

11. Building integration of Photovoltaic devices

H. Boileau Savoie University, FR

Learning outcomes

At the end of this chapter, the reader will be able to:

- Evaluate the advantages and disadvantages of the different integration techniques, depending on the objectives of a project
- Understand and/or help the work of an architect.

General information

The following categories of construction products and technical processes are usually used, allowing various configurations for the integration of solar photovoltaic devices to a building's frame:

- photovoltaic modules on metallic vats;
- integration on tilted roof;
- photovoltaic modules integrated on plastic or bituminous seal;
- Semi-transparent modules or translucent ones to carry out elements of frontage, solar canopies, and shaded areas, sun protections.

These various technical solutions are detailed in this chapter.

The technique for mounting the modules is in general the same one as that used for the structural components that they replace. Consequently, an integrated photovoltaic roof will use the techniques of the roofers and the mounting of a photovoltaic façade falls to the façade specialists. The role of the person in charge of the study, the coordination and/or the realization of the project will be primarily to specify that the characteristics of the photovoltaic element ready to replace the structural component are equivalent, while guaranteeing the operating conditions of the photovoltaic generator. Many manufacturers exist today who specifically produce modules for integration. The leading vendors of standard modules widened their range towards larger modules, without framework and with a broader edge without cell, allowing integration. The “custom-tailored” module is generally more expensive, but it often makes it possible to adopt more powerful mounting techniques and adapts better to the architect's concept.

The photovoltaic systems integration solutions are classifiable in two main categories:

-Proprietary systems (offered by a manufacturer) consist of an integration structure/frame associated with photovoltaic panels. Some of these are the flexible membranes, tiles and slates in which sealing is provided by overlapping the modules, and the standard systems, whereby sealing is ensured without overlapping.

-Devices not linked to a particular type of PV sensor/module. These solutions are used to enable the purchase of the photovoltaics from any provider of choice. Photovoltaic tiles area Iso included in this category, as they are offered as normal tiles do not need a special frame.

Photovoltaic modules integrated in metal frames

At the beginning, the photovoltaic metal frames were used mainly with amorphous cells. They were using a flexible support allowing an easy joining on metal supports. Increasingly, the manufacturers are developing products using crystalline cells.

Various types of metal frames exist in the market; their primary difference is the alloy or metal employed (steel or zinc generally), and then they are distinguished by the junction type between the frames. One distinguishes several types of connections between the frames, the “covered junctions”, the “junctions with clips”, the “junction with standing seams”, and the “angular junctions”.

Covered frame junctions

It consists of a metallic covering along the edge of two successive metal frames to carry out the sealing. The fixing of the frames is then carried out on the elevated parts.



Figure 2.1 Covering junctions

Junctions with clips

The joining of the two frames happens by superimposing an additional metal section that covers the two ends of the frames. The edges are folded up towards the interior in order to guarantee the sealing. Moreover, the edges of the frames are folded to avoid water upwelling during rainfall or cleaning.

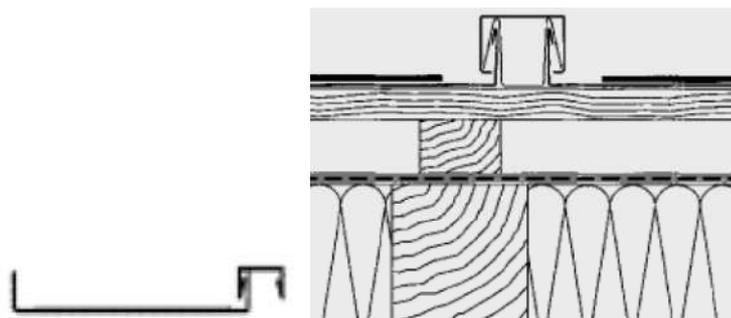


Figure 2.2 Junction on cleats

Junctions with a “standing seam”

The standing seam technique characterizes a longitudinal assembly of the vats juxtaposed on inclined roofs. The folding and the closing of the profile are carried out in an artisanal way, or mechanically using machines (profiler and seamer).

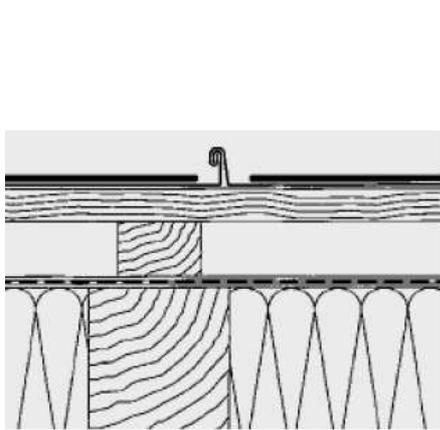


Figure 2.3 Junction with standing seam

Junctions “with corner joint”

The corner joint technique is usable for slopes starting from 25°. The closing of the joints of the pre-profiled frames is particularly simple, owing to the fact that the finished corner joint is produced by folding only one wing.

The frames are positioned on a floor boarding; a free space is reserved at the back of the frames for the connections boxes of the modules. Connections to the boxes must thus take place before the fixing of the frames on the carrying structure.

In order to guarantee a ventilation under the modules, a minimum space must be left free under the vats, and the minimal slope of the roof must be 6° (again considering the evacuation of water from rainfall and condensation).



Figure 2.4 Implementation of the Rheinzink panels (according to manufacturer’s documentation)

Lastly, one can quote the following manufacturers of photovoltaic metal vats (non-exhaustive list): RHEINZINK, KALZIP of Corus System Building, ARCELOR MITTAL, SUN LAND 21,...

Conclusion on the photovoltaic frames

The photovoltaic metal frames are ideal solutions for roofs traditionally covered out of metallic panels. It is however necessary to take some precautions for their use:

- All of the metal frames use adhesives to fix the photovoltaic modules on the frames: the sustainability of the joints is a paramount element in the design and the implementation of such roofing.
- The ventilation of the photovoltaic frames is all the more important as the cells are sensitive to the rise of temperature. Even though certain cells behave relatively well when they warm up (- 0.2%/°C), this is not the case for other cells (e.g. multicrystalline type) where the productivity falls drastically if proper ventilation is not provided (- 0.45%/°C). Thus, for these types of products, it is preferable to preserve a broad opening for air to circulate under the frame and to favour large roof slopes (at least 15 - 20°).
- The modules positioned on roofs or facades are difficult to reach and must be considered with the goal of no need for control or maintenance. Consequently, the quality of wiring takes a very particular importance. The modules with plug-in terminals for the cables are preferable over the connector blocks with tightening screws that tend to be loosened in the long run. To facilitate the wiring of the photovoltaic chains on facades and roofs, the connector ranges are regularly improved.

Lastly, it should be noted that the photovoltaic steel frames require more metal than a traditional tallied photovoltaic module. Since metal requires more energy for its production and rolling, the energy runback time of photovoltaic modules in steel frames is longer than that of traditional modules.

Ref. : <http://www.rheinzink.fr/>

Integration of photovoltaic systems on tilted roofs

Most existing systems have constructive similarities regarding the waterproofing systems present on the circumference of the installation (flashings):

- On top, a metal or plastic flap is fixed under the line of tiles (or slates) located above the installation and covers the upper part of the installation without blocking the cells. If the installation is at the top of the roof, the sealing element will be the ridge sheathing.

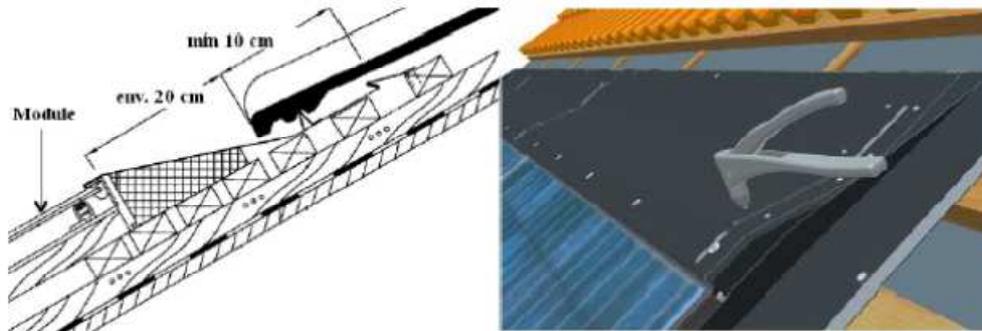


Figure 3.1: Diagrams about the sealing at the top of a PV installation (assembling notice for the systems “Sol Montagesysteme25i” from S.E.N and Energyroof)

- At the bottom, a polymer or lead flap covers the upper part of the tiles (or slates) and overflows under the PV installation. At the end of the roof, a protrusion of the module above the drain or the use of a blocking element will ensure the sealing by preventing upwelling.

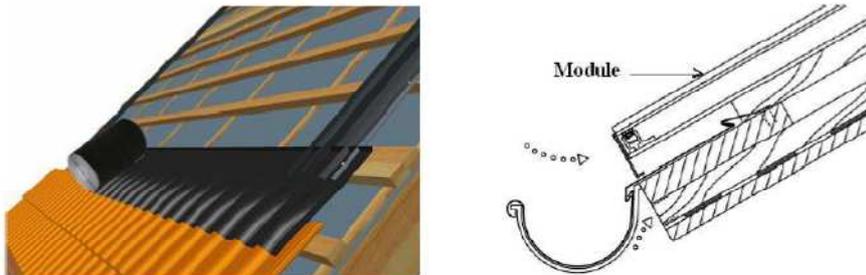


Figure 3.2: Diagrams of the bottom sealing of a PV installation (assembling for the systems “sol Montagesysteme25i” from S.E.N and Energy roof)

- To the left and right, in the majority of cases, a metal drain duct on the sides of the roof and the installation conveys the water collected to the drain located at the bottom of the installation. In other cases, the sealing is carried out by a technique similar to those described previously, using polymer bands.

The recurring elements of the waterproofing systems are the rails and profiled aluminium, the seals and the panels.

The integration systems are thus differentiated mainly by the solutions used to ensure the sealing between the panels and the attachment unit of the modules on the roof.

Lastly, some manufacturers of roof integrated photovoltaic systems (non-exhaustive list): CONERGY, FONROCHE ENERGY, MARCHEGAY, MECOSUN, SCHOTT SOLAR, SCHÜCO, SOLARCENTURY, SOLARWORLD, SUNTECH POWER, SYSTOVI, TENESOL, VOLTECSOLAR...

Photovoltaic tiles

The photovoltaic tiles were primarily developed to offer an adaptation of photovoltaic systems on individual roofs, in order to increase the chances of acceptance and use by the public.

However, they present considerable disadvantages:

- ✓ The smaller the tiles are, the more the number of connections and thus the risks of malfunctions increase. In addition, the installation time is lengthened.
- ✓ Their cost is much higher than traditional modules for the same power. Therefore, tiles are generally reserved for small power installations.

Little feedback exists on the performance of PV tiles under real operation and in the long run. However, they can be approximately estimated as similar to the performance of modules of same type.

The major element to supervise for the installation of crystalline tiles is the ventilation of the underside, which could reduce the anticipated production if the space under the tiles is not sufficient enough for their cooling during summer.



Figure 3.3: Overall Picture of a roof with Solar Century tiles

The polycrystalline or monocrystalline photovoltaic tiles ensure the sealing of the roof by overlapping and mechanical fitment of the PV modules.

The following criteria make it possible to specify and evaluate the photovoltaic tiles in terms of performances and risks:

- The weight kg/m^2 (from 8 to 50), and the number of tiles per m^2 is variable depending on the products;
- The slope of the supporting roof;
- The surface power ratio density of about $130 \text{ W}_c/\text{m}^2$ for the polycrystalline modules and $140 \text{ W}_c/\text{m}^2$ for the monocrystalline ones;
- The variable output efficiency, ranging from 13 to 15% according to the technology of the modules;
- Connecting technology of the modules (MC3, MC4, IPC65,...) ;

Lastly, some manufacturers of photovoltaic solar tiles (non-exhaustive list): ALEO SOLAR, ENFINITY, CAPTELIA, IBC SOLAR, MOUNTING SYSTEMS, KYOCERA FINECERAMICS, ROTO-FRANK, SOLARCENTURY, SOLAR FABRIK, St GOBAIN SOLARSYSTEMS,...

Flexible membranes

A traditional structure of a roof adapted for the installation of a amorphous silicon photovoltaic membrane is generally made from a steel frame that plays the part of mechanical stand, a heat insulator, then a seal.

The heat insulator is mechanically fixed on the roof; the photovoltaic membranes are fixed mechanically to the insulator and thermally welded.

Two options for the connecting cables of the membranes:

- Connections are carried out externally on the roof;
- The cableway is driven under the membranes (see figure 5.1);

Then, the cables are gathered in one or more passageways to the interior of the building through the insulator and the carrying structure. Once the cables are brought inside the building, the electrician can perform the electric connection.

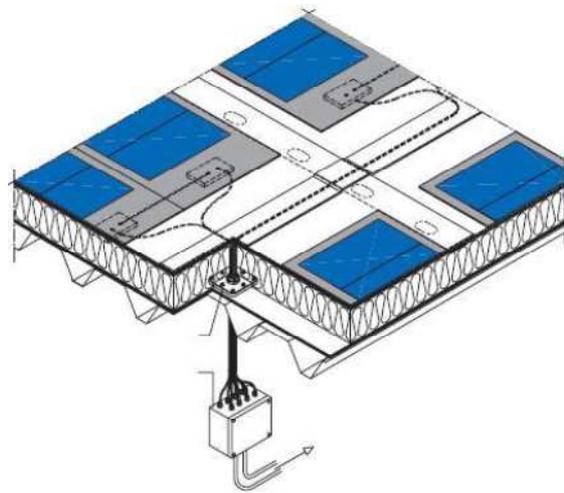


Figure 5.1: Example of a roof with, and photovoltaic passage seal of the cables (Alwitra manufacturer)

The following criteria allow the specification and evaluation the photovoltaic membranes in terms of performances and risks:

- The weight varies from 5 to 10 kg/m² depending on the products;
- The surface power ratio density is of about 50 W_c/m²;
- The output of about 7 to 8%;
- Connecting technology of the modules (MC3, screw MC4 or connector blocks);
- The possibility or not of walking on the membranes;
- The risk of breaking the cells;
- The risk of undoing of the photovoltaic modules;
- The passage of the cables in an outlet duct (depending on the product used);
- The necessity or not (depending on the product) of perforating the insulation and the structure for the passage of the cables towards the inverter;
- The need for specialized or certified mounting teams;
- The loss of performance from temperature increase.

Lastly, some manufacturers of photovoltaic seals (non-exhaustive list): DERBIGUM, ALWITRA, SMAC, UNISOLAR, MEPLE, SOLARDIS,...

Ref.: The newspaper of photovoltaic October 2011, special issue #6

Photovoltaic façades

They use the same attachment units as the conventional plated facades. Generally, these are vertical rails fixed to the skeleton of the building, at a certain distance, to take account of the thermal isolation and ventilation of the panels. The mounting flanges must allow a very precise alignment of the rails and longitudinal displacements due to dilation. The fasteners of the photovoltaic plates on the rails must also ensure a good alignment and a light vertical tolerance. Moreover, the assembly, the wiring and the possible replacement of only one module must be possible. The assembly systems usually employed for the fixing of ceramics plates on façades are good candidates for the assembly of such panels.

Good underside ventilation needs to be taken into account in case of great height. We should not forget that the collecting conditions are not optimal (lower by approximately 30% than on a roof). A southern façade shows interesting conditions of collecting in winter, eastern and western are more underprivileged and a preliminary calculation is essential.



Figure 6.1 Photovoltaic façade, Lappeenranta University of Technology, Finland (courtesy H.BOILEAU)

Translucent and semi-transparent PV modules

Any type of translucent and semi-transparent modules can be adapted to be used as a brise-soleil or canopy. From an aesthetic point of view, some have a particular shape that is appropriate for this kind of application.

The anchoring types used are similar to those of architectural elements added on the façade. The important mounting part is the body that holds the modules, since it must hold them without blocking nor degrading them. Certain systems make it possible to integrate modules without framework and support them with metal joints and elements (see Figure 6.1.1, left); others use modules with frameworks fixed on metal supports (Figure 6.1.1 on the right: view

from under and in the middle : view from top).



Figure 6.1.1: Examples of support and sun visor

Attachment units using clips or hooks are possible. Modules specifically dedicated to use as brise-soleil or canopy exist. Those have points reserved for fixings, which are zones without photovoltaic cells and can be drilled for mounting on the support (Figure 6.1.2).



Figure 6.1.2: Fixing of the modules by boring in zones without cell

Many suppliers of such canopies exist on the market. Main suppliers of the photovoltaic sector (MSK, SCHOTT SOLAR, TENESOL, SCHÜCO,...) usually are able to provide this kind of service. Additionally, many façade material providers and manufacturers of openings or architectural elements offer lines of products with photovoltaics.

Translucent modules

The polycrystalline and monocrystalline translucent panels available have a structure identical to the traditional modules, with the difference being that they are encapsulated between two layers of transparent materials, either with Tedlar in the back, or out of bi-glass. The part that does not contain photovoltaic cells thus lets the sunlight go through what gives an effect of squaring on the projected shade.

The translucent panels are perfectly adapted for integration on canopy or brise-soleil. They combine several functions: constructive processes that substitute the conventional building materials, protection against overheating during summer due to the direct solar radiation, electrical production, and finally higher aesthetics.



Figure 6.2.1: Example of integration of translucent modules

Semi-transparent modules

The transparent, semi amorphous silicon standard modules in thin layers consist of traditional bands of cells (preceded of serialization integrated in tile by three rays of laser), separated perpendicularly by rectangular slits (Solems patent) or circularly (Sanyo patent), whose distance between two slits must be lower than the diameter of the pupil of the human eye.

Therefore, a person located behind the module sees perfectly images on the other side of the module, with a light opacity related to transmittance (typically the coefficient of luminous transmission range is between 5 and 10%). The modules assembled in double glazing make it possible to minimize the transmission of the solar contributions while letting only 10% of the light go through.

The semi-transparent modules can be integrated into buildings using many different integration systems, and thus their applications are multiple (e.g. canopy, façade, brise-soleil).



Figure 6.3.1: Examples of integration of modules in façade and canopy



Figure 6.3.2: Example of façade integration and canopy of semi-transparent panels Schott-Solar

Photovoltaic shelters

Beyond the charging of batteries for electric vehicles, shelters can contribute to the adoption of new uses and new services:

- street furniture,
- public lighting on the ground and in the air,
- luminous posting,
- ...

The massive adoption of such shelters requires the reduction of investment costs:

- Foundations of steel piles instead of concrete blocks,
- Lighter carrying structures by favouring a “system of integration”, combining primary carrying frames and galvanised steel supports for PV modules.

Assets of the PV shelters:

- mature technologies,
- electrical production near the places of consumption,
- direct valorisation of renewable electric mobility,
- user comfort, protection of the vehicles against the rain and the sun,
- energy valorisation of already artificialized surfaces (no more consumption of existing natural or agricultural landscape),
- important land potential,

An exposed parking space produces approximately the energy an electric vehicle requires for 15.000 km/annum.

Challenges and Prospects:

- The adequacy of the shelter's electric production for the needs of the vehicles has to be checked,
- A connection to the electric grid will guarantee the resupply and avoid the wasting from over-production,
- The optimized management of the vehicle's load is required, considering the solar production versus the time tariff of the electricity sent to the network,
- The shelter should be equipped with stationary batteries for the management of fast or optimal load,

- To imagine smart electric vehicles, capable of drawing current while refilling its batteries under the shelter, storing energy for discharging to the private residence or to the network during peak periods demand, then refill at the off-peak hours.

Ref.: *Le Journal du Photovoltaïque* April 2013, special issue #

Conclusion

This inventory of fixtures shows that each category of photovoltaic products has specialized applications. For a given project, the photovoltaic product can be generally chosen from one or two product categories, according to the architectural characteristics of the project:

- ✓ photovoltaic metal frames;
- ✓ integration of modules on roof;
- ✓ photovoltaic tiles;
- ✓ photovoltaic covers;
- ✓ finishes of façades and balconies (semi-transparent and translucent modules);
- ✓ photovoltaic shelters.

Generally, the fields of application for each category are the following:

The photovoltaic metal frames will be advantageous for applications reserved to the traditional metal frames (habitat in mountain region, industrial and commercial buildings). It is recommended to take some precautions when choosing the metal frames; there is some negative feedback regarding the degradation of the photovoltaic rolled-iron products on the frames over time. It is advisable to favour suppliers having correctly dealt with the problems of differential expansion and to make sure that the supplier offers a long guarantee with the product (higher than 10 years).

The systems of installation of photovoltaic modules on roof are well adapted to roofs of houses but are also usable for other roofing surfaces. Few systems seem to guarantee an optimal underside ventilation of the modules and proper use of ventilation air. One would indeed need installation framework guaranteeing 5 to 10 cm of entirely open space between modules and roof to ensure the satisfactory cooling of the modules by natural or forced ventilation.

The photovoltaic tiles, are primarily intended as traditional house covers, which represents a relatively limited field of application. They steadily are more expensive than modules, their implementation is time consuming and requires many electric connections that increase the risk of malfunctions. Moreover, tiles using crystalline silicon technology seem disadvantaged for this kind of application because ventilation at the underside of the tiles is, in most cases, difficult to ensure.

The photovoltaic seals seem well adapted to industrial roofs where this kind of sealing is favourable. It is advised to favor products that allow the routing of the cables on the sealing

and avoid the drilling of the roof's insulation. It is also a technology that offers easy access to the cables where necessary (provided that one can walk on the insulator). It is also recommended to control the locations of the sealing agents and to select water proofers that will guarantee the defect-free installation of the membranes.

For the **applications using photovoltaic modules in façades**, even if they are semi-transparent modules, translucent or opaque, they replace a double skin or a facing. The integration units are derived from the existing systems of the façade sector who have broad feedback on the performance and the mechanical resistance of the mounts. Since the electric performance is guaranteed by the providers of the modules, these facade systems appear among the most reliable building integration products. The principal parameter to be checked is the good ventilation of the module's underside, for both the case of a double-skin and the case of a facade.

Thus, in all of the aforementioned applications, the challenge of proper ventilation seems decisive for the good performance of the photovoltaic installations. It will thus always be necessary to gauge the installation methods of the products, and to provide a sufficient underside ventilation for the modules.

Bibliography

- The guide of photovoltaic - Ralf Haselhuhn, Uwe Hartmann; Edisun Power France 2014
- Photovoltaics in the urban environment: lessons learned from large-scale projects; Bruno Gaidon, Henk Kaan, Donna Munro Earthscan 2009; ISBN: 978-1-84407-771-7