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Performance Analysis of Building Integrated Photovoltaic Application with Tilt and Azimuth Angle in Bangladesh

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PERFORMANCE ANALYSIS OF BUILDING INTEGRATED PHOTOVOLTAIC APPLICATION WITH TILT AND AZIMUTH ANGLE IN BANGLADESH

Strictly as per the compliance and regulations of :

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Md. Hafizur Rahman [α] & Jinia Afrin [σ]

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I. Introduction

The BIPV application is a very important issue to overcome the world energy crisis. Now the building owners not only can fulfil their electricity demand but also can sell the surplus energy produced following this advanced system. Hence this BIPV system is getting highly preferable to the building owners for fulfilling the energy demand. According to the International Energy Agency (IEA), PV-suitable surfaces can be increased by about 35% incorporating BIPV on building facades [1], [2].

The performance of the BIPV is highly dependent on the tilt and azimuth angle. Since BIPV is related with fixed angle orientation of the solar modules, the optimum possible tilt angle orientation should be considered before building construction. For this reason this paper highlights the influence of tilt and azimuth angle on the BIPV application considering time and temperature issue.

II. Solar Irradiance

Solar radiation is a very important factor that directly affects the solar cell output performance. Fig. 1 shows the radiation spectrum for the extraterrestrial space (AM0) & for the sea level or earth's surface (AM1.5). The irradiated solar energy is 1.353kW/m2 at the average distance between sun and the earth. The irradiation considered for the earth's surface is approximately1kW/m^2 which is a reference value since it depends on many factors. The AM1.5 is a standard for the PV device whose surface is tilted at 37° facing the sun rays [4].

A solar cell is mainly designed for absorption of a portion of the total radiation spectrum. From the Fig. 1, it is seen that a large amount of irradiance spectral is available in the visible spectrum (390nm-700nm) which stands in the opposition of the UV (<390nm) and infrared light (>750nm). PV solar cells are designed for the absorption of the visible spectrum only [3], [5].

Table 1: Daily Average Bright Sunshine Hours In Dhaka City

Month	Daily mean	Minimum	Maximum
January	8.7	7.5	9.9
February	9.1	7.7	10.7
March	8.8	7.5	10.1
April	8.9	7.2	10.2
May	8.2	5.7	9.7
June	4.9	3.8	7.3
July	5.1	2.6	6.7
August	5.8	4.1	7.1
September	6.0	4.8	8.5
October	7.6	6.5	9.2
November	8.6	7.0	9.9
December	7.55	6.03	9.13

The solar irradiation exposed to the PV array for fixed position is calculated from the following equations [6].

$$G_s = G_d + G_r \qquad (1)$$

Where, G_s is total solar irradiation in kW/m^2, G_d is direct component of solar irradiation in kW/m^2 and G_r is diffuse component of Solar Irradiation in kW/m^2.

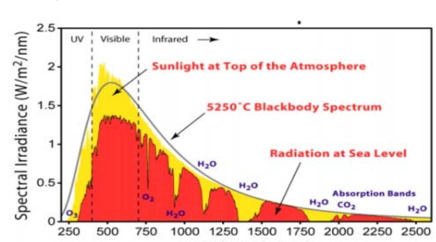

Figure 1 : Practical solar radiation spectrum [11]

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$$G_d = (H\cos\theta - \sin\theta\cos\alpha\sin\delta\cos\varphi_n + \sin\theta\cos\alpha\sin\varphi_n\cos\omega + \sin\theta\sin\alpha\cos\delta\sin\omega)\times G_{od} \quad (2)$$

Where, H is sun elevation, θ is oblique angle of the sun in radian, α is azimuth angle, δ is declination of the sun in radian, φ_n is north latitude, ω is hour angle in degree, G_{od} is direct irradiation in radian.

$$G_r = \frac{G_{or}(1+\cos\theta)}{2} + 0.2G_o\frac{1-\cos\theta}{2} \quad (3)$$

Where, G_{or} is diffuse (horizontal) irradiation in radian, G_o is global horizontal irradiation in kW/m^2. The sun elevation is given by (4) [6].

$$H = \sin^{-1}(\cos L\cos D\cos T + \sin D\sin L) \quad (4)$$

Where L is latitude in degree, D is declination of the sun in degree, T is hour angle in degree [6].

From Table 1, daily average sunshine hours are obtained from which the idea of average amount of solar power generation can be achieved. This type of statistics can help to determine the optimum tilt angle for grid connected building integrated photovoltaic application. Again, Fig. 2 represents the practical data curve of the solar irradiance against time which is obtained at KUET campus of Khulna city at 7th March, 2012.

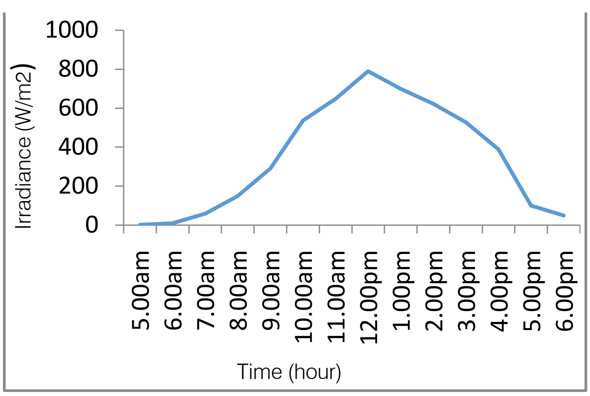

Figure 2 : Practical solar irradiance preview against time at KUET campus of Khulna city at 7th March

III. Tilt and Azimuth Angle

The BIPV system performance is mostly affected by tilt and azimuth angles. The solar irradiance exposed on the array is highly affected by the tilt and azimuth angles. The optimum tilt angle depends on the local latitude. According to Duffie and Beckman the optimum angle is $\beta_{opt} = (\phi + 15\deg) \pm 15\deg$ (where Ø is local latitude) [7]. In the winter and summer season the tilt angle is to be increased and decreased respectively. The optimum tilt angle is 10° for March to September and 40° for October to February estimated for November 2007 to October 2008 at Dhaka in Bangladesh [10].

Figure 3 : Orientation of PV modules at 4 different slopes [9]

Since it is not possible to move the PV panel for BIPV system, it is needed to analyze the yearly performance to obtain optimum average solar irradiation with consideration of tilt and azimuth angles. For a fixed orientation of PV panels the optimum tilt angle is calculated mathematically given by Eq. 5 [8].

$$\frac{d}{d\beta}\left(\sum_{i=1}^{n} G_{tt}(i)\right) = 0 \quad (5)$$

Where $G_{tt}(i)$ is the total irradiance for i hours and n is the total number of hours.

From Fig. 3, it is seen that there are 4 modules oriented at different slopes which can be taken as a model to analyze experimentally, where the researcher found that the monthly solar irradiation and temperature is 131kW/m^2 and 25°C respectively.

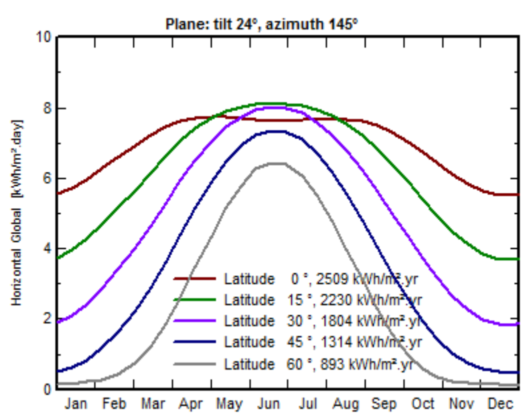

Figure 4 : Monthly Horizontal global radiation for different latitudes in Dhaka

At the tilt angle of 24° and azimuth of 145° monthly horizontal global radiation which is peak at June and July month is shown by Fig. 4. From figure it is seen that the horizontal global radiation is increased for decrement of latitudes.

IV. Simulation of PVArray at Various Tilt and Azimuth Angles

For simulation purpose two proposed arrays are taken in which each array consists of 50 strings in parallel and each string consists of 20 modules in series. The module taken for simulation is Solarex MSX-64. From the simulation study, eight various curves are obtained. From Fig. 5 to Fig. 8, it is seen that the obtained maximum powers are 114.66 KW(when tilt/azimuth angle is 21º/0º), 61.3 KW(when tilt/azimuth angle is 21º/180º), 95.18 KW(when tilt/azimuth angle is 1º/0º) and 88.23 KW(when tilt/azimuth angle is 90º/0º) respectively considering temperature throughout the day. Again from Fig. 9 to Fig. 12, it is seen that the maximum powers are obtained during 10:00hr to 13:30hr. So from theses simulations it is seen that if azimuth angle is varied from 0º to 180º, 106.48 KW power can be improved keeping tilt angle fixed at 21º and if tilt angle is varied from 1º to 90º, 6.95 KW power can be improved keeping azimuth angle fixed at 0º at the time of 11:30hr.

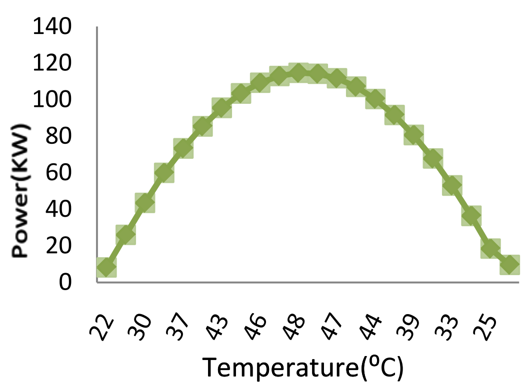

Figure 5 : Power data obtained against Temperature when Tilt/Azimuth is 21º/0º

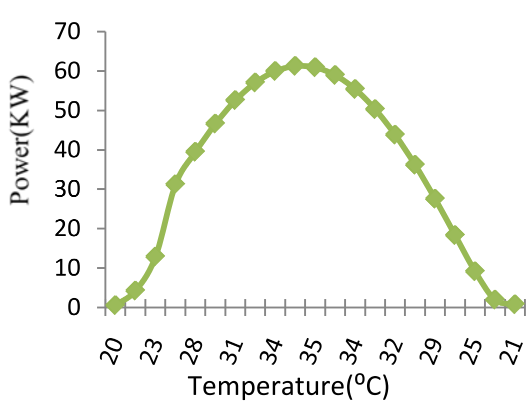

Figure 6 : Power data obtained against Temperature when Tilt/Azimuth is 21º/180º

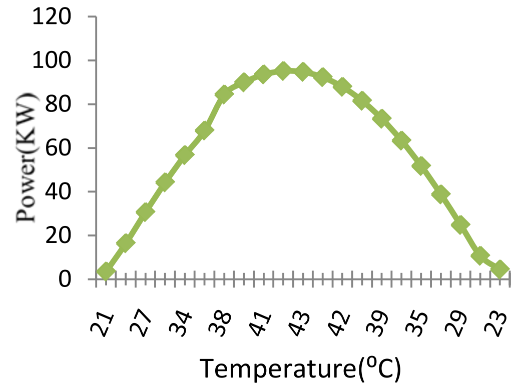

Figure 7 : Power data obtained against Temperature when Tilt/Azimuth is 1º/0º

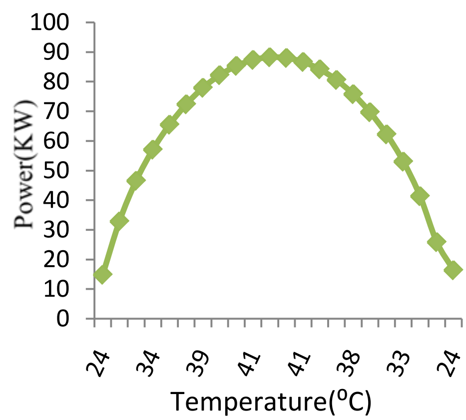

Figure 8 : Power data obtained against Temperature when Tilt/Azimuth is 90º/0º

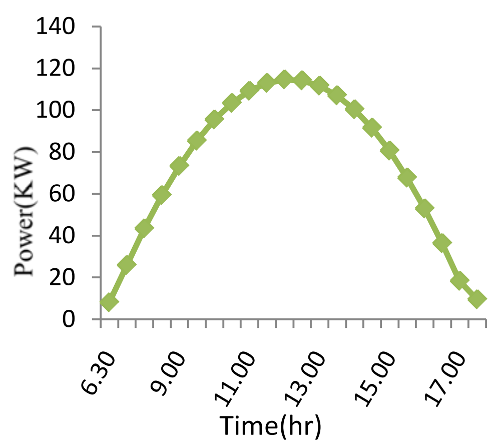

Figure 9 : Power data obtained against Temperature when Tilt/Azimuth is 21º/0º

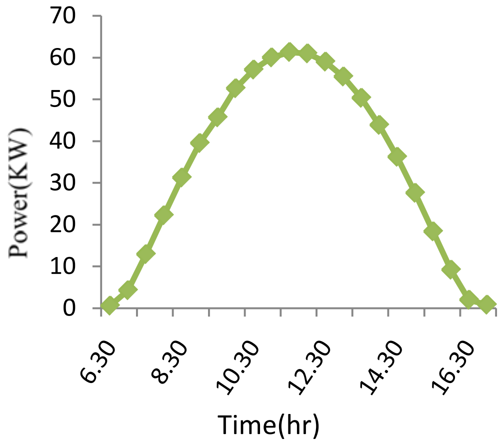

Figure 10 : Power data obtained against Time when Tilt/Azimuth is $21^0/180^0$

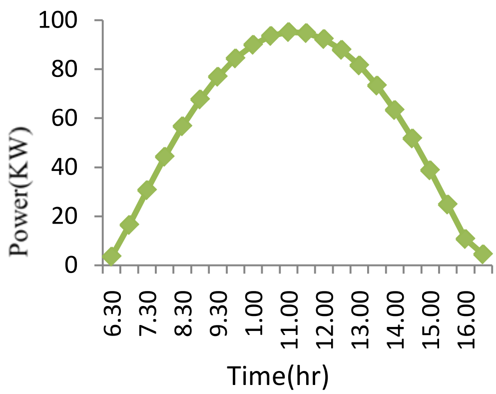

Figure 11 : Power data obtained against Time when Tilt/Azimuth is $1^0/0^0$

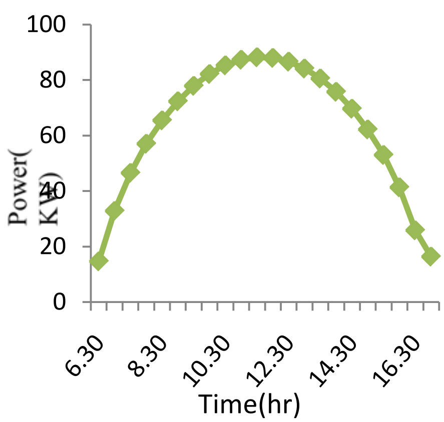

Figure 12 : Power data obtained against Time when Tilt/Azimuth is $90^0/0^0$

V. Conclusion

The power performance of the Building integrated photovoltaic application is analyzed in the case of Bangladesh climate condition. In the BIPV application the tilt and azimuth angle should be considered strongly for optimization of power. The optimum tilt angle especially for BIPV should be determined very carefully since PV modules are to be oriented at a fixed tilt angle. From the case study it is seen that both tilt and azimuth angle optimization plays a vital role for obtaining the optimal power.

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