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Review of building integrated solar photovoltaic technology and its applications

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Building Integrated Photovoltaic (BIPV) systems is one of the most promising technologies and has recently being experiencing a technological growth. There is a consensus that these advancements may lead us to novel methods for domestic energy generation. Technical improvements, governmental policy supportive and financial aids are some of the contributors to this development. However, the amount of building integrated solar power generation as compared to other forms of solar electricity generation methods is still negligible. In this study, a review is presented including the amount of work done in this area and their findings. It summarizes the current state-of-art of these systems.

Keywords: *BIPV, eenewable energy economics, solar ehotovoltaic, state-of-Art*

1.0 INTRODUCTION

Global applications of renewable energy are growing rapidly due to enhanced public concerns for adverse environmental impacts. Renewable energy sources have the potential to play a significant role in fulfilling the future electrical energy requirements. The application of these non-conventional energy sources offers great potential to satisfy energy demand at remote sites, where it is relatively expensive to run a transmission line from distant ac mains [1-2].

In terms of renewable energy generation, currently India holds an fifth place in the world with the installed capacity of renewable energy 32,269.6 MW or 12.95% of the total potential available in the country, as on March 31, 2014. The increasing energy demand and need to go for sustainable ways of energy generation are the motivation for looking for alternative ways of energy generations. Among the renewable energy sources, solar is the most prominent in case of Indian scenario as in most of our areas have almost 360 clear sunny days in a year. The wide availability, energy needs and the reduction in the prices associated with the manufacturing of solar cells makes it suitable for us.

The building integrated solar photovoltaic technologies are finding increasing applications as in small isolated power systems and being increasingly recognized for electricity generation in both small and large electric power systems. Building integrated photovoltaic (BIPV) systems, where solar cells are integrated within the original structure of buildings and utilizing solar radiation to produce electricity is emerging as a sustainable solution with respect to the aesthetical, economical and technical aspects [3]. The BIPV is forming an important part of market in future segment, mainly because it does not occupy additional space, which is required by the solar panels mounted on existing or newly build structures [4-6].

In-spite of all positive factors, these are facing problem of efficient energy conversion and adaptability. This paper deals with the studies of BIPV in order to discuss and categorize its

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barriers and their proposed solutions and finally summarize their associated pros and cons. This review will address related issues on applications of BIPV systems and the popularity to growth rate of PV in recent years and its future prospects.

2.0 DESIGN CONSTRAINS IN ADAPTABILITY OF BIPV

In BIPV the solar-PV cells are mounted above the existing structure or a new base is prepared for fixing the solar cells. The solar cells are not transparent thus it provides a shade as well generates power. The only issue in adapting theses panels in building walls is to have isolation from the environmental factors such as corrosion, structural strength and snow, rain water penetration [7-9]. Figure 1(a-b) shows the typical installation of BIPV [10].

FIG. 1 (A) TYPICAL BIPV INSTALLATION IN RESIDENTIAL BUILDINGS

FIG. 1 (B) TYPICAL BIPV INSTALLATION IN RESIDENTIAL BUILDINGS

In general, the BIPV are used in roof surface of the building because it provides high value of solar radiation and conventional structure can be used to install but the windows and facades are the other areas that can also be used. The design constraints in BIPV are classified into following categories and discussed as follows.

2.1 Technical Parameters

The technical parameters responsible for lesser ratio of BIPV installations are common features such as technology used, storage facility, power loss, system efficiency and output power quality.

The power loss estimation is an important factor to be included in the design of a BIPV. The power loss due to dust, air moisture on the panels, voltage drop in the connected cables, shading assessment due to upcoming nearby building structures is required to be considered [11].The output power in case of partial shading may cause a severe damage to the system if it remains for a long period or a constantly one part of the installation comes under the shadow. The tilt factor of the panel is also a parameter causing an effect on the output of the BIPV, thus the fixed tilt is no longer advised to be used in place of that a manual or electronic tilt mechanism are introduced [12-13]. The system cost optimization prefers the manual step tilting setup, which can be used to tilt the panels at two or three different angles as per the seasons.

The other parameter in technical section is the output power quality of the designed system. The basics of power quality are the harmonics, variation in the voltage and frequency. The power converter holds a significant role to play in case of power quality of the BIPV. The generated power from the solar is a DC power, an inverter is used to convert this power into AC power and the same is fed to the consumer loads. Thus the design and selection of inverter should be made as per the output DC voltage and current range of the solar-PV array. The generated harmonics from the BIPV may affect the other connected system as well.

The consumer loads which are expected should be carefully studied and the nonlinear loads must have taken into accounts. However it is suggested to use an additional dc-dc converter in the system to regulate the variation in the output voltage of solar-PV panel and provide a constant DC supply voltage to the inverter for improved power quality [14-16]. Harmonic filter are also be suggested to use with inverter for an improved power quality at the AC consumer loads.

Table 1 shows the classifications of power converters as per the application range.

TABLE 1

POWER CONVERTER CLASSIFICATION

S.No.	Power Converter Topology	Ratings
1	Flyback Converter	200W
2	Cuk Converter	500W
3	SEPIC Converter	500W
4	ZETA Converter	500W
5	Half Bridge Converter	600W
6	Push-pull Converter	1000W
7	Boost Full Bridge Converter	1500W

Table 2 presents the inverters selection options in such installations. The other part of the system is MPPT controller, which needs a significant attention. The performance of the BIPV highly depends on the tracking efficiency and response time of the used MPPT controller.

TABLE 2

INVERTER SELECTION PARAMETERS

Parameter	Central Inverter Installation	String Inverter Installation
No. of Inverters	One	Higher
MPPT	Less effective	Higher
Partial shading conditions effect	Higher	Lower & can be easily handled
Installation & Maintenance	Higher	Lower
System Cost	Higher	Moderate

The MPPT controllers are responsible for force the system to operate on optimum power point under varying environmental conditions.

The critical conditions such as partial shading, which is considered often in case of a BIPV installation, the MPPT controller plays a major role. Different algorithms are presented in the literature for MPPT control of a BIPV installation.

The anti-islanding is another feature which is required in BIPV installations. The islanding scenario includes a condition, where the loads and distributed resources connected through a grid are energized from a BIPV, while the remaining parts are disconnected.

It is required that this condition should be sensed within 2 seconds and immediately the system should be disconnected as specified in the IEC 61727 standard.

Figure 2 shows the proposed circuit configuration adopted for such systems.

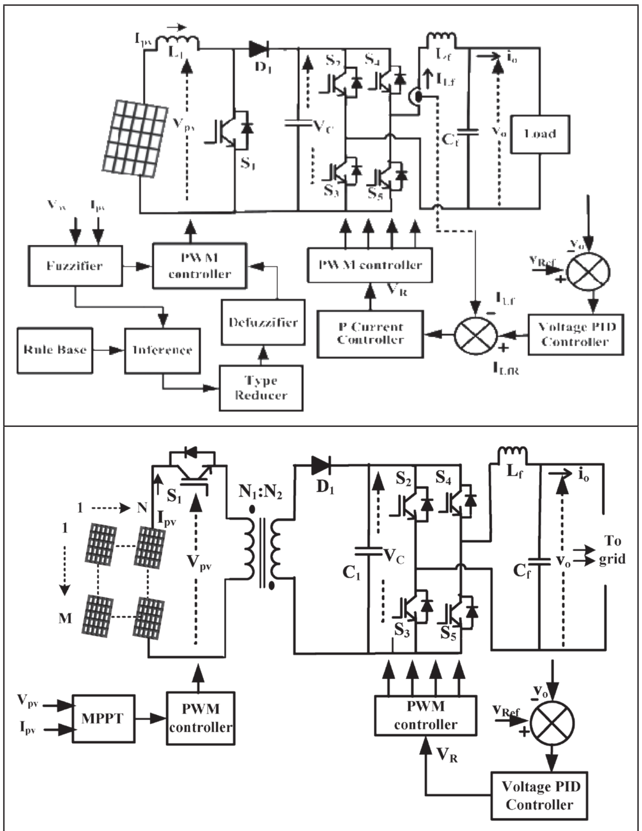

FIG. 2 (A-B) PROPOSED CIRCUIT CONFIGURATION FOR BIPV INSTALLATIONS

Figure 2 (a) and (b) presents the system proposed configurations for BIPV installations in residential and grid connected applications. Figure 2 (a) presents the system installation for the residential application of a low power system upto 5kW, which is not connected to the grid and is used for feeding the power to the local loads. Figure 2 (b) shows the system that can be used as a grid connected system.

2.2 Economic Constraints

The economic constraint is the major issue which comes into the picture, when we talk about BIPV. As in case of a BIPV project of 5kW with storage facility, the payback period calculated is more than 15 years and includes a high capital investment, thus the role of financial support becomes a factor to be considered [17-18]. The higher payback period is the parameter which requires an effort to convince the industry as well as the end user to recommend the BIPV installation.

In a country like India, where the demand of energy is increasing exponential, efforts are being made to promote the renewable energy sector for meeting the future energy demands. The MNRE (Ministry of New and Renewable Energy) has launched a JNNSM (Jawaharlal Nehru National Solar Mission) with the targets deployment of 20 GW of grid connected solar power by 2022 in three phases and to create an enabling policy & regulatory environment under the Mission to promote grid connected solar power generation [19]. Under the JNNSM central financial assistance upto 30% of the benchmark cost of the project is provided for setting up of the solar rooftop systems which generate the power and are connected to the grid.

The total cost of BIPV should be estimated and compared to the traditional installation for the economic viability of the installation.

The system cost consists of balance of system (BOS) components, which include inverters, an electricity storage system, and/or a grid-metered connection, fault protection, cabling, and wiring. Table 3 shows the area required (sq.ft) for installation of BIPV using different types of solar panels.

TABLE 3
AREA REQUIRED IN BIPV INSTALLATIONS (SQ. FT)

Type of Panels	System ratings		
	100W	2kW	5kW
Monocrystalline	8	160	400
Polycrystalline	10	200	500
Thin Film	15	300	750

Figure 3 shows the approximate area required in the installation of a BIPV system with grid connected configuration.

Figure 4 shows the approximate system installation cost of 1kW BIPV, it does not contain available subsidy and the land cost and involved in the conventional installation of 1kW SPV system.

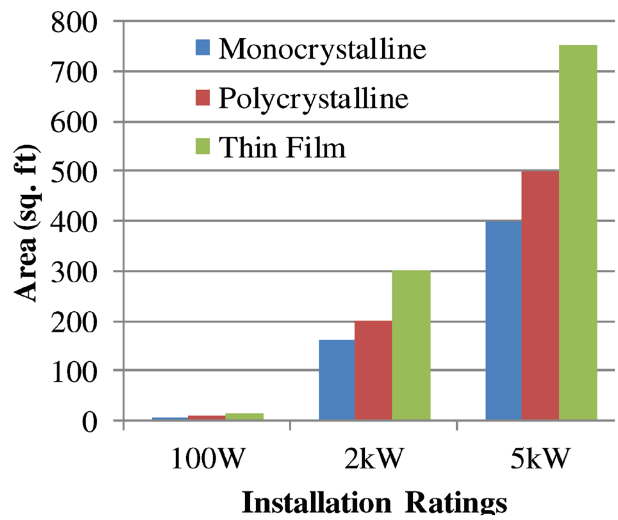

FIG. 3 AREA REQUIRED IN THE INSTALLATION OF BIPV

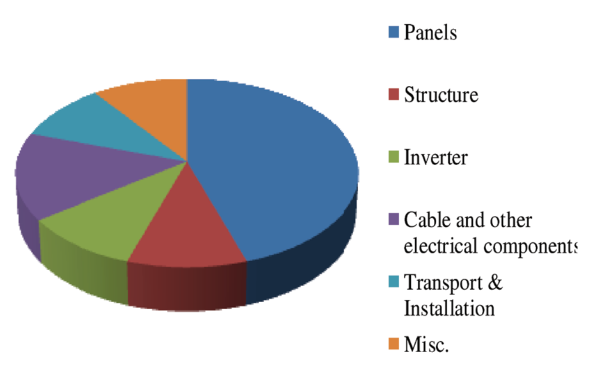

FIG. 4 COST INVOLVED IN THE INSTALLATION OF 1KW BIPV

These costs, as well as the costs of integration design and installation, should be evaluated. The technology of BIPV is stated to be in very early stage, however the cost is constantly decreasing due to rapid declination in the manufacturing of PV panels during last decades [20-24]. It is recommended to include BIPV at early stage as any kind of structure altering cause an extra expenditure of the overall project cost. It is reviewed and concluded in the literature [25-26], that planning at the design stage of building makes a difference of additional 5-10% in the construction cost of a building compare with the traditional one.

2.3 General awareness and appearance

The major share of BIPV installation depends on its awareness and acceptance by the consumers. Because of high capital cost and low conversion efficiency these systems are facing issue of applicability. The appearance of such system is required to be improved and success stories are needed to be projected for wider adaptability. The proposed a 3 dimension method consisting of socio-political acceptance, market acceptance, and community acceptance is needed to be reviewed in case of BIPV installations.

The aesthetic appearance of the BIPV is a factor that may be used to improve the system applications. Different types of BIPV panels based on crystalline silicon and thin film technologies that can be incorporated in the buildings include: Transparent PV panels, Flexible PV Panel and Opaque – Fixed PV panels [27].

BIPV system installed in a building provides a visible expression of the company towards its environmental commitment. The adoption level of BIPV technology is gradually growing in India with increasing number of system, and showcase of developments in this area [28-29]. Therefore, BIPV is a cost effective solution for introduction of solar PV into building envelope and is one the crucial step in starting a concept of Net Zero Energy building infrastructure.

2.4 Policy and Support Framework

Regulation and policies in favor of BIPV are current need for the market. In terms of BIPV as explained earlier the installation cost and payback period are higher side, thus the tariff differentiation becomes important in this scenario. The two different tariffs can be specified for buying and feed-in tariffs. These factors if included in form of policies will make a difference in this sector.

In Indian scenario the introduction of Electricity Act, 2003 and National Electricity Policy and Tariff Policy has addressed various issues such as Renewal Procurement Obligation (RPO) and introducing Renewal Energy Certificate (REC) mechanism. This has regulated the availability of renewable energy sources and requirements of targets to meet the obligated quantities in other places. This along with the JNNM has resulted in the growth of renewable sector in last few years [30].

The financial support from the Govt. is available in various forms such as installation subsidy, feed-in tariffs, tax rebates, and low interest loans. The Govt. has identified the research and development as an important factor for developing this sector. R&D subsidy is 100% of a project's cost in government R&D institutions, and 50% in the private sector [31]. The R&D subsidy for the private sector may be enhanced for initial stages of technologies that have longer time-horizons.

The Indian Govt. has also started the schemes, which provides funds for town and city level renewable energy planning. This local information infrastructure, comprising of local awareness, urban design, laws and smooth functioning processes, is an important step towards integrating renewable energy into economic life, and improving power delivery in the last kilometer. In addition to improving investment opportunities, this may also bring about greener, better designed and less polluted cities.

3.0 CONCLUSION

Aiming to address the issues in applications of BIPV, the review and state of art of BIPV technologies is presented and this study has shown issues and potential of BIPV systems. This article presented current trends and the issues in the application of BIPV in Indian market. The constraints are categorised into four groups and discussed in detail. The number of design considerations and constraints are discussed with reference to the technical, economical and policy perspectives. Therefore it is suggested that, to unlock the available potential of BIPV and its wider application policy and support framework is required to be structured. The development in BIPV technologies with reference to the power quality and reliability is a factor to be addressed using optimized system design and planning.

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