The Potential Application of Amorphous Silicon Photovoltaic Technology in Hong Kong

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Abstract

The use of fossil fuels to generate electricity has already been identified as a major contributor to global warming and climate change. Many countries have already made plans to reduce their fossil fuel consumption and increased the contribution of renewable energies in total energy supply. One of the commonly used renewable energy sources is the sun and the use of photovoltaic cells to convert solar radiation into electricity is rapidly expanding throughout the world.

Photovoltaic cells available in the commercial market can be classified into two main categories - crystalline silicon cells and thin-film cells. Crystalline silicon cells are generally more popular than thin-film cells as they have been developed and in use for over 20 years. However, the demand for modern amorphous thin-film cells is increasing in recent years due to their low embodied energy resulting in a substantial saving in manufacturing cost. Furthermore, amorphous thin-film cells are lightweight, flexible and vandal resistant which made them particularly suitable to be used in buildings. Some overseas researches suggest that thin-film cells perform better in low irradiance and high temperature conditions. Coupling with the fact that flexible amorphous thin-film laminates are more aesthetically pleasing than their predecessors. The technology shows a great promise for the future.

The paper will explore the potential application of adopting amorphous thin film technology as an integral part of building design and construction. The likely performance of amorphous thin-film cell operating under typical local conditions will also be discussed in the paper.

Keywords: *thin-film amorphous cells, embodied energy, application of amorphous thin film technology*

1. INTRODUCTION

The burning of fossil fuels gives rise to emission of greenhouse gases and air pollutants. The most significant greenhouse gas is carbon dioxide, which has been realized as a potential major contributor to global warming and climate change. The consequence of global warming has far-reaching impacts on our environment as well as our ecosystems.

Introducing more renewable energy sources may help containing fossil fuel use, thereby reducing greenhouse gas emissions. Solar energy is one of the renewable energy being widely used over the world mainly due to its clean and emission free properties. Solar energy can be used in many ways. One of the most common methods is to convert solar radiation into electricity through the use of photovoltaic (PV) technology. Over the past few years, photovoltaic technologies have been developed rapidly.

To promote greater adoption of renewable energy technologies in Hong Kong, the Energy Efficiency Office (EEO) of the Electrical and Mechanical Services Department (EMSD) always seeks opportunity to promote the use of new renewable energy technologies. Attention is now being paid to the flexible amorphous thin-film technology in view of the increasing popularity for applications in overseas countries.

A trial unit of flexible amorphous thin-film PV laminate was set up to investigate the likely performance of such technology under the geographical and climatic conditions of Hong Kong.

2. FEATURES

PV cells available in the commercial market can be classified into two main categories. They are crystalline silicon PV cells and thin-film PV cells. Crystalline silicon PV cells are generally more popular than thin-film PV cells as the former have been developed and used for over two decades. However, unstable raw material supply and high production costs are key drawbacks for crystalline silicon cells. Producing crystalline silicon ingots is a lengthy and energy intensive process as slicing the ingots into wafers is a precise process. The wafers are very fragile and must be mounted and housed in robust metal and glazed casings. Mounting supports for the crystalline silicon modules are also required for deployment these PV panel array onto buildings. The cells, metal casings and mounting supports will altogether add extra structural loading to the building. Sometimes, structural strengthening and steel reinforcement will need to be carried out in order to make possible for installations of crystalline PV modules in the existing buildings.

Contrary to crystalline silicon modules, flexible amorphous thin-film PV cells are encapsulated in UV-stabilized polymer therefore they are light in weight. The weight density is about 3.5kg/m^2 which is only one quarter of the weight density of the crystalline counterpart. As a result, flexible amorphous thin-film PV cells do not require mounting racks for fixing onto building structure. The flexible amorphous thin-film PV laminates do not impose excessive additional weight to the buildings. For existing buildings, costly structural modifications for installation of thin-film PV laminates will not normally be required. The overall installation cost is usually much less than the crystalline silicon modules which are embedded in glass layers. Another advantage of amorphous thin-film PV laminates is that they can be installed on the roof structure easily by "peel-and-stick" process. By using a series of "clamping batten system", flexible amorphous thin-film PV laminates can be installed in buildings easily and less costly.

Figure 1: Flexible Amorphous Thin-film PV Panels installed on curved surface
(Photo source: NREL)

The flexible thin-film amorphous PV laminates are form-flexible and glass-free, allowing them to be harmonized into the building easily. They can be hung on the facades surface of buildings, bonded to metal roofing, adopting well to the curved architectural features and building forms.

3. EFFICIENCY AND PERFORMANCE

In terms of efficiency, flexible amorphous thin-film PV laminates have around 6% of module efficiency, which is lower than crystalline cells (11% to 19%). In other words, flexible amorphous thin-film PV laminates have a lower energy density than crystalline modules. To build the same capacity of PV power system, the flexible amorphous thin-film PV laminates will require larger installed area. For example, constructing a 1-kW PV power system, flexible amorphous thin-film PV laminates will require an area of around 17m^2 whereas crystalline modules will require an area of around 6m^2 to 9m^2. Therefore, flexible amorphous thin-film PV laminates will usually not be favoured where there are space limitations.

However, some overseas research suggests that flexible amorphous thin-film PV laminates could perform better at high temperature and low solar radiation conditions. Flexible amorphous thin-film PV laminates can have up to 20% better performance on hot environment and up to 12% better performance in low and diffuse light conditions when compared equally rated crystalline modules. Bird droppings, leaves, water puddling, and dirt can shade or soil PV panels. 3% of shade or soil on crystalline modules can reduce output by more than 50% while only 3% output reduction is found on the laminates [1]. Therefore, crystalline cells can reduce efficiency more dramatic at high temperatures which are often experienced in rooftops, where PV panels get its most frequent deployment.

4. APPLICATIONS

Although the flexible amorphous thin-film PV laminates are rather new to Hong Kong, they have already been introduced into overseas market and the Mainland China for over 3 years. Applications of such technology include residential houses, commercial buildings factories, schools, parking lots etc. This technology is particularly suitable to be applied to light weight roofs or curved roofs. It also allows serving dual function of a weatherproof skin and a power generator.

The rated capacity of the projects over the World range from 68W to 700kW [2]. This technology has also been applied to new projects like the Beijing Capital Museum. Flexible amorphous thin-film PV laminates with rate capacity of 300kW were applied directly to the stainless steel roofing of the Beijing Capital Museum using the "peel and apply" adhesive fixing method. The system was expected to deliver more than 360,000kWh of clean energy every year [3]

5. TRIAL SETUP FOR FLEXIBLE AMORPHOUS THIN-FILM PHOTOVOLTAIC LAMINATES

5.1 Description and configuration

In order to find out the likely energy performance of the flexible amorphous thin-film PV laminates under the geographical and climatic conditions of Hong Kong, a trial unit was set up to measure the energy yield of the system. The measurement was conducted for a period of two 5-day weeks during

July and August 2007. The set up involved a piece of 68W flexible amorphous thin-film PV laminate, a charge-controlled inverter (or combo inverter), a battery, a light bulb which acted as a dummy load, and a multi-meter.

Figure 2: Performance Test of Flexible Amorphous Thin-film Photovoltaic Module Trial Unit

The direct current (DC) electricity generated from the flexible amorphous thin-film PV laminate was converted into alternating current (AC) by the inverter.

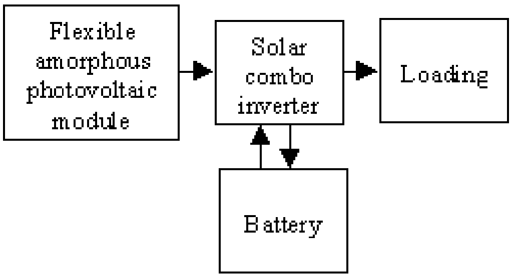

Figure 3: Block diagram to illustrate the Trial Unit for Flexible Amorphous Thin-film Photovoltaic Laminate

5.2 Data Collection

Key monitoring parameters including voltage, current, power factor, frequency input and output power were automatically recorded and collected at a 5-minute interval by the multi-meter.

Climatic data such as the global solar radiation (GSI), mean air temperature, relative humidity, etc. were obtained from the weather station of Hong Kong Observatory (HKO) located in King's Park over the monitoring period.

The measurement was carried out from end July 2007 and early August 2007. During this period, a mono-crystalline silicon photovoltaic system was also being operated at the same place. The energy performance of the mono-crystalline silicon photovoltaic system was also recorded for comparison.

5.3 Data Analysis

5.3.1 Global Solar Radiation

The global solar radiation recorded by the HKO during the measuring period is shown below:

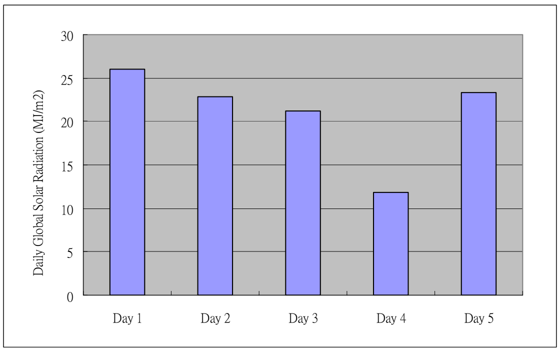

Figure 4: Daily Global Solar Radiation, July 2007

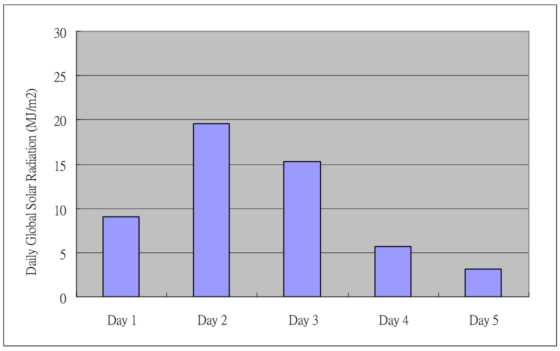

Figure 5: Daily Global Solar Radiation, August 2007

Most of the time on week 1 was sunny day with high solar radiation and most of the time on week 2 was cloudy day with few patches of rain during the daytime. These two weeks were selected especially to compare the performance of the two systems under two different weather conditions.

5.3.2 Findings and Observations

Based on the measurement collected, the performance of the two PV systems can be evaluated using an indicator called the Overall System Efficiency which is defined as:

Overall System Efficiency (OSE)
= Total Net AC Energy / Total In-plane Irradiation

The OSE of the flexible amorphous PV system was 5.69% on a sunny week (i.e. end July 2007) and 5.61% on a cloudy week (i.e. early August 2007), whereas the OSE of the mono-crystalline system during the same period were 8.53% and 9.04% respectively.

The OSE of the flexible amorphous PV system appeared to be fairly stable despite the system was operated under a hot weather during the first week and was operated under a diffuse light condition during the second week. The good thermal stability and high performance for diffuse condition of the flexible amorphous thin-film PV system were clearly observed.

The module efficiency of the flexible amorphous thin-film PV laminates and mono-crystalline PV panels being measured was around 6% and 12% respectively, the amorphous PV laminates appeared to be operated at optimum conditions for most of the measuring time.

6. CONCLUSION

Flexible amorphous thin-film PV laminates are suitable for integrating into building roof because they are light weight in construction and installation and offer good performance in high temperature and diffuse light conditions.

The stable performance shown in the recorded data from the trial unit of the amorphous thin-film PV laminates exhibited a potential application of this technology under local weather conditions.

7. RECOMMEDATIONS AND THE WAY FORWARD

Based on the findings from oversea researches, the performance of flexible amorphous thin-film PV laminate has been affected less by shadowing or soiling than their crystalline counterpart. The performance in shadowing effect can further be evaluated by deliberately covered up part of the laminate.

Data collection of this project will be continued for verifying the year-round performance. A pilot project would be considered as a showcase to allow an in-depth study on sustainable operation of the flexible amorphous thin-film PV technology in Hong Kong context.

8. REFERENCE

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