Unique features of cylindrical type solar-module contrasted with plane or conventional type ones

Hirohisa Hiraki¹, Akio Hiraki², Masakatsu Maeda¹ and Yasuo Takahashi¹

¹Osaka University JWRI, Incubation Building, 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan
²Osaka University, Incubation Building, 2-1 Yamadaoka, Suita, Osaka 565-0871, Japan

E-mail: hirahirohisa@yahoo.co.jp

Abstract. Due to their shape and construction, Cu(In,Ga)Se₂ [CIGS] cylindrical photovoltaic [PV] panels have unique features that planar or conventional PV panels do not have. For example, a) they capture sunlight over an angular range of 360°, b) they are self-ballasting (no roof penetrations, no attachments required) and c) they are high-reliability hermetically sealed cylindrical packages. In field tests in Japan, cylindrical PV panels have proven their durability against typhoons, and also their excellent electrical properties. Finally, as a new application of cylindrical PV panels, we suggest the new concept of fusion or combination of PV generation and agriculture.

1. Introduction

PV generation is an especially promising technology among renewable energies. Although crystalline silicon PV cells are currently the dominant technology, CIGS PV cells have been researched and commercialized in many countries like Germany, USA and Japan. This is because CIGS PV cells show the highest energy conversion efficiency of thin film PV cells, and the production costs of CIGS PV cells can be lower than those of crystalline silicon PV cells in principle. The strong points of CIGS PV cells are as follows: (a) high power output, (b) high reliability (no light-induced degradation), (c) wide spectral response, (d) strong spectral absorption, (e) possibility of low production cost.

Solyndra, the US solar panel maker, has adopted CIGS cylindrical type PV modules and succeeded in commercializing them. Solyndra’s PV panels are widespread in European countries and the USA, but are just entering the market in Japan. As depreciation in the price of PV systems has accelerated recently, it is difficult to spread PV systems without any unique features. To spread CIGS cylindrical PV panels in Japan, it seems the following 3 points are needed:

1. Having incomparable unique features.
2. Positive proof through field tests in Japan.
3. A new concept other PV do not have.

This paper describes the above-mentioned items (1)-(3).
2. Unique features of cylindrical PV panel

Figure 1 shows the appearance of Solyndra’s cylindrical PV panel. Due to its shape and construction, the cylindrical PV panel has many unique features that planar or conventional PV panels do not have. The main features of the cylindrical PV panel are as follows.

(a) Captures sunlight from an angular range of 360°

Cylindrical modules capture sunlight across a 360° photovoltaic surface capable of converting direct, diffuse and reflected sunlight into electricity as shown in Figure 2. Due to the cylindrical shape, the photovoltaic surface area can be larger than that of a planar module, so it can be expected to capture more sunlight and to generate more electric power than a planar module by optimum design of the panel structure. Also, cylindrical PV modules have functions of self-tracking and can capture more light early and late in the day.

(b) Self-ballasting

The cylindrical construction allows wind to flow through the panel and as a result no additional ballast, attachments or roof penetrations are required in wind up to 57.8 m/s.

(c) High reliability of hermetically sealed cylindrical package

Isolating CIGS films from moisture is very important for long-term stability. Cylindrical modules easily achieve high reliability by hermetic seals at the ends of the cylindrical packages.

3. Field tests in Japan

As PV generation needs to match the natural environment, field tests are indispensable. Currently, field tests have been done in some areas in Japan and a large amount of data will be acquired from now on. In the case of Japan, most customers worry about the reliability of self-ballasted installation. At first a wind tunnel test was done in Okinawa in order to win their confidence. We installed cylindrical PV panels when typhoon No. 9 (in 2011) struck Okinawa and checked whether the panels had moved or not. The panels had not moved at all, even though the maximum instantaneous wind speed of typhoon No. 9 was around 50 m/s. Cylindrical PV panels demonstrated positive proof of their durability against wind of 50 m/s through this field test. Figures 3-5 show the appearance of the field test in Okinawa.

Figure 1. Appearance of the cylindrical PV panel.

Figure 2. Collection of sunlight.

Figure 3. Preparation for the field test.

Figure 4. Typhoon No. 9 was passing over Okinawa.

Figure 5. Panels did not move at all.
Next, we report the result of power generation tests at Osaka. Figure 6 shows the correlation between power and irradiance. The nominal power of the cylindrical PV panels is 1 kW. From the test data, these panels generated 650 W when the irradiance was 700 W/m\(^2\). This result was about 95% of the nominal power, so it was a fairly good result.

We have also done a comparative study between a cylindrical PV module and a conventional CIGS PV module. Both modules were installed on a flat rooftop at an inclination of 0°. Figure 7 shows the correlation between power and irradiance for the two modules. For the conventional CIGS PV module (yellow dots), there are two curves for the same irradiance from 0.1 kW/m\(^2\) to 0.6 kW/m\(^2\) (this will be discussed later). And can also be seen, the slope of the curve for the cylindrical PV module and the conventional CIGS PV module are slightly different. The slope for the cylindrical one is higher than that for the conventional module. That means the cylindrical PV module can generate higher electric power than the conventional CIGS PV module.

**4. A new concept of a fusion of PV generation and agriculture**

Concerns for PV generation in Japan have jumped after the Great East Japan Earthquake, while the decrease in the agricultural population is getting worse. Creating a new technology that allows farmers
to earn sustainable income seems to be one solution to the decrease in the agricultural population. As shown in Figure 8, we suggest a new concept of fusion of PV generation and agriculture by using cylindrical PV panels that do not fully shut out the sunlight, wind and rain that are needed for plant growth. This concept can produce dual functions by using sunlight, that is, harvesting crops and converting sunlight into electricity. This attempt has the potential to relieve the decrease in the agricultural population.

We have already started a demonstration test for this concept at a small test field at Aioi city, Hyogo prefecture (Figure 9). And we have already harvested some crops and generated electric power. But, after this, demonstration tests for many farm products will be needed.

5. Discussion
As mentioned above, we acquired strange data from a comparative study between a cylindrical PV module and a conventional CIGS PV module. For the conventional CIGS PV module, there are two data patterns at the same irradiances from 0.1 kW/m$^2$ to 0.6 kW/m$^2$, while the data for the cylindrical PV module does not show such a strange pattern.

During our speculation about this reason, we paid attention to the difference of module shapes. One module has a cylindrical shape and the other is flat. The cylindrical shape has a function of self tracking and can capture more light early and late in the day. So we expected the power at early times to be different between the two. Figure 10 shows the correlation between power and irradiance from 7:30 a.m. to 9:30 a.m. The power of the cylindrical module is obviously higher than that of the conventional CIGS PV module. Figure 10 supports our speculation. In the case of sunlight from a high angle (from around 10:00 a.m. to 14:30 p.m.), the flat module can also capture sunlight easily, so the conventional module would have two data patterns at the same irradiance from 0.1 kW/m$^2$ to 0.6 kW/m$^2$.

![Figure 8. A new concept of PV generation and agriculture.](image)

![Figure 9. A small test field at Aioi city.](image)

![Figure 10. Correlation between power and irradiance from 7:30 a.m. to 9:30 a.m.](image)
6. Conclusions
(a) The cylindrical PV panel has many unique features compared to conventional plane PV panels.
(b) The cylindrical PV panel has its own applications such as agricultural fields.
(c) The abilities of the cylindrical PV panel have been proven through field tests in Japan.

References
[1] Kunioka A, M.Mizutani, Hagiwara Y and Nakada T 2001 Solar Energy Materials and Solar Cells 67 255-260.
[2] Morad R US Patent No.US2011/0045674 A1 Pub.Date: Feb.24.2011 Method and Apparatus for Inline Deposition of Materials on A Non-Planar Surface,
[3] Diaz J C and Fitzgerald M 2011 Tubular Glass Solar Energy Advancement Ceramic Industry 161 812-13