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FACADE INTEGRATED P.V SYSTEM. APPLICATION FOR INSTITUTIONAL BUILDING IN NIGERIA

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Abstract: **Solar Photovoltaic (PV) can be considered as one of the most reliable and promising renewable systems. This is of great importance for developing countries like Nigeria. this paper will investigate the facade photovoltaic systems (facade PV) integrated into institutional building in Nigeria. Comparing to the rooftop solar, the facade solar system can install a larger number of solar panels on the vertical wall of building. In addition, it also helps to reduce the energy consumption of building. However, the comprehensive study of facade solar system is still lacking in Nigeria. Therefore, in this study we present the general design process of facade PV for building, including choosing suitable solar panel, facade PV wall. The study will open a new room for application of facade PV system for the institutional building in Nigeria.**

Keywords: **PV facade, thin-film PV, micro inverter configuration, building-integrated photovoltaic (BIPV).**

1. INTRODUCTION

Building-integrated photovoltaic (BIPV) has been regarded as the unique way of harnessing solar energy which is the most abundant , inexhaustible and clean of all the available energy sources, transforming buildings from energy consumers to energy producers, and increase building energy efficiency due to its potential advantages: (1) low consumption of materials; (2) save labor and operational & maintenance costs; (3) high performance of electricity generation; (4) efficient thermal insulation; (5) good noise insulation and weather protection. Being a multifunctional technology, which convert buildings from energy consumers into energy producers. BIPV are used to replace conventional building materials and also used as insulative materials for building envelopes or as a supplementary power source of buildings. It is allowed to be an energy-related part of all kinds of building such as residential homes, commercial buildings, offices, schools, hospitals and so on. Those useful applications and advantages have made BIPV become one of the most rapid-developing segments in renewable energy industry. BIPV products are initially introduced into commercial market in the early 1990s as an integrated material which can be installed directly into the building roofs, shading devices, skylight and facades.

BIPV technology represents the opportunity for a triple advantage in architectural design. It harnesses solar energy, addresses some limitations of utility-scale PV and converts the building from an energy consumer to energy producer as a multi-functional component. In harnessing solar energy, it utilizes renewable energy from the sun which provides more energy in one hour than the all the people on earth require for a whole year .It also provides decentralized on-site energy right next to the point of use, thus reducing transmission and conversion losses, as well as ancillary costs limitations with utility-scale. Also, it serves as a multifunctional energy-producing building component used for roofing, cladding, glazing or shading.

There are two types of BIPV, called rooftop PV and façade PV systems are available. Although the former has been in many cities in Nigeria for a long time, the latter is still in its initial phase. Facade PV system takes advantage of the building's vertical wall to install solar panels and thus deploys a larger area of solar panels, enabling it to gain more energy production.

2. RESEARCH METHODOLOGY

Through a series of case studies in this paper, we propose the appropriate PV system components integrating into Nigeria's institutional building wall to generate energy from the sun and also improve the overall energy efficiency of buildings. We represent thin-film technology and suggest the appropriate types of building, and also, we suggest the type of solar panel and the PV wall for building. The inverter configuration used for facade PV is also considered, we also introduce the essential simulation software for the planning and design of facade PV systems.

3. LITERATURE REVIEW

Nigeria has a huge potential to harness solar energy power for future demand with a year-round average direct normal irradiance radiation of about 5.5KWh/m2 per day with most of its energy resources un utilized. The Nigerian policy and regulatory overview also reveal that the average solar insolation to be about 5.25KHh/m2 per-day and 7KWh/m2 per day in the northern part of the country with 500PV installation currently in use in the Nigerian federation.

Nigeria depends highly on fossils for the generation of electricity due to huge deposit of crude and natural gas in the country. However, with the huge deposit of crude oil and natural gas it generates less than 4,000MW of electricity with per capital consumption of 0.03kw. this is the current situation despite the fact that the total capacity was 11,756MW since 1999. (Oparaku 2007)

Building integrated photovoltaic technology has the potential of offsetting partially the cost of the modules by replacing part of the building materials as well generate the required electricity (Pearsall 2013). The integrated photovoltaic offers opportunity to replace other building component and this helps in offsetting the cost of the installation.

Solar energy is a clean source of power. Electric power generation from this source has less or no environmental hazard, unlike most conventional sources. Photovoltaic technology generates no noise through the inverter system could produce a system humming noise which in absorbed by the domestic noise background. (Tsoutsos et al., 2005) it was emphasized that PV system are free from radioactive or CO2 emission, CIS and CdTe modules are prone to emit toxic substance to the environment when fire incident occurs in the array. However, research shows that the Cd emission in relation to CdTe is 0.001 percent equal to the 0.01g/GWh. This is significant and has no implication on the human health. Solangi et al. (2011) outline the benefit of solar energy technology as follows

- No emission of CO2, NOX,SO2 OR PARTICULATE
- Transmission line from the grid are reduced
- Increase in national energy portfolio

In a recent research Solangi et al (2011) discussed that the emission of CO2 by African region as shown in the world emission table will reach 1524 million tone of CO2 by the year 20205.Nigeria depend highly on fossil fuel to generate electricity, in order to achieve the global challenges of CO2 emission reduction, there is need to integrate renewable technology in electricity generation.

4. FINDINGS AND DISCUSSION

THIN-FILM SOLAR PHOTOVOLTAIC TECHNOLOGY

Traditional rigid photovoltaic panels have been proliferated significantly in the market in the last decade with different designs for multifunctional uses such as smooth plate, roofing tiles, shading-mounting, exterior wall cladding, etc. Many traditional types are designed to be placed directly on to architectural sub-device or through a hard-frame before mounting to the building elements with a high mechanical quality, the PV cells of traditional panel are allowed to be made from crystalline silicon (c-Si). But, the rigidity of these products has led to the increase of load-bearing capacity of building elements. Furthermore, several researches in recent years have been made with concentrating on flexible forms of PV modules, (hereinafter called as thin-film solar PV). Various publications have shown results that thin film technology has unique advantages over the traditional silicon PV technology, such as: (1) lower consumption of materials; (2) independence from the lack of silicon supply;(3) simple manufacturing process; and (4) simplified materialshandling; (5) lighter weight; and (6) more flexible. That is the reason why thin-film solar PV has been used in a variety of buildings.

The classification of thin-film solar PV technologies can be made according to manufacturing materials as: (1) amorphous silicon (a-Si) thin-film; (2) cadmium telluride (CdTe) thin-film; (3) copper indium gallium deselenide / sulfide (CIGS) thin-film; and (4) silicon thin-film. commercial efficiency, all thin-film technologies are currently accounted for 4:5% of the world's total production (about 97:5 GWp) in 2017; in which CdTe, a-Si, and CIGS technology is accounted for 2:3%, 0:3%, and 1:9%, respectively. The maximum efficiency recorded from laboratory of thin-film is 22:9% for CIGS solar cells, whereas the practical number recorded from commercial project is 19:2%. These numbers for CdTe technology are 21% in lab and 18:6% in field test. However, there is a forecast that the market sharing of thin film technology may reach around 38% of the total production. Also, CIGS technology is anticipated to be more popular than other PV technologies due to its high efficiency and lower cost of production. Other thin-film technologies, due to its outstanding benefits over conventional PV technologies, will be put in further research to lower manufacturing costs by cheaper and faster manufacturing technologies in the future

PV panels

There are two types of PV panels that are suitable for institutional building in Nigeria. Example of those panels is given in Fig. 1.

1) PV cladding crystalline: PV cladding crystalline technology is ideal for the buildings that seek maximum energy production, and are well oriented towards the sun. Crystalline silicon technology is popularly used on canopy and skylight applications, spandrels glass, solid walls, and guardrails This PV cladding has the same mechanical properties as a conventional, architectural glass used in construction. Moreover, in addition, it also produces free and clean energy for building. Presently, the crystalline silicon glass efficiency can go up to 16%

2) PV cladding thin-film: The thin-film is ideal for so many building integrated solutions to create transparent or opaque solar PV panels, ideal for facades, canopies, skylights or curtain walls. Some benefits of PV cladding thin-film are

- PV thin-film can operate to a high performance at nonoptimal angles;
- PV thin film operates down to 10% of sunlight, thus higher the number of hours over the year in which to Generate electricity providing a more consistent energy yield. Thin-film alignment also renders panels less affected by shading;
- PV thin-film are less affected by high temperatures so do not require ventilation for optimal operation;

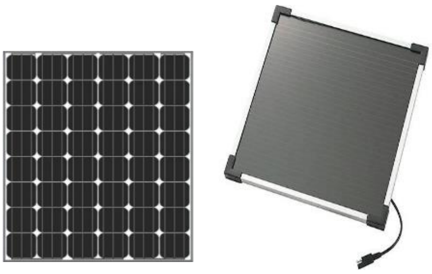

Figure 1: showing crytalineand thin-film solar panel respectively.

Facade PV walls

From an energetic perspective, the envelope of building acts as a buffer or intermediary between the interior and the exterior environment wall cladding system. The concept of facade PV wall is that utilizing the envelope of building to integrate solar panels. there are many other typical types that are suitable for the climate in Nigeria as below

1) Facade PV glazing: The glazed PV laminates for roof of building are often made by crystalline silicon cell with adjusted spacing or by laser grooved thin-film which actually provides filtered vision, encapsulated within glazed panels . In buildings they are often found in envelope systems together with extruded aluminium frames. They may be used as part of a semi-transparent roof, considered as skylight. The transparent functional glass is substituted with PV glazed panels, whilst the load-bearing part is equipped for the electric wiring passages. The solar cell pattern and assembly provide the proper solar and daylighting control replacing the traditional external louvers and defining a particular architectural appearance for building. These structures typically combine glass-glass PV laminates with adjustable light transmission, enhancing the architectural design of light and shadow and performing a fundamental role for the energy balance of the building. Facade PV glazing can be proposed in flat roof, pitched roof, and also sometimes in curved surfaces.

2) Curtain PV wall: A curtain PV wall is typically a continuous building envelope system where the outer walls are non-structural. A curtain PV meets the building envelope requirements such as load bearing, thermal insulation,

weatherproofing and noise reduction. Since PV is integrated in a complex building skin system, while using curtain walls, the energy parameters related to solar system such as thermal and visual comfort are specifically related to the PV design. Similarly, to facade PV glazing, the transparent functional layer is substituted with an active glazed panel including PV, whereas the load-bearing part, represented by the PV frame, is equipped for the electric wiring system. Different technological solutions are also included in the category such as stick system with transforms, structural-sealant glazing, suspended facade, or point fixed facade.

3) Rain-screen facade PV: This facade PV system generally includes of a load-bearing sub-frame, an air gap and a cladding panel. In summer, heat is evaporated due to the air cavity that is naturally ventilated through the bottom and top openings This is the reason why it is also called as cold-facade, since it brings a cooling effect for the wall and enhances the efficiency of the PV modules. Many constructive models and technological solutions are available for building. The solar modules could be integrated as the outer of building cladding like conventional cladding system.

4) PV Accessories: Buildings have solar accessories integrated into the design. These component parts include balconies, parapets, outdoor partitions, shading systems and several components. Among these, shading systems are Most commonly used accessory. The control of the indoor micro climate, requires the use of shading devices aimed to select the solar radiation for guaranteeing the thermo-hygrometric and visual well-being through a proper use of natural lighting. Shading devices can be of various type: applied on roof or facade; external, interposed or internal; fix or tracking (manually or electrically); vertical, horizontal or oriented; curtain or blind; mobile screen or panels; with special element (selective glass, solar thin-film, prismatic glass). Solar panels can be easily laminated in these accessories to achieve a perfect way to utilize the shadow function with energy generation.

MICRO INVERTER CONFIGURATION

Shading is an issue to PV facade system like other PV system. The shading of the façade PV is un avoidable and cause by many sources such as trees, enamouring buildings, or even from the wall of building itself. Moreover, the string inverter configuration which is common approach for rooftop PV, is not applicable for facade PV system. Instead of this, the micro-inverter configuration is a suitable approach since the DC-AC conversion and max power point tracking (MPPT) is conducted at individual solar panel level, the loss due to shading only one panel does not affect the overall energy efficiency of system. Unlike central inverter configuration, a micro-inverter on the other hand, will take advantage of the production of each individual panel. Because micro-inverter is integrated to the panel module. This will convert the power generated for each panel to the grid voltage. The dimension of micro-inverter is also smaller than others, for example Enphase inverter in Fig. 4. In general, the benefits of using microinverter are list as below:

- The core advantage of using micro inverter is that theoretically we can yield more solar electricity. The reason for this is that there are slight differences in voltages between solar panels. When they are in a string the voltage is reduced to the value of the lowest voltage panel in the string;
- If a facade PV system is facing multiple angles, meaning that some panels are facing south, east, and west, then micro-inverters are ready to produce energy. If we have shading issues from trees or a large chimney, again microinverters would be better than others. In these situations, the solar panels will be producing different amounts of electricity at different times of the day, but microinverters will ensure harvest all of the energy;
- Optimizers are an option for standard inverters as well, which function is very similarly to a micro-inverter. With an optimizer, we have a standard inverter, but we also have optimizers for each individual panel combating production differences;
- Micro-inverters typically have 25year warranties from supplier while other inverters typically have 5or10 years warranty;
- Micro-inverters and the add-on optimizers both offer an additional perk in system monitoring as well. With either of these devices, the system has ability to track the production of each individual panel, while with a standard inverter only can track the production of the whole system;
- If customer want to expand their PV system in future, micro-inverters are easy to plug and run. Meanwhile, with a standard inverter, it would be more costly to add another full unit

MODELLING FACADE PV SYSTEM

The benefits of facade PV are not only from generating energy from the sun, but also from the overall building energy consumption aspect. The facade wall helps to reduce the heat transfer into the building, hence reducing the energy load for Heating, ventilation, and air conditioning (HVAC) system. Besides that, transparent solar panel allows the nature light goes through, reduces the energy for lighting system. Therefore, we have to take into account these potential benefits in planning and designing facade PV system for building. We propose to use the following guideline for using softwares in order to fully understand the impact of facade PV to the building as below steps: Designing facade PV wall prototype: In this step the

- PV designer have to choose the suitable prototype of wall for solar panel.The consultants from architect and civil engineer are essential in this initial step in order to search a final decision for facade PV system;
- Facade PV simulation: In this step the PV designer uses simulators to estimate the generated energy from facade PV system. The input parameters of simulator include all the features of PV system such as solar rated power, the number of solar panels, power rated of microinverter, the number of installed micro-inverters, and also the environment parameters like average solar radiation,

5. CONCLUSION

Building-integrated photovoltaic (BIPV) is a new approach for institution building in Nigeria, in order to achieve the energy efficiency and increase the penetration of renewable energy. The use of façade photovoltaic photovoltaics on the wall has been demonstrated as an effective approach to solar energy gain. Thin film panel costs are declining slowly, while its performance is almost equal to mono-crystalline and polycrystalline solar panels. Therefore, we believe that facade PV system will be popular in Nigeria in near future.

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