Power Performance Analysis with Temperature and Tilt Angle Variation for the Building Integrated Photovoltaic Application in Bangladesh

[1]Suman Chowdhury, [2]Mohammad Mahbubur Rahman, [3]Md. Abul Bashar, [4]Mohendro Kumar Ghosh, [4]Niloy Chandra Saha

[1,3]Department of Electrical and Electronics Engineering,
[2]Department of Physics
International University of Business Agriculture and Technology,
Dhaka-1230, Bangladesh
[4]Department of Electrical and Electronic Engineering
Khulna University of Engineering and Technology
Khulna-9203, Bangladesh

Abstract— *This paper tries to investigate the power variation based on temperature level variation in the field of Building Integrated Photovoltaic Application. Again the tilt angle variation effect is analyzed with temperature variation to determine the power improvement level of PV system. From the analysis, it is seen that around 5.07% power can be improved at the temperature level of 30°C, if the tilt angle is varied from 90° to 21° keeping azimuth angle fixed at 0° considering Bangladesh climate.*

Index Terms— ***Solar irradiation, Temperature, tilt angle, BIPV.***

I. INTRODUCTION

The PV systems can easily be installed on the roof of residential and on the wall of commercial buildings as photovoltaic application [1]. The grid connected photovoltaic (PV) systems are very popular in industrialized countries and can be considered as the most promising PV application[2]. It is generally recognized that the PV's in building have potential to become a major source of renewable energy in the urban environment as mentioned by Tian et al. [3]. The electrical and thermal performance of PV systems (glass to glass) integrated as a cladding component in the building envelope has been evaluated by Bloem [4]. Given the limited or non-existent experience with BIPV applications in South Africa, the Fort Hare Institute of Technology designed and constructed an energy efficient building integrated photovoltaic (EEBIPV) house at the University of Fort Hare, Alice campus. The energy efficient house aptly named 'Langalinamandla', meaning powered by the sun, was completed in February 2009[5]. In advanced countries, buildings consume around 40% of the total energy consumption, which translates to about 30% of global carbon dioxide emissions (UN, 2010). For the United States and European Union, buildings account for 37% of their total energy consumption, while the amount stands at 39% for the UK (Perez et al., 2008; US GBC, 2007). Within Asia, the energy consumption of buildings is 31% and 40% for Japan and Hong Kong, respectively (ECC, 2008) [6]. Now the energy demand throughout the world can greatly be fulfilled by improving the performance of the bipv application. In this case, tilt and azimuth angle variation take place a significant role for improving the performance of the bipv system taking temperature consideration issue. In this paper, the performance is analyzed with tilt angle variation effect taking temperature consideration issue in Bangladesh climate.

II. SOLAR IRRADIANCE

The sun is the largest regenerative source of energy in the world. It is estimated that the annual sun exposure amounts to 3.9×10^{24}J=1.08×10^{18}KWh. This corresponds to more than 10000 times of the present world energy needs [8]. Moreover, a new method, called elevation angle constant (EAC) method, is developed to determine the solar radiation for any location in the world [9].

The inclusion of shading alone reduces the irradiation total of one particular day by 33.7%, whereas consideration of both shading and reflection by the wall results in a reduction of only 13.7%. Thus, taking into account the shading but not reflection, corresponding to methods based on solid-angle approaches, results in an error of 23.1% for the daily global irradiance [7]

Advanced research is still in progress to increase the efficiency of photovoltaic cells and optimize the production of energy through minimization of power losses and better utilization of incident solar irradiance [10].The efficiency and proper operation of photovoltaic systems depends on a number of factors. Environmental conditions as well as system design constitute the most important factors in the operation of the PV systems and these can have a significant impact on the efficiency and power quality response of the whole system [11]-[13]. As shown in figure 1, there is a maximum spectral intensity of 0.48 μm wavelength in the green portion of the visible spectrum, in the ultraviolate region (0.40 μm) there is 8.73% energy of the total energy, in the visible region (0.40 μm to 0.70 μm) there is 38.15% and in the infrared region (0.70μm) the remaining 53.12% energy is occupied.

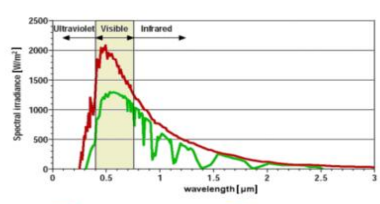

Fig. 1 Extraterrestrial and Terrestrial Spectrum of Sunlight

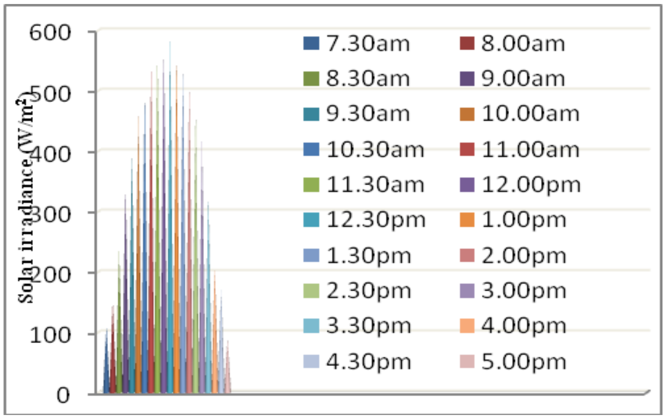

Fig. 2: Solar irradiation data at half hour intervals obtained in KUET campus taking orientation of South 23° on 7th March 2012.

Figure 2 shows the various levels of solar irradiance in W/m^2 taking the data from 8.00 am to 5.00 pm at a half hour interval on 7th March in 2012 in the KUET campus in Bangladesh. From the data it is seen that the high solar irradiance level was standing between 10.30am to 2.00pm.

III. TILT ANGLE

A photovoltaic (PV) system should be installed to maximize the solar contribution to a particular load. Optimum PV inclination and orientation depends on local climate, load consumption temporal profile and latitude [16–18]. Optimizing the output power of a photovoltaic panel improves the efficiency of a solar driven energy system. The maximum output power of a PV panel depends on atmospheric conditions, load profile and the tilt and orientation angles[14]. For solar energy applications, the optimum orientation is usually suggested to be south-facing in the northern hemisphere, and the optimum tilt angle depends only on the local latitude, $\beta opt=f(\varphi)$.

For standalone systems, system reliability is a very important factor. For most areas, winter is characterized by low irradiance. Thus, the most unreliable season can be set as the design benchmark. By considering the winter season (December, January, and February), the optimum slopes can be found. The maximum point occurs at south-facing orientation with the slope angle of 41 deg (φ +18.5 deg), while the value of yearly total irradiance drops by 4.32%. If the slopes of PV modules can be adjusted monthly, or the panels are only utilized for certain months, the results for monthly optimum slopes are also different. The highest tilt angle appears with the value of 46 deg in December, while the angles become negative in May, June, and July [15].

Figure 3: Tilt and orientation angles of a PV panel[13]

Figure 3 shows a diagram of the tilt and orientation angles of the PV panel which can be used to determine the optimum tilt angle for getting maximum power performance from the BIPV system.

Table 1 shows the practical data of voltage and current obtained from a PV module named as KC40REB in KUET campus on 8th and 9th October 2012 in Bangladesh.

TABLE 1: PRACTICAL DATA OF MAXIMUM VOLTAGE AND MAXIMUM CURRENT.

Date	Time	Maximum Voltage(V)	Maximum Current(A)
8.10.12	8.00 am – 9.00 am	17.42	1.41
8.10.12	9.00 am – 10.00 am	17.29	2.45
8.10.12	10.00 am – 11.00 am	17.22	2.86
8.10.12	11.00 am – 12.00 pm	17.23	1.81
8.10.12	12.00 pm – 1.00 pm	17.58	0.68
8.10.12	1.00 pm – 2.00 pm	17.61	0.714
8.10.12	2.00 pm – 3.00 pm	17.18	1.29
8.10.12	3.00 pm – 4.00 pm	16.69	0.355
8.10.12	4.00 pm – 5.00 pm	15.91	0.143
9.10.12	8.00 am – 9.00 am	17.36	2.33
9.10.12	9.00 am – 10.00 am	17.04	0.645
9.10.12	10.00 am – 11.00 am	17.07	1.28
9.10.12	11.00 am – 12.00 pm	17.37	1.06
9.10.12	12.00 pm – 1.00 pm	17.41	1.27
9.10.12	1.00 pm – 2.00 pm	17.37	1.28
9.10.12	2.00 pm – 3.00 pm	17.35	1.49
9.10.12	3.00 pm – 4.00 pm	17.32	1.00
9.10.12	4.00 pm – 5.00 pm	15.40	0.117

Figure 4 shows the practical data for the observation of power obtained from PV module KC40REB in KUET campus taking consideration of a distinct time interval on 8th and 9th October in 2012.

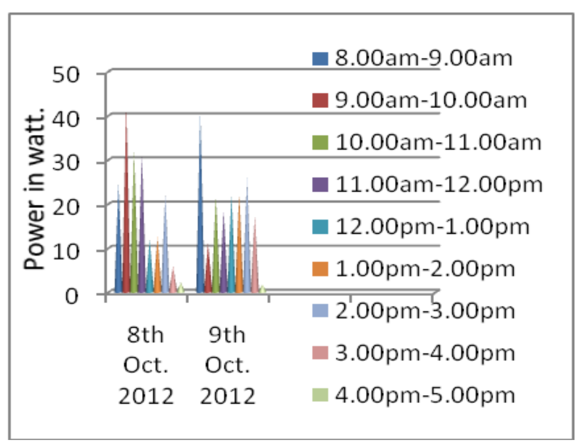

Figure 4: Practically power obtained from PV module KC40REB in KUET campus.

IV. CHARACTERIZATION OF PV ARRAY TAKING THE EFFECT OF TEMPERATURE AND AZIMUTH ANGLE VARIATION

For characterization of PV system, two PV arrays are taken where each PV array consists of 50 PV strings in parallel connection. Each PV string consists of 20 PV modules (Solarex MSX 64) in series connection. From power data analysis of the PV system, five different types of figures are obtained taking various consideration. From fig. 5, it is observed that at the temperature of 22°C, the maximum power obtained is 8.18 KW whereas this power is incremented to 85.41KW at the temperature level of 40°C taking consideration of tilt/azimuth angle at 21°/0°. Furthermore fig. 6 represents that at the temperature level of 24°, the maximum power obtained is 14.71KW whereas at the temperature level of 40° this power is incremented to 84.16 KW taking consideration of tilt/azimuth angle at 90°/0°. Finally from fig. 5 and fig. 6, it is seen that more developed power is obtained for the tilt angle of 21° and always an incremental power is obtained for the increment of temperature in both cases. Now from fig. 7, it is observed that the maximum incremental power rate is 92.18% at the tilt/azimuth angle of 21°/0° when temperature is changed from 23°C to 25°C whereas in fig. 8, that incremental rate is 75.93% at the tilt/azimuth angle of 90°/0° when temperature is changed from 24° to 26°. Finally from fig. 9, it is observed that highest power improvement is occurred at the temperature of 36°C when tilt angle is changed from 90° to 21°.

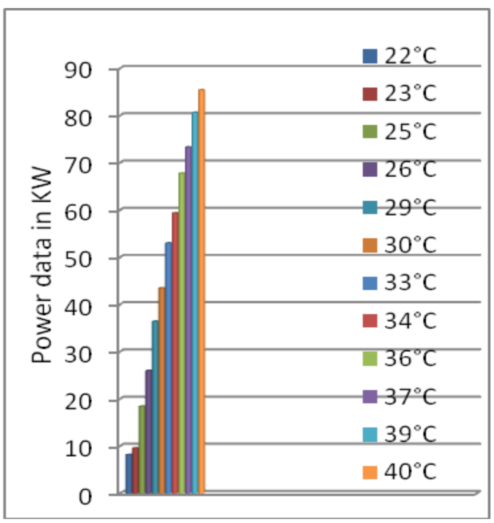

Fig. 5: Temperature effect on power variation with Tilt/Azimuth angle of 21°/0°.

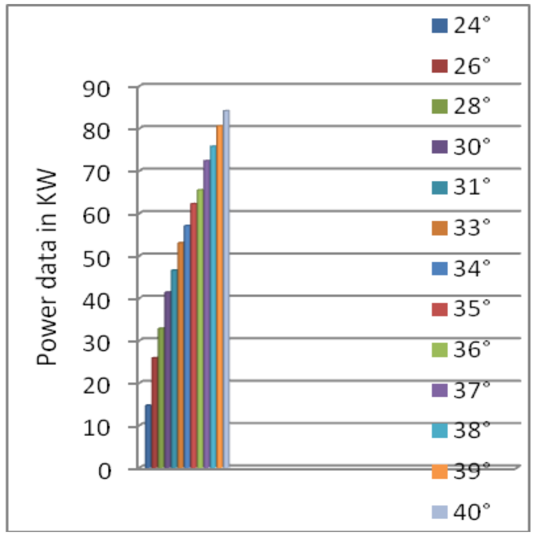

Fig. 6 : Temperature effect on power variation with Tilt/Azimuth angle of 90°/0°.

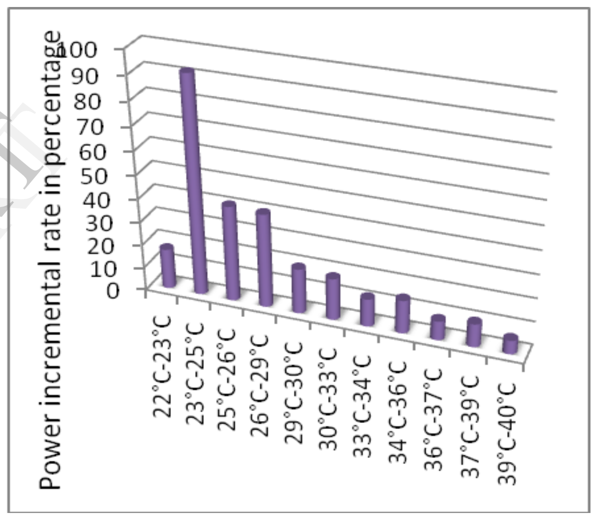

Fig. 7: Power incremental rate with temperature variation at Tilt/Azimuth angle of 21°/0°.

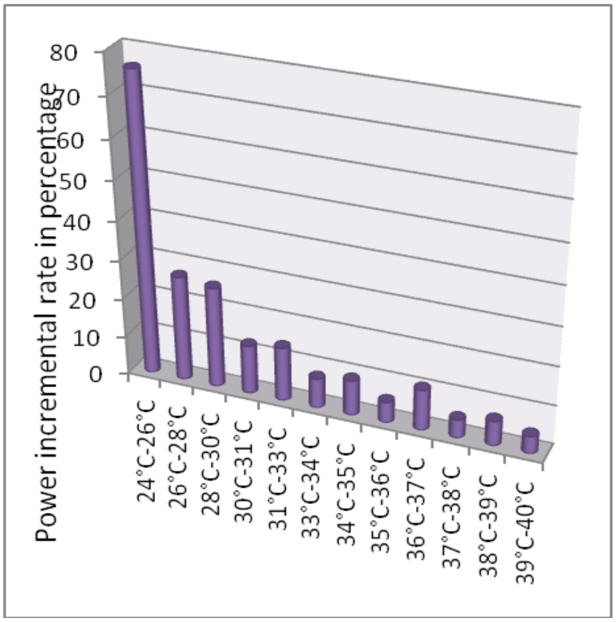

Fig. 8: Power incremental rate with temperature variation at Tilt/Azimuth angle of 90°/0°.

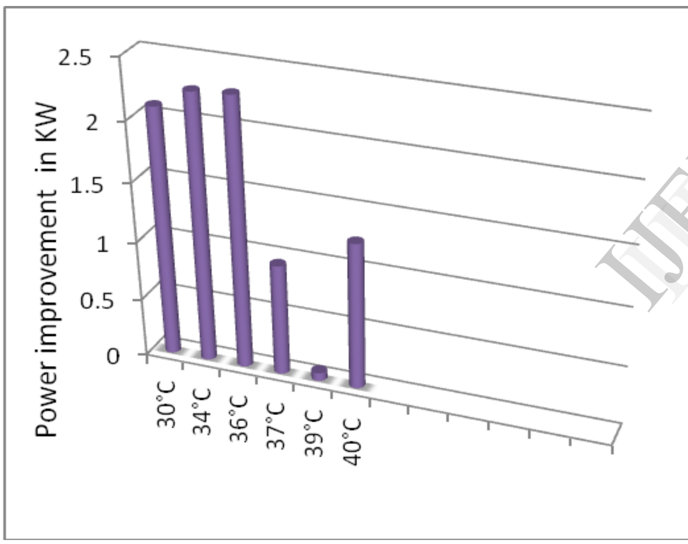

Fig. 9: Power improvement with tilt angle variation from 90° to 21°.

Conclusion

The maximum power generation with BIPV system greatly depends upon the temperature and the tilt angle. From the analysis, it is seen that about 96.44% power can be developed if the temperature is changed from 30°C to 40°C at the tilt/azimuth angle of 21°/0° whether it is 103.38% at the tilt/azimuth angle of 90°/0° considering same temperature change.

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