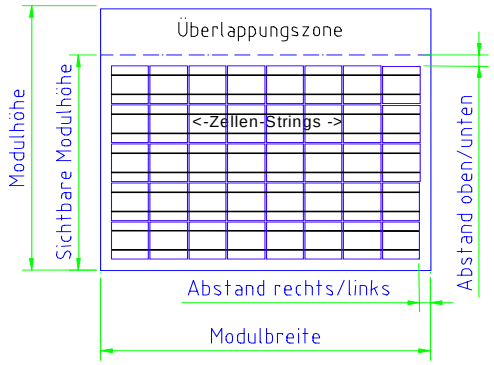


Figure 2 Module layout

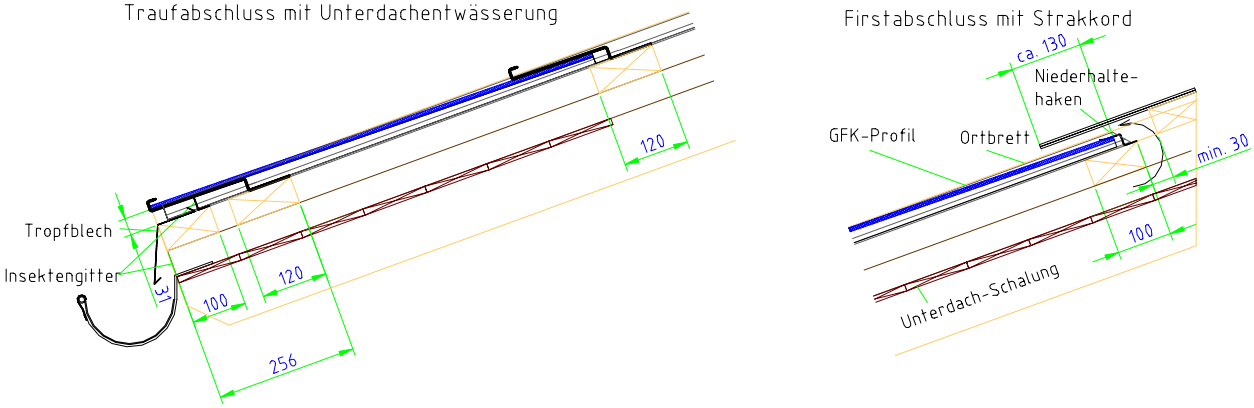


Figure 3 Side view eaves and ridge

5. Examples of edge contacts are shown in figure 3. Contact between the solar module, particularly its glass edges and hard materials such as steel or clay needs to be excluded at the planning stage. In the case of objects within the roof such as skylights, chimneys, dormers etc, particular care must be taken and precise measurements must be taken.

Once a layout has been made, Swiss Solar Systems AG can quote for the system components based on this specification.

1.5.2 Electrical layout

After geometric layout, electrical system layout can be done by means of the „MegaSlate Systemauslegung.xls“ Excel file. It is recommended that this is done only by experienced electricians as it requires current market knowledge regarding power inverters and electro-technical regulations.
Inside the module it is preferable to plan for connection of all cells in rows in order to keep the currents in the modules as low as possible, and connecting cables between the modules as short as possible. The modules are connected together in series, thus the voltages of the individual modules are summed. The corresponding voltages can be seen in the string check table in the system layout. The power inverter should be selected in accordance with the permitted number of modules in a string.

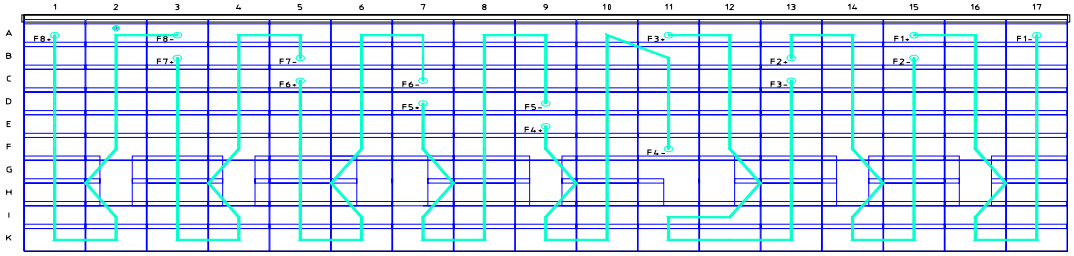


Figure 4 Example of a field distribution

One installation may include several power inverters. An application to the Federal Heavy Current Inspectorate (ESTI) is required for installations in Switzerland which supply more than 3.3 kVA single-phase or 10 kVA three-phase.

1.5.3 Construction documents

The following documents are needed for carrying out a project and should be produced by the person responsible for planning:

- Battening and/or roofing plan with module positions in above view and side view. Position of the battens and counter-battens, vertical water channelling sections and edge contacts, penetrations etc. In order to have a precisely fitting MegaSlate® sub-construction for the installation of the modules, the dimensioning on the roof has to be made starting from one fix point (in figure 5 it’s from the left down). Figure 5 shows an excerpt from a roof plan with view from above. For complicated roofs it is recommended that the plan is printed with and without module positions – without modules can be used for example for the roofer to position the battens.
- Field distribution - see figure 4.
- Electrical system layout (power inverters, fields) These could, for example, be produced using the „MegaSlate Systemauslegung.xls“ file.
- String check table: the string check table can be produced using the „MegaSlate Systemauslegung.xls“ file.
- Detail drawings of the edge contacts.
- Documentation of components and equipment used.
- Electric scheme, high and low tension, cf. figure 8.
- Complete list of materials (tools and system materials), cf. section 3.1.

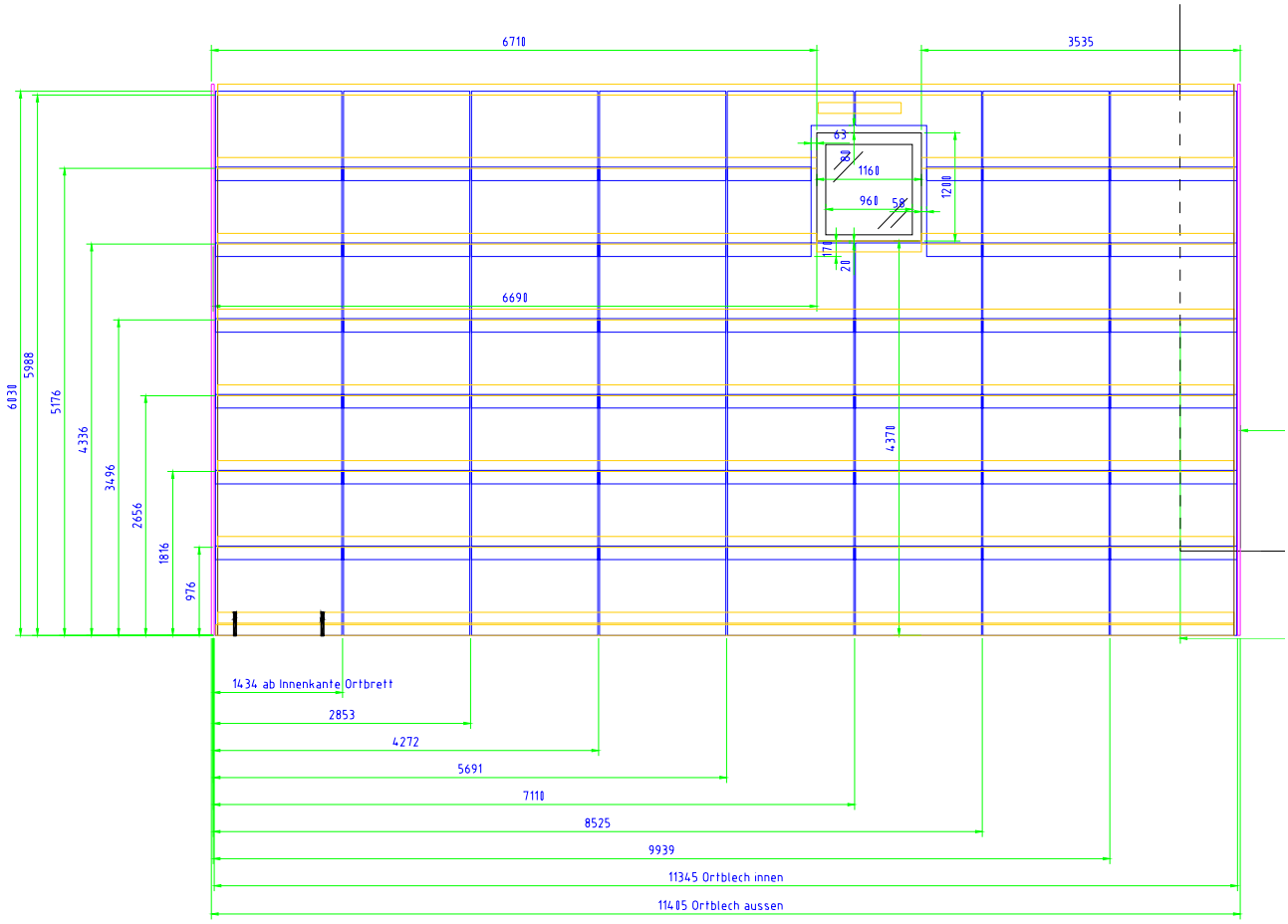


Figure 5 Roof plan (view from above) indicating position of modules and vertical GRP- profile

2 Execution

2.1 Batten layout

The counter-battens with a recommended minimum thickness of 50 mm are laid out as for a conventional roof. A MegaSlate® batten consists of square-shaped timber with a cross-section of at least 30 x 120 mm (or 25 x 120 mm in areas with particularly low winds and low snowfall), or 30 x 100 mm for the somewhat smaller standard thin-film elements. Well-dried wood should be used for the battens and according to the regulations should be fixed to the counter-battens, for example with two chipboard screws D= 6mm or sufficiently large, galvanised nails at each crossing point.
One possible eave- and ridge- end is shown in figure 3. The distance between the battens (central) corresponds to the visible height of the PV element (cf. figure 1.) The uppermost batten can be positioned with a little less space as the ridge holding hook is shorter than the „normal“ hook (cf. figure 3.) It is important when installing the ridge and eave ends that adequate ventilation is ensured, i.e. ensure that the ventilation sections are as large as possible.
It is important to note that the battens are of the exact dimensions specified in the project documentation (check again!). The PV elements cannot be tailored to the battens at this stage!

2.2 Installation of the PV-specific substructure

Once the battening has been installed and checked, the position of the vertical GRP-profiles is drawn on the battens. This is also visible on the roof plan. It is recommended, especially with roofs of long vertical slope, to screw the GRP-profiles to the two vertical battens in the middle to minimise thermal stresses. The sections are screwed through the outer lips as shown in figure 6. The holes in these lips need to be drilled in advance. Countersunk screws should not be used. The GRP-profiles are to be fixed above and below only laterally with screws or nails, such that the brad touches the outer lips of the section and the head holds it down. Again, no countersunk screws should be used for lateral fixation. For precise alignment of the GRP-profiles it is recommended that a vertical chalk line be drawn for each section as the GRP-profiles are elastic and may be somewhat buckled.

Figure 6 Fixation with screws and nails

Next, the hooks are positioned. The vertical distance between them corresponds to the visible height of the modules (cf. figure 1.) A distance of about 15% to 25% from the right and left edge of the module is recommended for horizontal positioning. The installation gauge with adjustable distance (available from 3S) may be of service, or a tape with positions marked on it, since the positions need to be adhered to with great precision. When using the installation device, the hooks

are ideally installed row by row (definition of term: rows run in the horizontal direction). Figure 7 shows GRP-profiles of a roof with installed PV substructure.

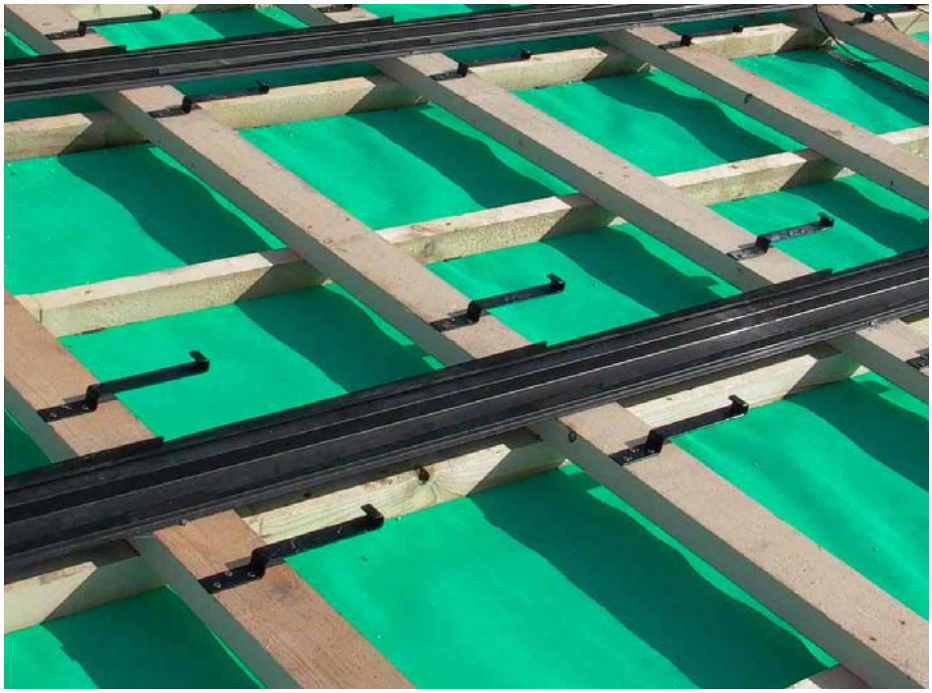


Figure 7 PV substructure

If the hooks are not installed precisely the PV elements will not rest at the correct angle and may impinge on one another. The spacings must correspond exactly with the rubber support in the GRP-profiles. The uppermost row of ridge holding hooks (two per PV element) are installed only after placement of the PV element.
Positioning of the lowest row of hooks needs to be particularly precise to ensure that the modules are properly aligned. This can be achieved, for example with a line stretched between the outermost hooks or through drawing a straight chalk line (before positioning of the sections).
At the eave ends, an insect shield should be installed between the fascia board and the lowest element if possible, otherwise a 2.5 cm crevice will be open. A z-shaped perforated plate with a side piece of 22 mm could be used. To protect the rear surface of the module this sheet should have a self-adhesive foam strip placed on the upper edge. In any case an insect shield is recommended at the lower end of the counter batten (cf. figure 3.) The contact edges at the verge and eaves (for example eave flashing and verge flashing and general flashings) have to be securely fastened before the PV elements are positioned.

2.3 Installation of the string cable

The string cable is installed according to the field distribution plan and the correct ends (+ or -) are temporarily attached to the correct positions on the battens, ideally on the batten which lies underneath the middle of the relevant PV element. The junction box end is then passed to the roof aperture through the battens and temporarily attached at that point (in the case of touch-safe connectors at the cable ends) or in the case of open ends, connected straight to the junction box. **There is a high voltage as soon as the solar modules have been connected!**

The cable ends must be clearly labelled with field number and polarity (for example attach a red sticker for the positive pole). In the case of complicated roofs it may be helpful to write the relevant field number and polarity at the correct location on the sub-roof. Cables with adequate length

exceeding the minimum required need to be ordered. Subsequent lengthening or replacement of cabling is vastly more troublesome and expensive than shortening longer cables or simply taking up the slack by pushing them back into the sub-roof.

Important: The junction boxes form the „border“ between the roofer’s and the electrician’s jobs. The appropriately trained roofer positions the string cables (only in the case of touch-safe connectors) up to just **before** the junction boxes, and the electrician completes the remaining electrical installations. Only the electrician is authorised to connect the string cables to the junction boxes!

2.4 Installation of the PV elements

As soon as the previously described steps have been completed, the installation of the PV elements can begin. These are usually installed starting from above and moving downwards so that standing on the elements can be avoided. First the string element which will be connected to the string cable itself should be positioned. It is essential that correct polarity is observed when connecting to the next element. Once two PV elements have been connected to each other, polarity-safe connectors mean that it is only possible to connect the correct pole thereafter. To make connection of the cable to the next element easier, the PV element which is being installed can be carefully held upright in the hook below the element which has already been installed. Then the cable connectors can be joined together.



Then it is easily lifted out of the hook, the upper edge is placed on the rubber overlay and pushed as flat as possible under the hooks of the element above it, until it can be positioned correctly in its own hooks. The element needs to be pulled down until it rests right down within its own hooks and is horizontal.

2.5 Functional checks during installation of the PV elements

It is recommended that the strings are checked for correct function after the installation of every 10 or so MegaSlate® elements. To do this, both ends are connected to an appropriate instrument (for example a multimeter capable of measuring direct current to at least 10 A), and the voltage measured and compared with the relevant values from the string check table. The current should only be measured if an appropriate DC circuit breaker is available. Under no circumstances should the cable connectors be used as circuit breakers.

The electric arc which occurs when unplugging the connectors destroys the contacts. Caution, the high voltage is life-threatening! Arcing may also cause burns or eye injuries. String inspection should only be carried out by a trained specialist electrician.

2.6 Junction boxes and power inverters

Connection and installation of the power inverter and junction box must be carried out by a specialist electrician!
The junction boxes collect the DC inputs (string cables) from the PV elements. From the junction box, the collected DC is fed into the power inverter using a special cable. The power inverter changes the DC current into AC, ensures optimal performance („Maximum Power Point Tracking“, or MPPT for short), and is responsible for synchronisation with the grid.
The junction box (depending on the power inverter the junction box may be integrated) is usually installed in the building's attic. Country-specific regulations need to be adhered to. Usually the excess voltage suppressor is connected to the potential equalisation with a 16 – 25 mm^2 conductor. In Switzerland, for example, a steel box is recommended, or attachment to a fireproof plate or wall. In Germany (installation according to the IEC norm 60364-7-712) a steel box is not permitted. As to whether the junction box needs to be connected to the external lightning protection, this is controversial and subject to country-specific regulations. If no junction box is needed and the strings are to be connected directly to the power inverter, then proceed according to the installation instructions of the power inverter being used.
The connection between the junction box and power inverter is made using a shielded DC cable with adequate cross-section. The shielding should be connected to earth.

Depending on type, it is preferable to install the power inverter in the cellar, in a dry and well ventilated room. For this purpose „dry“ means, in the case of most power inverters, that the humidity is not high enough to cause condensation. The AC-side cabling must be installed by a specialist electrician. Connection of the installation to the electricity grid may only be carried out by a licensed electrician after prior consultation with the responsible electricity company. Figure 8 shows an example of the electrical setup.

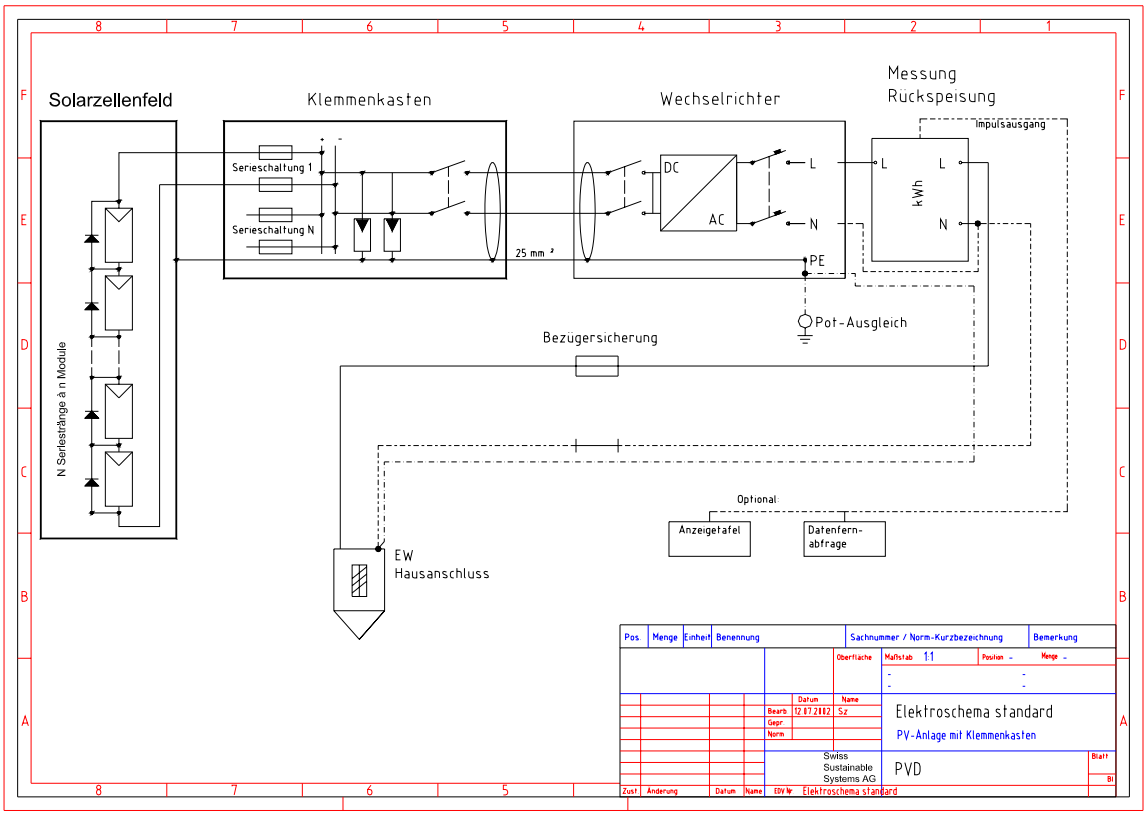


Figure 8 – Example of electrical scheme

2.7 Initial operation

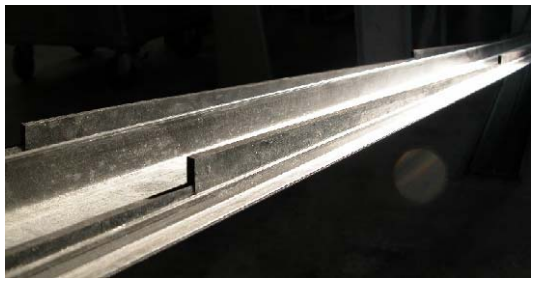
Once the PV elements have been joined together according to the plan, a final measurement needs to be made and recorded by a specialist. In the case of touch-safe connectors at the ends of the string cables, this can be carried out prior to connection to the junction box. In the case of open ends, these need to be attached to the junction box first, in accordance with the instructions. The measurement is then made at the contacts in the junction box. The DC circuit breaker in the junction box should remain open. For each string, short-circuit current and open-circuit voltage should be measured. The appropriate circuit breakers need to be used! Further, the earth connection should be tested. The values measured should be compared with values from the string check table. If an electronic load is available the whole current-voltage curve can also be determined.

3 Important further information

3.1 System components

The MegaSlate® system consists of the following components:

1. PV elements with cables and cable connectors
2. Power inverter
3. Junction box
4. String cable (connects module rows with junction box or power inverters) with cable connectors
5. PV dummy elements (optional)
6. GRP-profile with attached rubber supports with dual function as eaves gutter and MegaSlate® support



7. „Normal“ or „Small“ hooks to retain the PV elements and dummy elements

8. Ridge holding hooks to retain the upper elements at the ridge board.

9. Screws to affix the hooks (standard 5mm x (batten thickness + 5) mm, galvanised Torx countersunk-wood or chipboard screws
10. Screws to affix the wastewater sections (standard 5 x 35 mm, roundhead wood screws)
11. Galvanised broad head nails, approx. 40 mm for lateral mounting of the GRP- profiles

3.2 Materials

The PV elements consist of silicon solar sells, clear glass, EVA (ethyl vinyl acetate), a highly durable plastic rear film (tedlar composite), tin-plated copper soldering ribbons, plastic sockets, semiconductor bypass diodes, connecting cables and connectors (halogen-free.)
The GRP-profiles consist of glass fibre-reinforced plastic in fire protection class B2. The supports consist of weatherproof rubber.
The hooks are made of plastic-coated steel (mild steel or V2A). The components used are not in any poisons class.

3.3 Handling and transport

All components should be handled with care. The PV elements are particularly breakable. During transport, unloading, intermediate storage and installation they must be handled with great care. Because of the electrical connections on the modules, they need to be protected against contact with water (rain, snow etc). The electronic equipment (junction boxes, power inverters, sensors etc) should be stored in a dry place. The GRP-profiles need to be protected against physical damage. Excessive bending during the handling of long sections should be avoided due to the risk of breakage and injury.

3.4 Electrical connections, cable types

Only cables intended for use with solar installations should be used. Double isolated heat-resistant halogen-free single-core cable is recommended for connection of the PV elements. Shielded cable with an adequate cross-section is recommended for connection of the junction box and power inverter. The connectors between the modules are touch-safe.

3.5 Edge contacts and connections

Edge connections should usually be dealt with by a tinsmith or roofer. This covers the flashings, ridge covering, eaves, insect shields, inflow sheets, skylight edges, chimneys, dormers etc. Junctions with normal roofing materials requires prior inspection and planning, and should be carried out under the auspices of an expert who is authorised to carry out the related operations. Materials for these edges (for example titanium zinc, copper, galvanised tin etc) should be selected in accordance with materials used on the roof.

Important: The GRP-profiles are only large enough to cope with water that runs over the edge of the modules. They should not be used as „collective“ water channels under any circumstances. It is also of absolute importance that the collected water is never channelled directly into the GRP-profiles but onto the middle of the module (small amounts) or even better into other channels appropriate to the task.

3.6 Safety precautions and instructions for walking on the roof

General safety precautions

1. Do not touch the PV elements with metal items such as hammers, screwdrivers, carabiners etc.
2. Do not damage the cables (risk of death! High voltage, up to 800 V): if necessary, arrange for cables with damaged insulation to be replaced by a specialist
3. Never disconnect connectors when under electric load
4. Try to avoid carrying tools on the belt when working near the PV elements (risk of damaging the modules if tools are dropped onto the glass surface!)

Special precautions for walking on the modules:

1. Do not walk on the modules unless this is unavoidable
2. Personal safety: If there is no fall protection at the eaves, work only when roped up, with as short a rope length as possible
3. Risk of slipping, especially when wet. In certain circumstances there may also be a slip risk even if the surface is dry and/or level.
4. Minimise loading (for example avoid standing on corners, edges and hooks)
5. Use soft and clean rubber soles (no stones stuck in the sole, etc.)
6. Because the risk of glass breakage and consequent falls to the sub-roof cannot be excluded, use shoes with a long leg or take other precautions to protect the ankle area.
7. Use the lightest employees possible for jobs involving walking on the modules (ideally less than 75kg)
8. Spread weight over several elements if possible
9. Stand on the areas indicated by ellipses in figure 9

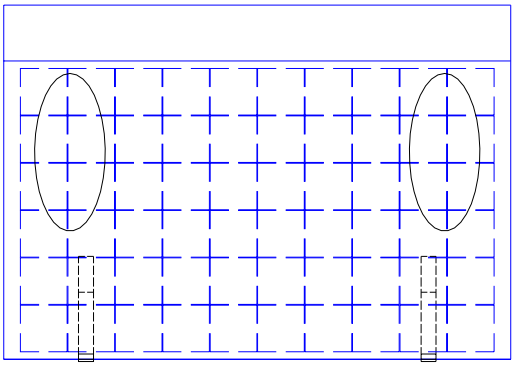


Figure 9 – recommended standing locations

10. Do not stand on the glass edges - the glass is most fragile at the edge!

3.7 Troubleshooting and element replacement

If there are irregularities in the voltage and electrical testing of individual strings, these need to be repaired to enable safe and optimal function of the installation. Problems may be caused by defective cells or modules, poor connections at the cable connectors, partially or completely disconnected cables, wrong number of interconnected modules (errors in string construction) etc.
The string check table can be used (with regard for the module temperature) as a reference when undertaking voltage measurements. For current measurements, a plausibility check (comparison between different modules with the same light exposure) can be informative.

In general, the following procedure is recommended in the event of any departure of the measured open-circuit voltage from the expected voltage according to the string check table, or clear difference in measured short-circuit current compared to a reference module or string.

1. Think over the installation of the module once more. Take note of the cabling plan and consider counting the elements. Check the cable connections as far as possible without disassembling. If the number is correct and no problems are identified:
2. Open the string more or less at the middle and measure both halves. If one or other half departs from the expected values for voltage or current, repeat this procedure for this half of the string until the faulty component or connection is identified.
3. Exchange or repair the components or the problem
4. Perform check measurements

Caution: the connector between the modules must never be used as a circuit breaker or switch when measuring. Never separate connectors when loaded.

Swiss Solar Systems AG
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