It’s not just power generation: The positive effect of building integrated photovoltaic design on architecture

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Abstract. From the perspective of solar photovoltaic power generation system and the building integration, studied the practical application and functionality of the PV tile, Aluminium Honeycomb panel PV Components, Vacuum Glass PV Components and FRP Board PV Components. Five positive effects of photovoltaic system on buildings are summarized: beautifying building facades, replacing original building components, upgrading or expanding the building use function, improving the building use comfort and improving the building energy saving effect.

Keywords: PV; PV Building; Building energy conservation

1. The positive effect of PV on architecture

1.1. Landscaping Building Facade
The aesthetic characteristics of PV components, such as colour, shape and texture, can affect the overall appearance of the building. Such as Turpan BIPV Comprehensive Building, using the colour and size of PV components, arranging the texture of the local grape cool house. (Figure 1)

1.2. Replace the original building elements
Building materials photovoltaic components through the solar cell and metal substrates, glass substrates, organic materials, such as the integration of different types of substrate, so that it can have the corresponding function with the building components. It can replace the original building components installed in the corresponding parts of the building.

1.2.1. PV Tile. Photovoltaic tiles are the integration of solar panels and roof tiles,
many solar tiles can form a solar roof (Figure 2). When applied to building roofing, it has the same power generation function as the ordinary battery board, and maintains the harmony of the architectural style.

1.2.2. Aluminium Honeycomb panel PV Components. Aluminium Honeycomb panel PV components is the solar cell integrated with the common building decoration material Aluminium Honeycomb board. (Figure 3) Compared with the ordinary PV modules, the aluminium Honeycomb panel PV members can greatly enhance the insulation, temperature rise and noise reduction performance of the components, and can be used directly instead of building elements for building walls, facades, roofing and other parts. (Table 1)

| Component Type                  | Heat transfer coefficient (W/m²•K) | Noise reduction (db) | Back plate temperature (℃) |
|---------------------------------|-----------------------------------|----------------------|-----------------------------|
| Aluminium Honeycomb Panel PV components | 1.0 ~3.0                          | ≥35                  | 48.6                        |
| General PV components           | 6.0-6.8                           | ≤25                  | 65                          |

1.2.3. Vacuum Glass PV Components. Vacuum Glass PV components is a new type of flat panel PV component made of vacuum glass as the substrate, which has two advantages of solar cell and vacuum glass. (Figure 4) The heat transfer coefficient of the vacuum glass PV component is less than 1 W/m²•K and the thermal insulation performance reaches the level 10. Compared with the hollow glass PV components, it can effectively reduce the energy consumption of building more than 50%. (Table 2) Often used in building walls, lighting roof and other parts of the installation.

| Component type                  | Heat transfer coefficient (W/m²•K) | Surface temperature (℃) |
|---------------------------------|-----------------------------------|--------------------------|
| Vacuum Glass PV Components      | ≤1.0                              | 61.2                     |
| Central control Glass PV component | ≥2.4                            | 78.1                     |
1.2.4. FRP Board PV Components.
FRP Panel PV Components is a flat panel PV component made of FRP plate as substrate. (Figure 5)The organic material has the characteristics of light weight, strong structural safety and convenient transportation and installation. FRP daylighting Board has certain heat insulation performance, has good daylighting performance, and does not exist the expansion crack and so on. Compared with insulating glass, it can reduce the cost and reduce the surface temperature of the component. (Table 3) It can be used for building curtain wall, lighting roof, building outdoor light facilities and other parts.

At present, the heat transfer coefficient $K$ value of single-layer plate is 2.7 $\text{W/㎡•K}$, and multilayer plate is 1.0 $\text{W/㎡•K}$, which meets the requirement of building performance in the FRP plate photovoltaic members have been developed.

| Component type               | Heat transfer coefficient ($\text{W/㎡•K}$) | Surface temperature (℃) |
|------------------------------|---------------------------------------------|--------------------------|
| FRP Board PV Components      | 1.5~3.2                                     | 64.5                     |
| Central control Glass component | ≥2.4                                      | 78.1                     |

1.3. Promote or extend the building’s use function
Using part of the physical properties of PV components, through the means of architectural design to upgrade, improve the use of the original building, or the existing building function to expand, so that it has a new use function to create more benefits.

Such as an office building in Shanghai, on the roof of the podium layout of the steel structure of the rain shed, combined with the steel structure of the photovoltaic roof. (Figure 6) Solar cells can absorb more solar energy; reduce the direct radiation to the roof of the solar energy, with thermal insulation effect. In addition, photovoltaic roof can absorb the direct sunlight and partially reflected light, which converts most of the solar radiant energy into electrical energy. The photovoltaic roofs on both sides of the podium can get a good shade effect, and the commercial facilities such as coffee, cold drink and so on are expanded in commercial space. (Figure 7)

1.4. Improve the comfort of building use
Research and Development building of Trina Solar Co., Ltd. to improve indoor daylighting comfort through PV components. (Figure 8) The PV components and the coated glasses are arranged, and the low transmittance of
the PV components is used to prevent excessive sunlight from entering the room. At the same time, using the coating glass between PV components for lighting and ventilation, improve the indoor lighting comfort.

The central control building combines the local climatic conditions, and sets up the solar daylighting atrium. Not only solve the atrium of the relevant room lighting, but also to prevent too much sunlight into the room to avoid indoor temperature rise according the use of photovoltaic components. (Figure 9)

1.5. Improve the efficiency of building energy saving PV components in the construction of a variety of installation forms, generally based on the construction project itself, the basic conditions of the comprehensive consideration and reasonable design. Additional functions are derived from the installation of different PV components (table 4).

Table 4. Energy-saving effect of buildings with different installation forms of PV components.

| Installation form          | Additional Features                                      |
|----------------------------|----------------------------------------------------------|
| Parallel roof Installation | Thermal insulation, ventilated roof                     |
| Wall Combination Installation | Effectively reduce the temperature of building wall and reduce the cold load of air conditioner |
| PV curtain Wall            | It has the function of shading and saves the building area |
| PV sunshade Panel          | Has the function of shading                               |
| Lighting Roof              | Reduce lighting Load                                    |

1.5.1. PV Roof Energy Saving. Building Roof is the best layout of PV panels, it has incomparable advantages: good sunshine conditions, not easy to occlusion, to maximize the reception of solar radiation, and PV modules can be close to the building roof structure installation, reduce the adverse effects of wind. At the same time, solar PV modules can also be used as insulation layer shielding roofing.

Ministry of Housing and Urban and rural construction of the building will be tiled on the roof and with the roof 150–200mm distance, photovoltaic components to prevent direct sunlight roof, reduce the roof temperature. (Figure 10) The heating cavity air is heated by the back plate of the component, which accelerates the air flow, thus taking away the heat in the cavity, reducing the component and the roof temperature, also reducing the loss of the power generation efficiency.

1.5.2. Energy Saving of photovoltaic wall surface. The PV system is arranged on the exterior wall of the building, and the solar energy is collected rationally. Not only can the solar energy photovoltaic modules be used to convert the solar energy into electricity, but also can effectively reduce the temperature of the building wall and reduce the cooling load of indoor air-conditioning.
Shanghai Solar Energy Engineering Technology Research Centre arranges the photovoltaic curtain wall in the outside 100~150mm of the building. (Figure 11) After heating the back plate of the component, the air is heated and the air flow is accelerated, thus taking away the heat in the cavity, reducing the temperature of the component and the wall.

1.5.3. PV Curtain Wall Energy Saving. Photovoltaic curtain wall and the main building can take off a distance, effectively blocking the sun on the wall of direct, while avoiding the back of the photovoltaic wall heat directly into the room.

In the two floor of the central Control building, the east and south facade is provided with a thin film photovoltaic curtain wall. Photoelectric curtain wall has shading effect, reduce the heat generated by indoor radiation. The photovoltaic curtain wall and the outer surface of the building form cavities, photovoltaic curtain wall absorbs solar radiation after heating the air in the cavity, through the top of the daughter wall set ventilation openings, combined with the bottom of the ventilation steel grille, so that the photovoltaic wall and building outside the wall and indoor heat from the bottom of the effective discharge, can effectively reduce the energy consumption of building refrigeration. (Figure 12)

Test data show that the building through the shielding of photovoltaic curtain wall in the summer can effectively block direct sunlight, save a lot of air-conditioning energy consumption, energy-saving effect is very obvious. (Table 5)

**Table 5. PV curtain wall test data.**

| Test points | Temperature (℃) |
|-------------|-----------------|
| No blocking outside wall on the south Side | 53.5 |
| Inner surface temperature of curtain wall | 49.5 |
| The South Side exterior wall (exterior has the photovoltaic curtain wall) | 38.2 |

1.5.4. PV Shading Energy saving. PV shading System uses PV modules as exterior sunshade components, and it is a typical application form of PV architecture, which has the functions of shading and power generation. The form includes plate shading, vertical shading, louver shading, etc.
On the atrium roof of the central control building, set the light transmittance of 30%-40% glass-clamped crystal silicon photovoltaic ceiling. In the construction of the east, south, west facade set Sunshade, the second floor of the east and south to set the light transmittance 20% film photovoltaic curtain wall, to meet the needs of building lighting. (Figure 13) At the same time, it can effectively block the strong light direct to the exterior wall of the building, block excessive light into the room, so as to improve the indoor environment effect.

1.5.5. Energy saving of PV lighting roof. Although the photovoltaic roof can save the atrium illumination Energy, it may cause the indoor temperature to rise and increase the cooling load because of the heating of the PV component. The central control building is provided with a double glass clamp crystal silicon photovoltaic roof at the top of the atrium, and an open ventilation window is arranged around the roof of the skylight. (Figure 14)

**Figure 14.** Map of the central control building lighting top signal.

2. Conclusion
At present, the design of photovoltaic system is divorced from architectural design which restricts the application of PV in architecture. In order to realize the integration and synergy of the integrated design process of PV building. First of all, we should speed up the research and development of more types of building materials and component PV modules, and form the industrialization capability to promote the development of photovoltaic scale. Secondly, we need to strengthen the training of building PV-related talents and provide a full range of talents for building PV. Third, in order to improve investors’ confidence in the photovoltaic industry, We should further improve the relevant standards, standards and related Atlas of building PV, and establish the testing centre and certification organization of the products. As well as the completion of construction acceptance and maintenance of technical procedures. Finally, the government agencies should subsidize the building integrated PV System project, and introduce relevant policies to encourage the development of new photovoltaic components, and gradually expand the scope of PV component applications.

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