TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 14, No. 2, May 2015, pp. 185 ~ 190
DOI: 10.11591/telkomnika.v14i2.7338

Building Integrated Photovoltaic Market trend and its Applications

M Tripathy*[1], P K Sadhu[2]
Department of Electrical Engineering, Indian School of Mines, Dhanbad-826004, India
*Corresponding author, e-mail: meetarani_tripathy@rediffmail.com[1], pradip_sadhu@yahoo.co.in[2]

Abstract

The development of BIPV technology and their implementation in construction of building envelop provides an aesthetical, economical and technical solution. This paper presents the building envelope products, and their properties. BIPV products for pitched roof, flat and curved roof, transparent and semi-transparent facades and skylights have been highlighted in the paper. The properties of BIPV products include solar cell efficiency, open circuit voltage, and short circuit current, maximum power and fill factor. Few successful worldwide existing BIPV Projects with different product categories are also listed in a tabular form. The major considerations for a successful project are proper orientation of BIPV module, suitable distance between buildings, avoidance shadow effects and suitable architectural considerations BIPV technology is a sustainable and cost effective method and the future of this technology is promising as it creates zero energy and zero emission buildings.

Keyword: *BIPV, BIPV test conditions, feed in tariff, market trend*

1. Introduction

A large global emission of carbon dioxide (CO2) gas, are pushing the world into dangerous condition. Because of industrial revolutions, carbon emission from burning fossil fuels has grown exponentially. By end of the year 2030, the total emission of CO2 is expected to exceed 10 billion tons [1]. Moreover, because of sharp increase of fossil fuel prices and concern about global warming, there is a trend of wide acceptance for the power supply to consider more and more renewable energy sources in many parts of the world [2]. The European commission has set a target of achieving 20% of total energy budget from renewable sources by the year 2020 [3]. This will stabilize the greenhouse gas emission thus reducing the contribution to global warming. Among all the renewable resources, solar energy is the most abundant, inexhaustible and clean one [4]. World's present energy requirement is 15Tera Watt i.e. 10^4 times smaller than solar energy incident on the planet. It is estimated that the solar energy received within less than one hour would be sufficient to cover one year of world's energy budget [5]. Photovoltaic technology is one of the elegant technologies available for the efficient use of solar power [6]. Without any environmental harm, this technology produces electrical power by converting solar irradiance into direct electric current by using semiconductors [7]. In future scope for PV application, there are four major factors must be considered viz. cost reduction, increase of efficiency, BIPV applications and storage system [8]. BIPV technology transforms building from energy consumer to energy producer [9]. In this advancement, construction technology is required to be merged with BIPV technology for better performance [10]. Here, the photovoltaic modules become true construction element serving as building exteriors, such as roof, facade or skylight [11]. The BIPV also serves as weather protection, thermal insulation, noise protection etc [12]. BIPV semitransparent installation allows some of the light for day lighting or viewing. Rooftop solar photovoltaic (PV) systems is gaining popularity because lack of ground space and large availability of unused roof space. The BIPV technology reduces the total building material costs and mounting costs, since BIPVs do not required brackets and rails [13]. BIPV system generates electricity out of sunlight with no pollutions. For an efficient BIPV system, various factors must be taken into account such as PV module temperature, partial shadowing, installation angle and orientations etc. BIPV installation is increasing every year. The designers and architects are using BIPV products with innovative methods whereas; manufacturers continue to create new products to meet the market

Received January 15, 2015; Revised April 10, 2015; Accepted April 24, 2015

requirement. Some companies, such as *Sanyo, Schott solar, Sharp and Sun-tech* are working on new BIPV products for facade, skylights and windows. Implementation of Feed-in Tariff (FiT) and other government support schemes for solar energy have caused wide acceptance throughout the world.

2. BIPV Products

2.1. Definition of Different Parameters of Building Integrated Photovoltaic Products

The properties of different BIPV products are defined as follows:

1) Solar cell efficiency (η_{cell}): It is the ratio of peak power $P_{\max}$ generated in a solar cell to the radiation power reaching at solar cell. Solar cell efficiency decreases at lower insolation and at higher temperatures. $\eta_{cell} = \frac{P_{\max}}{EA}$, $P_{\max}$ is the peak power in Watt (*W), E* is the input light irradiance in $Watt / m^2$ and *A* is the surface area of the solar cell in $m^{2.}$
2) Packing factor (*PF*): It is the ratio of total solar cell area to total module area including the frame area. *PF* is always less than 1.
3) Solar module efficiency (η_m): It is the ratio of peak power of a solar module to the radiation power reaching across the total module area including the frame area. η_m is always less then η_{cell} , $\eta_m = \eta_{cell} \times PF$
4) Open circuit voltage (V_{oc}): It is the output voltage of a solar cell or solar module in open-circuit condition at a specific irradiance (*E*) and cell temperature.
5) Short circuit current (I_{sc}): It is the current in a short circuit solar cell or solar module.
6) Peak power ($P_{\max}$) : Maximum output power of a solar cell or solar module at a specific insolation and solar cell temperature $P_{\max} = V_{\max} \times I_{\max}$
7) Fill Factor (*FF*): $FF = \frac{P_{\max}}{V_{oc} I_{sc}} = \frac{(VI)_{\max}}{V_{oc} I_{sc}} < 1$.

2.2. Classification of BIPV Products and their Applications

Based on the function, the materials used and their mechanical characteristics, BIPV products are classified into five main categories [14]:

1) Standard in-roof systems
2) Semi-transparent systems
3) Cladding systems
4) Solar tiles and shingles
5) Flexible laminates

All the above products excluding flexible laminates involves same type of technologies namely c-Si and thin film. The flexible laminates have only the thin film technology. Under all the above categories, different types of PV applications are integrated into different parts of the building systems. The different parts are: roof, external building walls, semi-transparent facades, skylights and shading systems [16].

Flat roofs and pitched roofs are ideally suited for PV integration. Usually there is less shadowing at roof height than at ground level. Roofs often provide a large, unused surface for integration. A more elegant way to integrate PV is to use PV Shingles or PV Tiles. The PV module is mounted like any shingle or tile and the work can be carried out by a roofing contractor. Flat roofs have the advantage of good accessibility, easy installation and provide a free choice for the orientation of the PV units. The added weight of the PV array on the roof must be considered, as the uplifting force of the wind, which can blow the modules away.

Semi-transparent glass modules mainly used for aesthetical reasons. This module protects the sun lights to building surfaces and interiors. The required light passing through the desired structures can be customized by dimensions and adjusted the number and spacing of cells in the case of crystalline silicon technology. For thin-film, the transparency can be controlled by changing the manufacturing process. More transparent the module, less the energy efficiency of BIPV module. Semitransparent BIPV modules of different shape can be used as shading elements above windows or as part of overhead glazing structures.

PV panels are integrated into building walls as a standard cladding element. The cladding void helps to maintain internal temperature of the building by controlling solar gain in the summer and by encouraging the thermal stack effect which helps to draw air through the building spaces. This way the energy demand of the building can be reduced.

Solar tiles and shingles are designed to interlace with conventional roofing tiles or cladding materials. Sometimes larger tiles are used in whole roof or wall. Thin panels are also used in standard roofing systems. The important categories of the application where PV tiles and shingles are used are pitched roofs. Normally PV roof tiles with mono or poly crystalline solar cells are used with the classical roof tiles.

Flexible laminates are attached to the roofing system, which provides specific features. However, the rigid standard PV modules don't give the similar features. Flexible laminates can be used effectively in flat and curved roofs. This gives advantages like light weight PV system, efficient under wind load and rack mounting system can be avoided since this can be directly pasted to the roofing material. Flexible PV laminates offers the benefits of the waterproofing membranes with the advantages of converting solar energy to electrical power.

2.3. BIPV Market Trend

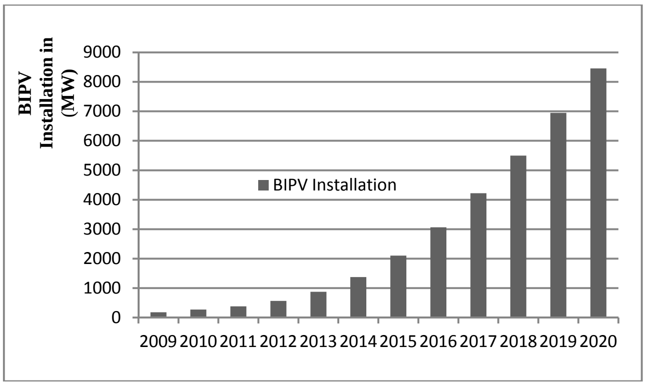

Figure 1. BIPV Market: Global Installation Capacity Forecasted Till 2020 in *MW* [15]

Table 1. The competitive structure of the BIPV Market (Solar Buzz)

PV Module Manufacturer	Country	% of Market share
Suntech	China	9.2
Yingli Green Energy Energy	China	7.6
Canadian Solar	Canada	7.6
Trina Solar	China	6.9
Sharp Solar	Japan	6.0
Solar fun	China	5.4
First Solar	USA	5.3
Jabil Circuit	USA	4.2
Solar World	USA	4.1
Sun Power	USA	3.6
LDK	China	3.4
Sanyo Electric	USA	3.3
REC	Norway	3.0
Kyocera	Japan	3.0
JA Solar	China	2.8
Jinko Solar	China	2.6
Ningbo Solar Electric	China	2.5
Renesola	China	2.1
Others	-	17.4

There is a huge potential of the BIPV market in all over the world. However, there is established market in most of the countries in Europe i.e. Germany, Spain, France, Switzerland and Italy. Many governments in above countries are subsidizing the BIPV technology by implementing Feed in Tariff (FiT) system. This concept allows shelling back excessive power to the grid at a higher price than the grid price of the electricity. Worldwide growth rate of BIPV during last seven years is approximately 50% of installed capacity in every year. There is more than 1300 MW of installation till date. The future BIPV market growth is shown in Figure 1 till the year 2020. BIPV installation in 2020 is expected to grow with a growth rate of 30% till 2020 in each year. The expected installation is more than 8000MW by end of year 2020. Table 1 presents the overall business of PV modules by different companies. It is observed that there is no leading PV Module manufacturer in the world. Moreover the manufacturer like Sun tech occupies the PV market only 9.2%.

Table 2. List of Major BIPV projects with different photovoltaic categories [17]

PV categories	Project name	Project location	Latitude/ longitude	Year of establishment	Capacity of the project
Roof -top integration	Black River Park commercial Roof Top Solar Project	Cape Town, South Africa	35˚ 55' S 18˚ 22' E	2014	1.2 *MWp*
Roof- top integration	Solar PV plant, Punjab	Amritsar, Punjab, India	31˚ 37'N 74˚ 55' E	2014	7.52 *MWp*
Roof- top integration	Centro Ingrosso Sviluppo compano in Nola	Nola-Naples, Italy	40˚ 55' 33 .96" N 14˚ 31' 38.64" E	2013	20.252 *MWp*
Roof- top integration	Riverside Renewable Energy-Holt logistics Refrigerated warehouse	Gloucester City, New Jersey	39˚ 53' 29.67" N 75˚ 7' 0.12" W	2012	9 *MWp*
Roof- top integration	Avidan Energy Solution	Edison , New Jersey, USA	40˚ 30'14.4" N 74˚ 20' 57.84" W	2011	4.26 *MWp*
Roof- top integration	Goodyear Dunlop logistic centre	Philipps burg, Germany	49˚13' 59.88" N 8˚ 27'E	2011	7.4 *MWp*
Roof -top integration	Toys "R" Us distribution centre	Flanders, New Jersey, USA	40˚ 50'52" N 74˚ 42' 34" W	2011	5.38 *MWp*
Roof- top integration	Boeing 787 assembly building, South Carolina	North Charleston S.C, USA	32˚ 58' 28.52" N 80˚ 4' 8.99" W	2011	2.6 *MWp*
Roof -top integration	Shanghai No. 1/2 Metro operation Co. Ltd	Hongqiao Railway station, Shanghai, China	31˚ 12'N 121˚30' E	2010	6.68 *MWp*
Roof- top integration	FedEx	Wood bridge, New Jersey, USA	40˚ 33' 38.88" N 74˚ 17' 33.36" W	2010	*2.42 MWp*
Roof- top integration	GSA Bean Federal Centre	Indianapolis, Indiana, USA	39˚ 47' 27.6" N 86˚ 8' 52.8" W	2010	*2.012 MWp*

3. Architectural Design of BIPV Module Mounting Structures

Important aspects of designing BIPV Module Mounting Structures (MMS) are site conditions such as wind speed, rain fall and temperature. Various module mounting structures made up of different material e.g. galvanized iron, aluminum structures etc are used in different BIPV project [18]. The paramount components in BIPV MMS are vertical columns, rafters, purline, brackets, mounting clips, cable carriers etc. For a larger life time of BIPV system, corrosion in mounting structures is avoided by following galvanization. The standard thickness followed in galvanization of structure is 100-120 microns. However, for cold formed steel the galvanization thickness can be reduced to 80 microns. Strength and durability are major aspects for designing the structural components of MMS. Tubular section may be a good option for better connectivity among the structural components [19]. Galvanized 'Z' section purline is used for carriers DC cables for avoiding corrosion. This helps to have an integrated wiring management system. Figure 1(a) & (b) shows the different type of purline and the cable system. For providing BIPV supported column with vertical adjusted angle is shown in Figure 1(c).

Figure 1(a). Mounting whip attached to Z-section purlin

Figure 1(b). C- section purlin to accommodate cable

Figure 1(c). BIPV supported column with vertical adjustment

4. Conclusion

Following are the conclusions drawn from the present extensive review work on BIPV products and their technology.

1) BIPV systems can be installed over all areas of building envelop. Most preferred place for the placement of solar module is roof top due to ample of solar irradiance. However, there is large facade surface of a building for integrating solar modules. Thin-film solar module is flexible and can be placed in any uneven parts of the building surface. Curtain wall is another option in BIPV technology, which is fastest growing market segment.
2) Building designer must be convinced that PV systems are alternative solution in comparison with other construction material. PV manufacturer and the building designer should work together for developing new products for building integration, which can generate electricity as well as can replace other construction material.
3) Many governments have introduced Feed in Tariffs (FiT) for subsidizing BIPV technology. FiTs system has made BIPV technology more popular and accepted in worldwide. The results show that BIPV technology shall be sustainable and cost effective in future as research continues to offer cheaper and more efficient system.

References

[1] Enkvist, Per-Anders, Jens Dinkel, and Charles Lin. Impact of the financial crisis on carbon economics: Version 2.1 of the global greenhouse gas abatement cost curve. McKinsey & Company. 2010.
[2] WTRG economics. Oil price history and analysis. 2008. See also :< http:// www.wtrg.com/price.htm>.

[3] European commission, Communication from the commission to the European parliament, the Council, the European Economic and social committee and the committee of the regions-20 20 by 2020 Europe's climate change opportunity. Com (2008) 30 final.
[4] Parida, Bhubaneswari, S. Iniyan, Ranko Goic. A review of solar photovoltaic technologies. *Renewable and sustainable energy reviews.* 2011; 15(3): 1625-1636.
[5] Lewis, Nathan S. Powering the planet. *MRS bulletin.* 2007; 32(10): 808-820.
[6] Strong, Steven. Building integrated photovoltaics (bipv). *Whole building design guide.* 2010.
[7] Rode, Johannes, Fabien Crassard. The evolution of building integrated photovoltaics (BIPV) in the German and French technological innovation systems for solar cells. 2007.
[8] Raugei, Marco, Paolo Frankl. Life cycle impacts and costs of photovoltaic systems: current state of the art and future outlooks. *Energy.* 2009; 34(3): 392-399.
[9] Prasad, Deo, Mark Snow. *Designing with solar power: a source book for building integrated photovoltaics (BiPV)*. Routledge. 2014.
[10] Pagliaro, Mario, Rosaria Ciriminna, Giovanni Palmisano. BIPV: merging the photovoltaic with the construction industry. *Progress in Photovoltaics: Research and Applications* 2010; 18(1): 61-72.
[11] Peng, Changhai, Ying Huang, Zhishen Wu. Building-integrated photovoltaics (BIPV) in architectural design in China. *Energy and Buildings.* 2011; 43(12): 3592-3598.
[12] Photovoltaic. http://en.wikipedia.org/wiki/photovoltaics#cite_note-jac-0.
[13] Neuwald J. All you need to know About Building Integrated Photovoltaic-part 2, roof consuit, http://www.rootconsult.co.uk/articles/kalzip2.htm (accessed November 9, 2011).
[14] Fraile D, Despotou E, Latour M, Slusaz T, Weiss I, Caneva S, Helm P, Goodal J, Fintikakis N, Schellekens E. *PV* Diffusion in the Building Sector. European Photovoltaic Industry Association, Sunrise Project. 2008.
[15] Frost & Sullivan. *European building integrated photovoltaic market*. Report. 2008.
[16] Building Integrated Photovoltaic: A new design opportunity for architects.
[17] List of photovoltaic installation. 2014. http://en.wikipedia.org/wiki/ List_of_rooftop_photovoltaic_installations.
[18] Xu JC, Liu CF, Hou GQ. Analysis structure of installation component which combined with architecture (BIPV). *Solar Energy 5*. 2009: 61-62.
[19] Eiffert, Patrina, Gregory J Kiss. Building-integrated photovoltaic designs for commercial and institutional structures: a sourcebook for architects. DIANE Publishing. 2000.