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Shading systems with PV - A new market for prefabricated building elements?

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Abstract

PV technology proves step by step to be suitable for various types of building integration. One option to utilize PV modules in the building facade is to use them, in addition to an electricity production, as a shading element. The exploitation of this synergy effect helps to reduce the total costs of such a PV installation and to create added values to the PV as well as to the building and its shading system. At the same time there is a growing need for carefully designed shading systems on the building market due to an increasing use of large window openings and curtain walls in today's architecture. New market opportunities for PV could be developed if the mass production of such a PV shading element could be achieved. This paper analyse carefully the prerequisites of a well designed shading system and investigates the option to combine their functions with PV, with the perspective to develop a multifunctional prefabricated building component.

INTRODUCTION

In today's architecture the development of new building materials, in particular the advances of glass technologies and new construction techniques, has led to the use of large window openings and curtain walls. In particular glass is getting a popular building material. In spite of advantages like

- easier access of daylight,
- rooms which appear to be more spacious,
- unobstructed views to the outside (but also to the inside),
- less weight of building materials and therefore less use of energy for the utilisation of construction materials, etc.,

there are also some disadvantages, caused by the unprotected access of sunlight to the interior space, in particular

- the disturbance by glare and
- the overheating of buildings, specially on south orientated facades and in hotter climatic regions.

Unless it is intended to continue to use vast amounts of energy for running Heating, Ventilation and Cooling (HVAC) equipment it will be necessary to utilise some kind of sun shading device for getting suitable comfort conditions within a building.

The utilisation of some kind of sun shading system in architectural design and construction is already much older than these latest developments in building construction. But in the past the size of the wall openings was small in relation to the building perimeter. It was sufficient to protect the interiors by simple shading devices unless the rooms were so cold that the solar heat was in fact highly welcome.

In contrast shading systems for large window openings and curtain wall facades, which today sometimes cover the entire building envelope, need to be designed very carefully, for serving their function to reduce the intensity of solar light and heat entering through the glass openings, as well as to reduce the necessary cooling loads of a building to an acceptable level.

The objective of this paper is to make an assessment of the different architectural design aspects of shading elements and to identify options to combine their functions with the use of PV.

For this reason the paper investigates the following boundary conditions, which need to be taken into account for designing PV Shading Systems for large window openings and curtain wall facades:

- PV Shading Systems in the context of building facade performance expectations
- The impact of site location and orientation on the design of PV Shading Systems
- Advantages/Disadvantages of fixed and movable PV Shading Systems
- PV Shading Systems in the context with other solar techniques
- PV Shading Systems and their impact on the design of a building

The primary function of sun shading devices is to provide protection against glare and direct sunlight when it is needed. In hot climatic regions they often become a vital necessity. They need to be differentiated from „Canopies" and other similar looking structures, which are not intended to provide protection against the sun but to serve for example as a shelter against rain or just as an architectural object.

PV SHADING SYSTEMS IN THE CONTEXT OF BUILDING FACADE PERFORMANCE EXPECTATIONS

The building facade serves as the interface between the inside and outside world. In a certain way it needs to operate like a living organism. Increasing performance expectations make the building facade a more and more complex and multifunctional building component, which has to serve many different tasks at the same time. It is at the same time a doorstep as well as a border. It can be built up out of one layer or out of a sequence of different layers.

PV shading elements for building facades need to be integrated in this complicated structure. They are external facade elements which have to fulfil at least two functions: to provide shading when it is needed and to allow a maximum electricity production, which requires an unobstructed access of direct sunlight onto the PV generator. These two particular performance requirements have to go hand in hand with a long list of other facade performance expectations which need to be fulfilled.

In addition to an electricity production and a shading function it could also serve as an access gallery or as a balcony, which allows an easy access for cleaning windows and carrying out maintenance work on the facade or just to step outside the building (see Photo 1: Hamburg Electricity Works)

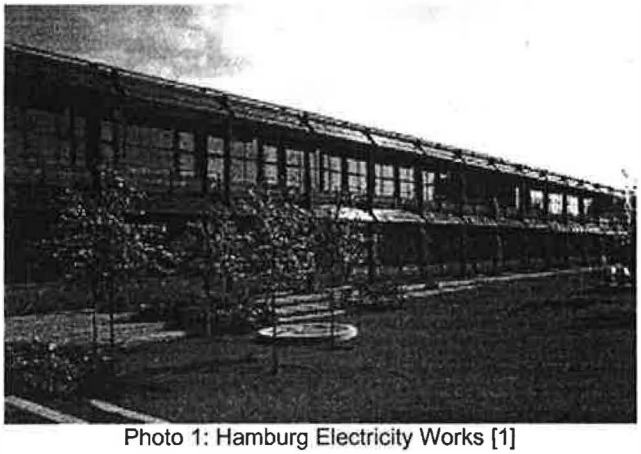

Photo 1: Hamburg Electricity Works [1]

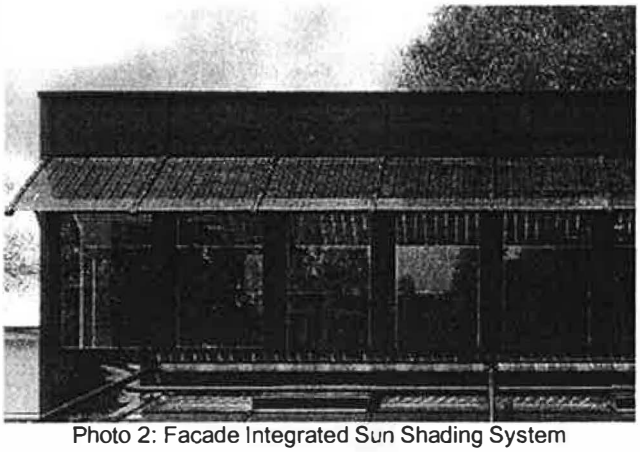

Photo 2: Facade Integrated Sun Shading System (Schüko Top Sky) [2]

Structurally PV Shading Elements might be integrated into curtain wall structures (see Photo 2: Facade Integrated Sun Shading System, Schüko International KG, Germany), or load bearing structure of a building or in contrast they might be used as a separated element which is mounted at the facade or installed in front of it.

PV Shading Elements need to serve design and aesthetical requirements like other building materials, components and construction techniques of a building facade, which are visible on the inside and the outside of the building.

As part of a building facade they are also part of an urban context. With the choice of volumes, dimensions, forms, textures, materials and colours of a building the architect establishes a dialogue between the new building and the urban context according to his individual visions.

It is not possible to develop one common list of building facade performance requirements for all different types of buildings and locations. Out of the overall set of requirements the architect has to select those which are important for his particular building project.

THE IMPACT OF SITE LOCATION AND ORIENTATION ON THE DESIGN OF A PV SHADING SYSTEM

Designing a sun shading device which is supposed to operate well, is a question of taking numerous physical aspects into account, like the position of the sun, the reflection and absorption of building materials, the air flow along the building facade, etc., as well as considering different structural and architectural aspects. The orientation of the building and the choice of sun protection methods depends also on the users assessment of solar heat and light.

In hot climates, for example in the Mediterranean countries, typical houses are often almost wholly secluded from the access of direct sunlight. Day time activities tend to be confined to the cool interior or shaded courtyards. This kind of sun protection is based on collected experiences and not on scientific research. It is in southern hot climates a vital necessity. But the effort of people in northern latitudes to catch as much sun as possible is equally important.

The choice of sunshading device must be based primarily on the climatic conditions of the actual building site. Within these given limits the architect can influence considerably the intake of heat and light by the first steps of the design process by making the decisions for the building orientation, shape and construction. The building could face towards the strongest and longest and the weakest and shortest solar radiation.

But such primarily design decision may not be feasible owing to the general town planning scheme, the shape of the plot, the position of adjacent buildings, or simply economic reasons.

The amount of sunshine to be expected for a planned building in a specific location is also dependent from the degree of latitude, the path of the sun and specially, with regard to the considerations of utilising PV in combination with a shading device, by local weather conditions, which are unfortunately, in most cases, not known due to a lack of appropriate weather data for a specific site location.

Fixed Shading Elements

Fixed Shading Elements for building facades require in general less maintenance and are therefore in particular suitable for the utilisation of PV. The shading effect of Fixed Shading Elements is limited to a given time of the day and the calculated angles of the sun.

In midsummer, when it is supposed to be hottest, they are able to provide on south orientated facades (maximum deviation from due south ±15°) a suitable and effective protection against solar heat. Also at the winter solstice, when the sun lies down at the horizon and its rays are welcomed to warm up the interiors of habitations in northern regions, an additional protection against glare, like for example a curtain, will be needed.

In contrast, facades which are more orientated to the east and west receive in summer a higher amount of solar light and heat than south orientated facades. In winter the same facades receive much less solar light and heat.

In these cases an effective protection with horizontal shading devices is not possible. It would be necessary to

develop some additional side fins, which provide a protection against the solar radiation from the side.

For moderate climates it may be more advisable to keep east and west windows to a minimum and to use for example movable horizontal louvers.

A Fixed Shading Element, like any other interfering object, cuts out part of the visible sky-vault. As a result the shading device will influence the amount of entering light, which is sometimes desirable in case of glare, but it will also reduce the illumination excessively and will therefore encourage the use of artificial light in the building.

Other aspect which needs to be considered is the deposition of dirt and in moderate climates also snow on such shading devices and the psychological aspect that fixed shading systems might cause some obstruction of the view outside. Then the problem arises to choose between a desirable view and the punishing sun exposure (specially in hotter climatic regions).

Movable Shading Elements

Movable shading devices are more flexible in their applications. They are effective during a longer time of the day and can be adjusted to individual needs. For large buildings with many different users it is not advisable to control and operate them centrally.

Their disadvantage is that they have to face ever changing weather conditions and therefore tend to cause trouble after a while like most other mechanical and moving parts on a building exterior. They require maintenance and services, so the overall maintenance costs for a building necessarily increase, specially for high rise buildings where it is difficult to reach the external facades from the ground.

For the same reason in multi-storey buildings it is necessary that movable shading systems can be operated from inside either electrically or manually. Depending on the height of the building they also must be able to withstand high wind pressure forces.

These two different types of shading systems have each its own value but the most effective sun protection can be obtained by combined installations.

In most cases the sun protection device needs to be installed near the window. But there are also cases where it is desirable to cover the entire facade with a sun protection grille, which can be found often in tropical climatic regions.

Any type of external sun protection device should, if possible, be placed at a reasonable distance from the facade or should be designed that air can pass through grills and blinds (see Photo 3). In the space thus created between facade and sun shading device, hot air can escape and, in the process, exert a cooling effect on the facade. Does the hot air get trapped by the shading device, the concentrated heat would impair the cooling effectiveness of the shading installation. The choice of the material for the sun protection devices has a contributory effect to it. In the end a sun protection device will only work efficiently and satisfactorily where there is adequate and effective ventilation.

Depending on the size, a sun protection device placed in front of a building facade will allow to create a building exterior with different depth which can also be exploited as an architectural design feature for creating an interesting play of light and shadow on the building exterior. It may also help to form a transition space between inside and outside.

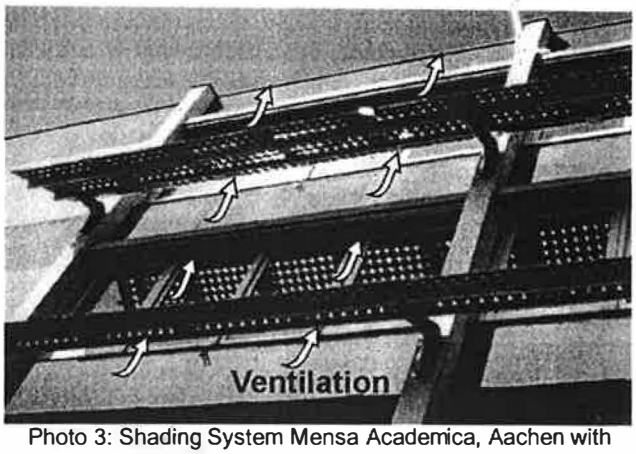

Photo 3: Shading System Mensa Academica, Aachen with sufficient ventilation gap between facade and PV shading device [3]

PV SHADING SYSTEMS IN THE CONTEXT WITH OTHER SOLAR TECHNIQUES

General considerations

While designing PV-Shading Elements it is necessary to keep in mind that any shading system in front of a window

- requires an unobstructed access of direct sunlight to the PV-generator
- reduces the amount of daylight entering the building,
- causes more or less an obstructions of the view outside and
- may be in concurrence to the use of daylighting techniques or other solar technologies, suitable for building integration

In addition, the utilisation of different solar energy techniques on a building must be seen in the context of building procedures. Some solar energy techniques can be used to complement each other or can be used next to one another while other techniques, in turn, exclude each other as different requirements for their realisation must be met, or they even would have a negative effect on each other.

To avoid design defects where one technique might impair another, it is necessary to know the requirements and limits of the different active and passive solar energy techniques suitable for each particular building project and to take them into account as early as possible in the general design and energy concept of a building.

Daylighting techniques and PV Shading Elements

Windows are natural light source elements within the external building structure. As a transparent element of the building facade they establish contacts with the outside world but also produce glare and thermal problems.

Shading devices and low transmittance, heat-absorbing or heat-reflecting glasses are used to restrict solar heat gains and to reduce the glare. However such reflective and solar-control glasses also reduce the transmission of daylight. In side-lit rooms the daylight distribution falls of rapidly with the increasing distance from the window.

To provide to such rooms a better visual comfort it is in some cases of interest to use also some kind of control element which redirect, alter and distribute the incoming daylight. Suitable for this type of daylight modulation are lightshelfs, prismatic systems or holographic optical

elements. To operate well all these systems need to be orientated, like a PV module, in a specific way towards the direct sunlight, unless it is only intended to make use of the diffuse sky.

For this reason the increase of daylight in the interior space must be seen in direct concurrence to an additional electricity production of a PV generator.

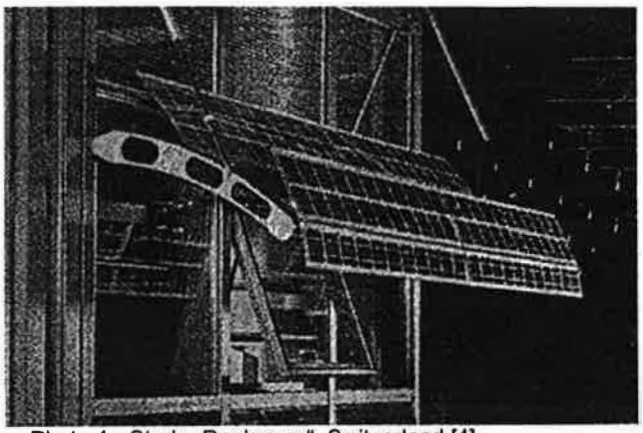

Photo 4: „Study „Denkraum", Switzerland [4]

It has been tried once in an interesting attempt to combine both functions within one shading element (see Photo 4: „Study „Denkraum", Switzerland"). But in this study, called „Denkraum", the shading element can not serve both functions at the same time. Either it operates as a PV-generator, directed with an optimum angle to the sun, or as a lightshelf when the movable PV modules are turned upside down and the backside is orientated to the sky.

To be able to operate well, such a system relies on a complicated mechanical structure and needs to be operated in a precise manner. Unless regular services and maintenance are provided it might be not ensured that it will fulfil its functions over a longer period of time. In addition it need to be mentioned that such a horizontal shading system will provide sufficient shading only on south facades unless the shading elements can function as movable horizontal louvers.

CONCLUSION

The functions of Shading Elements are mostly interrelated. The composition of sunscreens with its spatial character and multitude of forms offers a fertile ground for exploiting sensual experiences inside and outside the building. They can be used additionally ,for example, as an access gallery or as a balcony. But their main role is to act as a spatial insulator against the sun's radiation.

Owing to the path of the sun, which constantly changes both its altitude and orientation, Shading Elements vary according to their orientation. For different orientated facades they need to change in type and dimensions, to be able to provide effective shading. A particular shading element provides only most effective shading for one particular site location and facade orientation.

Therefore PV Shading Elements which are suitable for mass production as well as effective shading for different locations and orientations would need to be designed like a meccano system of unit construction, which allow a variation and adaptations to different shading requirements. Alternately, efforts could be concentrated on the integration of PV in movable horizontal louvers which provide effective shading for different orientations.

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