Building Integrated Photovoltaic

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BIPVs offers tremendous potential to building designers or Architects, provided that their introduction is well considered and catered for from the very beginning of the design stages and not left afterwards. They can influence building orientation footprints, layout and form; this is apart from changing the building as well as being an important element of the environmental setting and building systems. It is important here to stress their recognition as an essential part of the energy strategy of the building and it's functioning, since careful and proper integration of PVs with other building elements is a key factor to their success. Moreover, their high aesthetical values in terms of neat, coloured and high-tech prestigious appearance can be a corner stone for more innovative architectural designs.
To ensure proper integration of PVs into the building fabric we need to point certain factors that influences Pv performance as they are integrated in a building design. As well as assessing the nature and type of loads involved. Influence of PVs on building factor is also important, since PVs are considered expensive nowadays it is fairly important to use them as optimal as possible; this remind us with the use of glazing in the middle ages, which was expensive and rare, nowadays we see them almost every where.

BIPV | Building Design with PV, | Photovoltaic facades | Photovoltaic temperature

1. PVs in the design brief

A well-defined clear brief always forms a strong start to a successful project. Here the main goals are clearly stated and highlighted and whether to include PVs in the building energy strategy or not. If they are to be considered then they need to be part and parcel of the initial design concept of the building and must comply with architect design needs and engineers functional requirements [1][2][3].

Reasons behind adopting PVs as an energy solution are:

- Supplying on site all or part of the annual electrical requirement of the building in order to reduce running costs.
- Supplying the peak demand or more likely a portion of it.
- Environmental benefits. Operation free from emissions of (COx, NOx, SOx). And their harmful impacts.
- Creating innovative architectural and engineering solutions.
- Using them as educational or demonstrative projects.

In fact, the decision of how much of the load we want the PVs to contribute to is most crucial at this stage, since it determine how large area PVs will be. Also important is how and when it is expected that PVs can be successfully a viable solution. As a rule of thumb PVs can worth considering if:

- Location: building has a clear unobstructed access to solar radiation.
- Usage: building has an electrical demand that grantee full utilization of power generated on site.
- Design: PVs will have an effect on the building form and aesthetics, satisfaction of the community, client and architect is therefore has to be sought.

1.1. Site considerations

In theory, the more solar radiation and the more uniform the radiation is on the array the better. Site location is therefore critical. As stated earlier, northern latitudes receive less radiation than moderate and tropical zones. For example, Edinburgh receives about 90% of the annual amount of solar energy received in London.

Site topography should be examined as well as prevailing conditions. In the former avoiding shading is the main issue, due to the manner in which PV modules are wired, shading may have a somewhat disproportionate effect. This is explained in appendix (a). This necessitate that the architectural design should seek to avoid any obstructions that forms shadowing effect on the PV modules. Whether they are telephone poles, chimneys, trees or even parts of the building itself such as stairs, lifts or adjacent buildings is very often gives approximation to the losses in radiation due to adjacent building shading. Nowadays computer software can assist in measuring this effect.

While the effect of prevailing wind conditions are favourable summer time since they allow for maintaining the temperature of modules with in acceptable range, however, in winter infiltration problems should be minimized. The art is in achieving the right balance.

Orientation is also of crucially importance, yet there is some flexibility for design options. While the most desirable orientation of the array is due south, slight deviations up to ± 20° result in collection of up to 95% of incident radiation or even more. ± 30° deviations make a slight Drop in the radiation intensity. The main difference between a surface orient 10° to the east of due south or to the west of it is in the period of time the radiation will be received rather than the amount received.

1.2 Building type

PV arrays can suit a vast range of building types such as offices, hotels, schools and industrial buildings. Offices normally have good match between supply and demand all the year round. Since the usual working hours from 9:00 am to 5:00 pm, which is the period were power generation from PVs is maximum. This is apart from weekends

. Houses on the other hand, tends to use energy 7 days a week, however with the pattern of demand distributed in the day and at night, which may require some sort of storage facilities which may increase the cost. Yet still there may be individual or electrical suppliers be interested in PV applications.

Commercial and industrial buildings with large roof areas offer significant scope for PVs installations.

1.3 Design and construction

A team of specialists headed by an architect normally carries building design. The team will work with in a framework of a brief defined by the client responsible for the project. The brief describes all the required functions and activities with in the building, these are transferred into spaces and supporting services. Some governing standards and special requirements have to be met, such as space or area allocations (I.e. how many m^2 allocated for each type of activity), access to natural light, natural ventilation, percentage of built area, height restrictions and so forth. Generally an image of the building will be created from the formation of the brief.

If we consider a brief that doesn't consider PV system but call for a typical low-energy design suitable, for example in the suburbs of a city. A common feature of this building will be the use of solar radiation for day lighting all the year round and as a passive means for heating. With the use of PVs in a building an additional advantage for this sun's energy will be production of electricity on site.

If we ask ourselves what difference PVs do for such a building if they were added to it's brief?

The answer is that they are expected to make a number of changes to the construction and methods, building appearance, and methods of handling issues such as day lighting, natural ventilation, building services, etc.

Firstly, in construction terms, building integrated PV systems need to play the same role as the traditional walls and roofs element they replace. Therefore they need to satisfy the same requirements of the element they replace, which we can list them as:

-Appearance.

-Weather tightness.

-Wind load.

-Lifetime of materials and risks and consequences of failure.

-Safety. (Construction, fire, electrical, etc)

-Cost.

In addition to this to ensure proper function of PV systems a number of measures have to be undertaken to the building design to ensure this, among them will be:

- Avoidance of self-shading.
- The effect of potentially high temperatures.
- The desirability to ventilating the back of the modules to improve efficiency.
- Possibility of using heat generated at the back of modules.

- Provision of accessible routes for connectors and cables.

PVs can make a remarkable difference in the shape and appearance of the building, to which some sort of statutory or building permission from the public body concerned for building licensing has to be made, if they are going to be in other positioning than that for normal walls and roof tops.

1.4 Potentially high temperatures

The possibility of building up heat from any sort of solar capturing device needs always-careful consideration. The lifetime of the materials, thermal movement, temperature re-cycling, suitability of electrical cables used in high temperatures need to be well catered for and well specified. Acceptable performance may always be guaranteed if heat can be removed by ventilation. Normally natural ventilation can suffice. But in areas of high radiation (over 700 w/m^2) models can reach 70°C above ambient, here a sort of mechanical ventilation or other cooling devices may need to be incorporated.

1.5 Ventilation and modules

As stated above, ventilation is of great importance in order to maintain acceptable performance of PVs. There may be a number of ways to accomplish this, for instance, by using ventilation gabs between the modules and the internal skin facing the inside of the building, thus combining the building ventilation with the module ventilation. As a rule of thumb(1), air gab of 100mm at minimum is required; nevertheless, some studies show at gabs of 200mm or more the performance can be further enhanced(2) and(3).

1.6 Using the heat generated by PV systems

Heat generated by PV systems can be of potential value during the heating seasons. This can be used directly or be circulated by means of ducting work; but before doing so it is important to check the economical viability of such a solution. If for example the cost or ductwork is greater than the value of heat recovered in this case it is not considered economical. Since in highly energy efficient offices, casual gains from people and equipment usually contribute to great amount of heat for only 8-9°C out door conditions.

Other usage of PVs can be for providing hot water supply. However, it may be sometimes a bit costly to run coils of water behind PV modules.

Whenever heat is not needed, such as in summer time, it is important that measures are made so that it does not case overheating or add to the cooling loads of the building. Special consideration should also be paid to summer wind patterns so that they don’t infiltrate heat to inside.

2. Forms and systems

The effect of introducing PVs into a project brief will affect building form, this can take a variety of shapes, and the most basic ways are:

- Roof based systems.
- Façade systems.
- Sunshades and sunscreen.

Although non-building integrated PVs are not included here, much of these guidelines are valid to them.

The way to successful design of building integrated PVs lies between PVs providing a greater restriction to forms and shapes and those which are readily encapsulated into a form (i.e. a box) that is placed simply to the building form. Real buildings however many have angles and forms that need to respond to more than the output of PV arrays, this has to taken into account as the building design develops.

2.1 Roof-based systems

Roofs provides a successfully promising location for building integrated PVs this is due to:

- They are often free from over-shadowing.
- Roof slopes can guarantee high performance.
- It is often easier to introduce PVs aesthetically and functionally into roofs than walls.

Roof systems:

Position of PVs	System	Characteristics
Inclined roof	a. PV roof panel	Combined with roof structural system.
	b. PV roof tile	Similar to a. above and easier to integrate.
Saw tooth north light roofs	a. PV panels	Allowing day lighting, while having optimum tilt.

Curved roof	a. Opaque PV, flexible backing of modules of metal or synthetics, or rigid modules arranged in a curve.	Flexible and unlimited design possibilities.
Atrium	a. PV Roof panels	As for inclined roofs, including, transparent, semi-transparent and opaque PVs.

Source[4]

2.2. Ventilating roof system

Roof systems are normally easier and more straightforward to ventilate than façade systems, since generally any heat above normal occupants height will have less effect to occupants than that in facades.

For inclined roofs one solution is to have a sub-frame to support PV modules on the roof structure. This provides the possibility to include a 100mm gab for insulation or otherwise cross ventilation. In saw-tooth roofs, opening the north light provides means to take away the heat.

2.3. Façade systems

Facades have a very wide opportunity for PV incorporation. Because of their appearance as glazing units PVs can further enhance the general outlook of the building. Besides, having the ability of being integrated in other proven systems such as rain-screen cladding.

Façade systems

Position of PVs	system	Characteristics
Vertical wall	Curtain wall	Standard, economical construction. PVs can be introduced as opaque and semi-transparent.

Vertical wall	Rain screen cladding	Rain screen designs include ventilation gabs which can be use to reduce heat built up and run wiring or cables.
Wall with inclined PVs	Glazing or rain screen cladding.	PV efficiency improved. Complexity of construction increased. Potential to provide shading for window (if required), but a degree of self-shading.
Inclined wall	Glazing	Potentially enhanced architectural interest. PV output increased compared to vertical walls. Less efficient use of floor area.
Fixed shading devices	Glazing	Can enhance architectural interest entails a loss of daylight.
Moveable shading devices	Glazing	Can enhance architectural interest entails some loss of light

	but less than fixed shading devices. Increased PV output compared with all fixed systems.

Source[4]

2.3.1 Curtain wall systems

Curtain wall façade solution is a well-established external wall solution particularly in high prestigious offices that occupies the heat of many city centres around the globe. The mullion/transom stick system is the most common. See through areas will typically be double-glazed and opaque areas are either of opaque glass or insulated metal panels. PV modules can easily be incorporated similar to factory assembled double glazing windows. The outer panel might be laminated glass-PV-resin-glass and the inner pane, glass with sealed air gab sandwiched in between. Overall thickness of module will be typically 30mm.

A wide range of combinations can be fitted into the structural grid of curtain walls. These include transparent windows and opaque PV modules or both transparent and opaque PV modules.

Careful consideration should be paid to the positioning of junction box and cable routes.

2.3.2 Rain screen cladding systems

Rainscreen often consist of panels set at a slight distance from the building surface by means of fixing rails in such a way that gab created is used for ventilation, drainage and cable runners. The gab that always kept open has the advantage of maintaining performance through natural ventilation.

3. Summary of the effect of PVs on a design brief

From the above review of available systems and solutions of PVs, the effect of them can be clearly depicted in four main points:

- Footprint
- Façade
- Section

South oriented building for day lighting and passive solar gains provided that it is clear from over shading and obstructions will be suitable for PV integration. Also a footprint with the long axis to the east-west axis will give potentially large south facing facades and roof area as well, the fact that will be favourable for PVs integration.

Although facades and roofs can be of many similarities when it comes to PV installation, (roofs can be thought of as walls rotated at 90°) yet the walls can be slightly of critical consideration, since the built up of heat from back of PV modules can affect the occupants directly.

A major point here is that both roofs and walls or both systems have competing elements for winning a large surface area, either PVs for electrical generation or glazing for day lighting and visual contact. In practise this is solved during the development of the design it self, other factors like site characteristic, adjacent building or other obstruction may make it favourable for one system or another. Another reason behind the unlikeness to have a totally glazed south elevation is that it will lead to overheating problems summer time. Since low-energy offices, for example, are characterized with a maximum of 40% glazing of elevation area (according to part-L 95). Thus, PV could be used in much of the 60% of the wall, which is usually opaque.

The effect on the section will depend on the size of the PV array and the choice of the system, whether it is a wall or roof mounted. For instance, if we take the roof mounted, the section will tend to enlarge the south facing part of the roof pitch over that to the north and more properly adjust its tilt for optimum performance of PV modules; Whereas, the effect on façade section can be having a tilt back to improve performance.

References

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