Impact of BIPV Systems on Eco Systems Productivity

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ABSTRACT

Building Integrated Photovoltaic (BiPV) systems is a "Zero Land and Zero Water" power systems as it neither consume any additional land nor consume any water. Moreover, introduction of BiPV systems reduces the thermal load of the building. The integrated approach on power generation and energy conservation reduces the prices on BiPV systems and at the same times it reduces emission level as well as enhance the building life time. However, raising of temperature reduces the power out put of the system. Thus while question of architectural and electrical integration come in picture one has to account the temperature effect and introduce necessary arrangement to reduce the temperature of the system during its operation period. The main aim of the present paper is to address these issues from theoretical consideration as well as experimental observations.

Cladding of BiPV systems can be done in three ways; a. ventilated air-gap, b. non-ventilate / closed air-gap, and c. embedded roofing. Impact of these cladding systems compared with conventional roof with no PV and no air gap. One dimensional transient models of the above cases are derived to evaluate the PV performances along with building heating and cooling loads across the different cladding systems in order to select the appropriate PV integration with climatic variables. The results indicated that the BiPV systems mounted in fashion in the category "a" is suitable for the hot and humid climatic condition. The category "b" is suitable for cold and dry climatic condition and category "c" is suitable for cold condition. The above conditions may have also impacts on the energy bill of the building at the same time it has impacts on the indoor climatic conditions. The analyses showed proper architectural and electrical integration of BiPV systems reduce the thermal load component of the building to an extent of 30 – 35%.

KEYWORDS

BiPV Systems, Climatic Conditions, Impact of Temperature, Architectural and Electrical integration

INTRODUCTION

Electrical power generating stations require a considerable amount of land as well as water. With the increase in population there is enormous load on both land and water, particularly to the developing countries [1]. Thus, building up of centralized power stations poses constraints in the developing countries. For providing accommodation / shelter to the urban and semi urban areas, high raise building becomes a possible solution. Many high raise buildings are coming up at the outskirts of the major metropolitan cities of the developing countries. Supply and transportation of electrical power to these buildings face problems as their demand is very high and there is paucity of space around these buildings for installing additional power generating station. In some cases space is provided for keeping standby generating set for meeting the local demand at the time of power failure.

However, the cost of diesel, emission of Green House Gases (GHGs) and particulates imposed several problems to the local power generation using fossil fuels. In developing countries energy consumption in building sectors accounts for in the range of 25 – 30% of the total energy used in the country in keeping comfort condition [2]. Solar energy has a significant role in reducing the energy consumption pattern in the building itself. Building Integrated Photovoltaic (BiPV) Systems is a conception for “Zero Land and Zero Water” based power systems. With the integration of proper architectural design, the conventional building elements like roof tiles, asphalt shingles, façade elements, and shading devices have been replaced with photovoltaic (PV) modules [3]. This inclusion performs the same function of the building element and at the same time it also generates clean electrical power.

BiPV systems already made a meaningful contribution in the power budget in urban applications. Many countries set their respective targets for using PV in the coming days. It was reported that that the goal of the EU countries is to reach at a level of 2000 MWp capacity with PV electricity by 2010, which is the combination of both roof top applications as well as wall applications. This additional power systems will not only save in reduction of conventional energy use but also offset the peak electricity generation from coal and oil and also cut down the emissions from diesel generators. Eco system protection is predominating factor in using photovoltaic in buildings in the context of global climate change [2].

As soon as the solar radiation strikes the PV module surface, a part of it get absorbed, a part get reflected back and a part transmitted into the building envelop. The absorbed part converted into electrical and thermal component [4]. Thus, when PV becomes a building element it has significant influence on the heat transfer through building envelope and its consequent effect on the building’s heating and cooling loads. Relative little researches have been conducted to studies the influence BIPV systems in influencing the heating and cooling loads.

Researchers reported that ventilated systems helps in reducing the thermal load and at the same time it helps in enhancing the efficiency of the BiPV systems. However, the exact reduction in heating and cooling load with the applications of BiPV systems in bringing the comfort condition has not been clearly indicated. The main aim of the present paper is to conduct studies on the impact of BiPV systems in reducing the conventional energy load in keeping the exact comfort level and develop the design criteria considering the above aspects.

At the present moment BiPV modules are made up mainly with crystalline Si. and at elevated temperature their efficiency get degraded. In order to obtain optimum efficiency the BiPV systems required to keep at an ambient temperature. For this purpose the systems may be kept in active or in passive cooling arrangement. In case of active cooling the BiPV systems sometimes coupled with thermal systems along with force flow arrangement for extracting heat. In case of passive cooling arrangement for natural ventilation is the possible option.

Active cooling demand some additional energy from the systems and on the other hand the passive cooling does not require and additional energy. The passive cooling mainly involve with air ventilation through the gap introduced in between the PV module and the roof. The ventilation system is a function of parameters like physical orientation of the building, roofing materials and climatic conditions. The exact design of ventilation systems at particular climatic condition is a major tool in implementing BiPV systems.

In the present paper impact of efficiency of a BiPV system in three different conditions e.g. ventilated air-gap BiPV, non ventilated i.e. closed air-gap BiPV systems and roof embedded BIPV systems were considered. Building thermal load were calculated with reference to the conventional roofing systems with no PV and no air gap. The change in efficiency and building thermal load were calculated and compared with the experimental results. Theoretical results indicated that introduction of BiPV systems reduce the cooling load to an extent of 30 %. This additional savings in cooling load may be considered as power saving in the conventional systems which can add value in the cost of BiPV systems as well as in environment and climate [4].

METHODOLOGIES

In order to design the active or passive cooling arrangement it is essential to estimate the module temperature by considering the thermal energy exchange of the module with its environment through main heat transfer paths. In non-steady state conditions [5], the rate of change of PV module temperature with time is considered to be significantly greater than zero. The three modes of heat transfer e.g. conduction, convection and radiation are considered here. Module is also generating electrical power with time. If the heat capacity of the module is neglected, the energy balance equation can be written as;

$$G = E + h_o(T_p - T_e) + h_i(T_p - T_a) \quad \text{--------} \quad (1)$$

Where G is the total solar radiation absorbed by the PV module (Wm^{-2}); E is the electrical power density generated by the PV module, h_o and h_i are the heat transfer co-efficient ($Wm^{-2}K^{-1}$) of the on the outside and inside of the module surface. Tp, Te and Ta are the temperature (K) on the module surface and temperature of the air at outside and inside of the PV module.

The module temperature is estimated by considering the thermal energy exchange with its environment through the heat transfer paths. The main contribution for the heat transfer originates from the front and back surface of the module, while the heat transfer from the array to the structural framework is non significant. The resulting heat balance equation with time can be represented as following equation;

$$C_{mdl}\,[dT/dt] = Q_{lw} + Q_{sw} + Q_{con} - P_{out} \quad \text{----------} \quad (2)$$

Where Q_{lw} represent for heat transfer due to long wave radiation, Q_{sw} represent for short wave radiation, Q_{con} represent for convective heat transfer and P_{out} is the power out from the PV module.

To solve the eqn. 2 it is necessary to explicitly state the form of each of the long and short wave radiative exchange. The PV module heat capacity can be estimated using the equation;

$$C_{mdl} = \Sigma\, A.d_m.\rho_m.C_m \quad \text{-----------} \quad (3)$$

Where A is the area of the module, d_m, ρ_m and C_m are the thickness, density and specific heat of the individual layer.

The short wave heat transfer Q_{sw} can be represented as;

$$Q_{sw} = A.\alpha.\varphi \quad \text{-------------} \quad (4)$$

Where α is the absorption coefficient and φ is incidence radiation flux to the PV module.

The long wave heat transfer is represented using Stefan-Boltzmann law;

$$Q_{lw} = \sigma.\varepsilon.T^4 \quad \text{------------} \quad (5)$$

The convective heat transfer Q_{con} is the algebraic sum of free and forced convection of the PV module at the top surface and bottom surface and is represented as;

$$Q_{con} = -\,(h_{c,forced} + h_{c,\,free}).A.\,(T_{mdl} - T_a) \quad \text{---------} \quad (6)$$

The electrical power output from the PV array is represented as;

$$P_{out} = C_{FF}.\ E.\ln\,(k_1E)\ /\ T_{mdl} \quad \text{-----------} \quad (7)$$

Substituting the individual values of Q_{lw}, Q_{sw}, Q_{con} and P_{out} in equation 2 the variation of T_{mdl} with time can be estimated.

RESULTS AND ASSESMENT

A systematic studies on the variation of module temperature with climatic conditions have been studied at a BIPV systems installed at the north side of the School of Energy Studies Building at Jadavpur University, Kolkata, India. The following results were obtained for conducting studies for last three years. The results were tabled as below:

TABLE - I
Performance analysis of various types of cladding systems

Variables / Parameters	Type of the cladding - A	Type of the cladding - B	Type of the cladding - C	Normal roof without cladding
Average incoming solar radiation per day ($kWhm^{-2}$)	4.8	4.8	4.8	4.8
Normalized average Heat Gain	1	1.84	1.96	1.88
Normalized average cooling load	1	1.90	2.11	2.07
Normalized power output per day	1	0.944	0.583	0

Cladding: “A” stands for PV cladded on the roof with a ventilated air gap,
“B” stands for PV cladded roof with non-ventilated air gap and
“C” stands for PV embedded with roof without any air gap.

CONCLUSION

The performance comparison of the three roof cladded PV systems were compared with no cladding systems. Both theoretical and experimental observations were studied at hot and humid climatic condition zone. Both power generation and cooling load had been estimated. The results indicated that in hot and humid climatic condition the optimum method for roof cladding BiPV system is coupled with ventilated air gap because this integration leads to a high PV conversion efficiency with low cooling load. The PV cladded roof with ventilated air gap has high time lag and small decrement factor in comparison with other three roofs. The power out with the ventilated air gap is higher than the other systems due to cooling effect on PV module. Thus, reduction of energy bill due to cooling effect can be integrated into PV power generation should bring further reduction in PV cost in BiPV systems. The reduction of energy bill has impact on the CO_2 reduction. 30% reduction in cooling load indicated there is substantial reduction in CO_2 emission. Thus, application of BiPV justifies eco-systems productivities as well as lightning of load to the environment.

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