|| Volume 5 || Issue 6 || June 2020 || ISSN (Online) 2456-0774
INTERNATIONAL JOURNAL OF ADVANCE SCIENTIFIC RESEARCH AND ENGINEERING TRENDS

PHOTOVOLTAIC GLAZING IN BUILDINGS

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Abstract: - In the frame of zero-energy buildings, the integration of renewable energy sources along with energy saving strategies must be the target. PV glazing is an innovative technology which apart from electricity production can reduce energy consumption in terms of cooling, heating and artificial lighting. It uses Photovoltaic glass. Photovoltaic glass (PV glass) is a technology that enables the conversion of light into electricity. To do so, the glass incorporates transparent semiconductor-based photovoltaic cells, which are also known as solar cells. The cells are sandwiched between two sheets of glass. Photovoltaic glass is not perfectly transparent but allows some of the available light through. Buildings using a substantial amount of photovoltaic glass could produce some of their own electricity through the windows. The PV power generated is considered green or clean electricity because its source is renewable and it does not cause pollution. There are hundreds of years or just a few decades left of non-renewable resource, the fact remains that it is a finite resource. At some point, fossil fuels are going to either be gone or they are going to become too expensive to realistically use. We are in dire need to generate and innovate new possible ways to generate eco-friendly electricity. It's something of an uncomfortable fact that civilized society is almost completely reliant upon fossil fuels for nearly every aspect of its existence. While fossil fuels have been integral in the development of most industrial nations, there are a few realities of using them that society needs to come to terms with. There are many arguments in favor of society's need for renewable energy. In this context, the Photovoltaic glazing process in commercial, residential buildings and their impact on buildings energy performance and occupants comfort are reviewed.

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I INTRODUCTION

Photovoltaic glass (PV glass) is a technology that enables the conversion of light into electricity.

Figure 1 PV Glazing

To do so, the glass incorporates transparent semiconductor-based photovoltaic cells, which are also known as solar cells. The cells are sandwiched between two sheets of glass. Photovoltaic glass is not perfectly transparent but allows some of the available light through Buildings using a substantial amount of photovoltaic glass could produce some of their own electricity through the windows. The PV power generated is considered green or clean electricity because its source is renewable and it does not cause pollution. In addition to energy cost savings, potential benefits from the use of photovoltaic glass include reducing the carbon footprint of facilities, contributing to sustainability and consequently, enhancing branding and public relations (PR) efforts.

In environments where too much heat gets in with light, the reduced transparency can also save on air-conditioning costs. Variations have been designed for environments where more light are desired. For example, Sharp has developed a silted solar glass product that has gaps between solar cells to enable greater light penetration.

Another company, Onyx Solar, makes photovoltaic glass with a variety of options including different colors, gradient and patterns as well as double or triple-glazed products. Variance in photovoltaic efficiency and light penetration among these products enables multiple options for architectural design.

1. Need of the study

There are hundreds of years or just a few decades left of non-renewable resource, the fact remains that it is a finite resource. At some point, fossil fuels are going to either be gone or they are going to become too expensive to realistically use. We are in dire need to generate and innovate new possible ways to generate eco-friendly electricity. It's something of an uncomfortable fact that civilized society is almost completely reliant upon fossil fuels for nearly every aspect of its existence. While fossil fuels have been integral in the development of most industrial nations, there are a few realities of using them that society needs to come to terms with. There are many arguments in favour of society's need for renewable energy.

2. Objectives

1) This research paper aims to assess the potential for using Solar PV Facades in high-rise buildings.

2) This paper discusses the present status of different Solar PV technologies & facade types.

3) It intends to examine the relative performance of mono-crystalline & thin film technologies used for Solar PV Facades in high-rise buildings

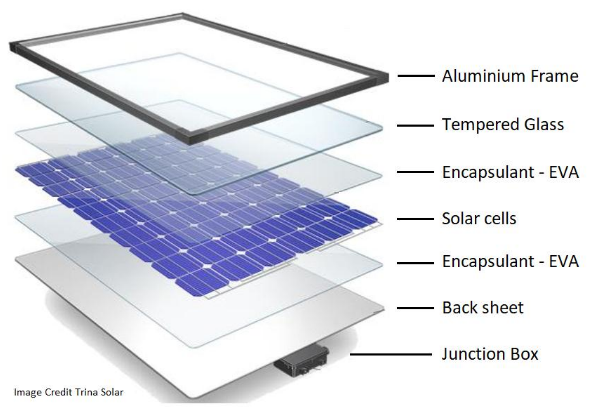
4) It also aims to analyze the monetary savings reduction resulting from use of Solar PV Facades in high-rise buildings

5) It also attempts to discuss the advantages & challenges related to the concept.

3. Research Methodology

Solar photovoltaic are made with a number of parts, the most important of which are silicon cells. Silicon, atomic number 14 on the periodic table, is a nonmetal with conductive properties that give it the ability to convert sunlight into electricity. When light interacts with a silicon cell, it causes electrons to be set into motion, which initiates a flow of electricity. This is known as the "photovoltaic effect."

However, silicon cells alone can't provide electricity for your home. They are paired with a metal casing and wiring, which allow the solar cell's electrons to escape and supply useful power. Silicon comes in a number of different cell structures:



single cell (mono crystalline), polycrystalline or amorphous forms, most commonly associated with thin film solar panels.

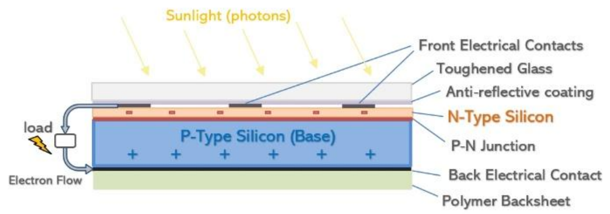
Solar PV Cells

Solar photovoltaic cells or PV cells convert sunlight directly into DC electrical energy. The performance of the solar panel is determined by the cell type and characteristics of the silicon used, with the two main types being mono crystalline and polycrystalline silicon. The base of the silicon cell can be built using different additives to create either a positive p-type silicon or negative n-type silicon. There are several different cell sizes and configurations available which offer different levels of efficiency and performance Fig. types of solar cell

Most residential solar panels contain 60 mono or polycrystalline cells linked together via *busbars* in series to generate a voltage between 30-40 volts depending on the type of cell used. Larger solar panels used for commercial systems and utility scale solar farms contain 72 or 96 cells and in turn operate at a higher voltage. The electrical contacts which interconnect the cells are known as *busbars* and allow the current to flow through all the cells in a circuit.

Glass

The front glass sheet protects the PV cells from the weather and impact from hail or airborne debris. The glass is typically high strength tempered glass which is 3.0 to 4.0mm thick and is designed resist mechanical loads and extreme temperature changes. The IEC minimum standard impact test requires solar panels to withstand an impact of hail stones of 1 inch (25 mm)



diameter traveling up to 60 mph (27 m/s). In the event of an accident or severe impact tempered glass is also much safer than standard glass as it shatters into tiny fragments rather than sharp jagged sections.

To improve efficiency and performance high transmissive glass is used by most manufacturers which has very low iron content and an anti-reflective coating on the rear side to reduce losses and improve light transmission.

Aluminum Frame

The aluminum frame plays a critical role by both protecting the edge of the laminate section housing the cells and providing a solid structure to mount the solar panel in position. The extruded aluminum sections are designed to be extremely lightweight, stiff and able to withstand extreme stress and loading from high wind and external forces.

The aluminum frame can be silver or anodized black and depending on the panel manufacturer the corner sections can either be screwed, pressed or clamped together providing different levels of strength and stiffness.

EVA Film

It is the abbreviation for ethylene vinyl acetate. EVA films are a key material used for traditional solar panel lamination.

With the help of a lamination machine, the cells are laminated between films of EVA in a vacuum, which is under compression. This procedure is conducted under temperatures of up to 150*°C*. One of the disadvantages of EVA films is that it is not UV-resistant and therefore protective front glass is required for the UV screening.

Backsheet

The backsheet is the rear most layer of common solar panels which as acts as a moisture barrier and final external skin to provide both mechanical protection and electrical insulation. The backsheet material is made of various polymers or plastics including PP, PET and PVF which offer different levels of protection, thermal stability and long term UV resistance. The backsheet layer is typically white in colour but is also available as clear or black depending on the manufacturer and module.

Dual glass panels - Some panels such as bifacial and frameless panels use a rear glass panel instead of a polymer backsheet. The rear side glass is more durable and longer lasting than most backsheet materials and so some manufacturers offer a 30 year performance warranty on dual glass panels.

Transparent solar panels

It uses a tin oxide coating along with titanium oxide that is coated with a photoelectric dye. The solar cells use ultraviolet radiation as well as infrared. The applications include windows used for power generation, lighting and temperature control.

Junction Box and Connectors

The junction box is a small weather proof enclosure located on the rear side of the panel. It is needed to securely attach the cables required to interconnect the panels. The junction box is important as it is the central point where all the cells sets interconnect and must be protected from moisture and dirt.

II LITERATURE REVIEW

R.S. Anand et.al (2009). In their research project they aimed for establishment of solar power station that will augment the energy supply of the institute and provide us with an in-depth evaluation of many existing solar technologies. The solar power station they built in a modular fashion such that some of the individual modules are utilized for demonstration and testing of technologies developed in house. Their research and technology activities centered on three main areas, namely, material and device research in photovoltaic technologies, system integration and power distribution and energy storage technologies is highly inter disciplinary requiring analysis and synthesis across departments. Their goal was oriented interdisciplinary research that leads to development of technology that can be integrated into the solar power station that they proposed.

Ted James, et.al (2011) Investigated that although the deployment of BIPV is relatively low, opportunities remain promising. Decreasing module costs, increasing consumer interest in solar energy, and policy schemes that support distributed generation systems have the potential to increase rates of BIPV market growth. The commercialization of solar products that have the full functionality of building materials has been very limited, but systems are increasingly being developed to account for design aesthetics and installation-cost reductions. This continuum of integration is leading to more solar products that may fully replace traditional building materials.

Dayal Singh Rajput et.al (2013) In his paper, the performance of solar photovoltaic panel subjected to environmental dust was experimentally studied. The effect of dust on the power reduction and efficient reduction of PV module was quantified. From the graph the maximum efficiency 6.38%, minimum 2.29% without dust & maximum efficiency 0.64%, minimum 0.33% with dust. The result shows that dust considerably reduces the power production by 92.11% and efficiency as 89%.

G.M. Tina et.al (2013) in her paper a five layer thermal model is used, as it is able to precisely estimate the operating temperatures of the PV layers in real outdoor operating conditions, especially when the ambient conditions on the front face of the PV module are different from the back ones. The temperature calculated by PV thermal model was useful to evaluate the thermal environment in a perimeter zone near a highly-glazed surface. The comfort simulation model is being fine-tuned and generalized in order to be able to evaluate comfort conditions for typical office spaces equipped with PV window. Her results indicate a very unacceptable thermal discomfort condition eventually, her model will help provide recommendations for components of high-performance facades in order to reduce or eliminate perimeter heating as a secondary source of heating in perimeter zones.

Bjørn Petter Jelle et.al (2015) Investigated that new and innovative solutions may reduce costs and increase the market share, e.g., in the retrofitting market. His solutions should be easily applicable, where an example of a future vision is paint applications of PV cells. It is crucial that all new technologies and solutions are thoroughly tested and approved in accordance with existing standards. Furthermore, there is also a need for development of new standards and methods, e.g., regarding long-term durability versus climate exposure.

Patrina Eiffert, et.al (2016) Investigated that PV will be largely accepted by builders, architects, and end-users only if the quality of BIPV systems fully meets the requirements of everyday construction elements. PV can be included in building projects only if architects and principals have sufficient knowledge about PV technologies and appropriate design tools to assist them**. Mustafa Araz,** et.al (2017) In his study, he had comprehensively reviewed the BIPV and BIPVT applications in terms of energy generation amount, nominal power, efficiency, type and performance assessment approaches. BIPV technology is a promising addition to the mix of renewable energy generation technologies. In his paper, he provided a comprehensive review of the current state of the art in the BIPV technology and have started with a brief description of BIPV systems, and then reviewed the current literature in detail. He also had summarized the previously conducted studies. [6]

Aseem Kumar Sharma et.al (2017) His research paper establishes that there is potential for substantial monetary savings & reduction in GHG emissions if Solar PV Facades are used in high-rise buildings in Mumbai, India. The concept can also be applied for high-rise buildings in other parts of India as well. The payback period of less than 2 years is also very attractive. There is a need to include Solar PV Facades from the concept stage for high-rise buildings to ensure proper integration & minimum cost. Thin Film technology is a good choice for Solar PV Facades in India. As Green building norms under TERI – GRIHA and IGBC-LEED certification process require energy efficiency of about 14% for the Building Envelope & 10% of the total building energy to be drawn from solar power, Solar PV facades help the high-rise buildings in meeting their norms.

Methodology & Planning Schedule:

Methodology-

The flowchart in Figure 3.1 presents the analyze process of the PV Model-site project. It started with an idea of PV integration and was finalized with a Model that was considered to be optimal in terms of the established design strategy, and the analysation process consisted of three main phases

- Phase 1: Selection of ‘places’ for PV integration
- Phase 2: Generation and optimization of design alternatives
- Phase 3: Evaluation process.

Phase 1 – Selection of ‘places’ for PV integration

Phase 1 assessed the ‘integratability potential’ of different parts of the building intended for PV integration. The ‘places’ that were identified were selected on the basis of two groups of criteria: (1) climatic and urban planning characteristics and (2) architectural characteristics.

The first group of criteria considers: (1) tilt, (2) orientation and (3) the shading effect. In terms of tilt, vertical surfaces were considered unfavourable, whereas in terms of orientation, northern and southern, as surfaces with less potential to accumulate solar radiation, were considered to be less favourable than western and eastern surfaces .At the same time, shaded surfaces were deemed unacceptable.

The second group of criteria considers: (1) position, (2) visibility from inside and outside the building, (3) accessibility, (4) function and (5) aesthetics. Shaded areas, areas with a low level of visual dominance and areas with inefficient orientation and tilt were eliminated by the evaluation criteria.

After justifying the ‘integratability potential’ according to the established evaluation criteria, the following ‘places’ were selected for PV integration: (1) the entrance facade, (2) the ‘quadrant’, (3) the internal courtyard, and (4) the rooftop.

Phase 2 – generation and optimization of design alternatives

This phase starts with the general idea of integrating PVs into the building, after which it focuses on individual building elements. The following points have to be decided upon in the case of each element of the building:

- exact position;
- PV type, the solar cell technology, shape and dimensions, colour, texture, transparency and frame of modules;
- tilt;
- Mounting option.

All the above-mentioned points are interdependent and the process is iterative. The point at which the selection process will start is unique in the case of each design element. Often several options are explored and the results are analysed in order to optimize the design solution. The selection phase consists of a sketch of different design options and the verification of the energy output, performed using model. Final solutions represent a compromise shared between energy performance, costs and aesthetics.

PV Glass alternatives: generation and performance prediction.

Different PV integration options were explored and finally four design alternatives were devised.

1. Design alternative 1 ‘PV wave’: The main idea was to create a striking visual effect at the entrance, to generate space for PV testing and, with a canopy over the rooftop and with the internal courtyard, to create a rooftop garden and a strong visual impression with shadows and light-play.
2. Design alternative 2 ‘PV Diffuse Sun ’: The main idea was to keep PVs integrated into several elements in a mutually compatible manner and in harmony with the entire building.
3. Design alternative 3 ‘PV Sky Garden’: The main idea was to create new space in the form of a tropical rooftop garden with interesting visual effects and views from both inside and outside the building.
4. Design alternative 4 ‘PV Cube ’: The main idea was to create a simple, but visually and spatially effective PV structure – a canopy over the roof.

Phase 3 – Evaluation process

PV integration is a complex process that requires a multidisciplinary approach that is design alternatives should be assessed against different, often non-mensurable, mutually conflicting criteria such as energy performance, economic performance and functional-aesthetic criteria. Therefore, PV model which was developed for analyse of PV glass at different condition was used in the evaluation of the proposed design alternatives and in the selection of the optimal result.

The set of all analyze assessment that were criteria selected for the evaluation of design alternatives of the PV glass by PV model was carefully specified by team in order to arrive at an optimal result that will strike the best balance between investor and architectural requirements.

Based on the values they refer to criteria functions analyzed can be divided into three groups:

- Electricity generation.
- Costs.
- Architectural value.
- Impact of Dust and weather

III CONCLUSION

PV integration is a complex process that requires a multidisciplinary approach that is design alternatives should be assessed against different, often non-measurable, mutually conflicting criteria such as energy performance, economic performance and functional-aesthetic criteria. Design alternatives of the PV Demo-site was carefully specified by the us and the design guide in order to arrive at an optimal design alternative that will strike the best balance between investor and architectural.

In the experiment of the solar photovoltaic panel subjected to environmental dust was experimentally studied. The effect of dust on the power reduction and efficient reduction of PV module was quantified. From the graph we can see that we get the maximum efficiency 6.38%, minimum 2.29% without dust & maximum efficiency 0.64%, minimum 0.33% with dust. The result shows that dust considerably reduces the power production by 92.11% and efficiency as 89%.The electrical parameter of solar panel are sensitive to the dust density so it is very essential to provide auto cleaning mechanism to remove the dust particles from the surface of the panel in order to ensure high performance.

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