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SOLAR ENERGY POTENTIAL IN BANGLADESH

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Abstract- *In view of the growing needs of energy in Bangladesh, the efficient use and development of renewable energy sources has become a major issue in the country. Solar energy is the alternative energy source that can be used to supplement the conventional energy sources particularly in Bangladesh. This has brought the intention of several national and multinational companies to design and implement a major work plan for energy conservation and construction of renewable energy sources like wind mills and solar panels. Fortunately, Bangladesh is among those countries in which sun warms the surface throughout the year and therefore has a strong potential for solar power generation. This study was conducted to explore those areas which are most suitable for solar energy potential using fifty eight meteorological stations covering the whole country. Angstrom equation and Hargreaves formula was used to calculate monthly solar energy potential by utilizing monthly weather data of bright sunshine hours, mean maximum and minimum temperatures. The lowest solar radiation intensity 76.49W/m^2 observed at Sylhet during June and highest 339.25W/m^2 at Cox's Bazar during December. The average monthly solar radiation intensity remains 136.05 to 287.36W/m^2 in the country. The results indicate that the values of solar radiation intensity greater than 200W/m^2 were observed in the months February to October in Sylhet, March to October in almost all regions of Dhaka, April to September in Khulna, Northern Areas and Chittagong regions while March to October. For 10 h a day, average solar radiation intensity ranges from 1500W/m^2/day to 2750W/m^2/day in Bangladesh especially in Chittagong, and Cox's Bazar regions throughout the year. In an area of 100 m2, 45MW to 83MWpower per month may be generated in the above mentioned regions.*

Keywords: Solar energy, Solar radiation, Radiation intensity

1. INTRODUCTION

The energy crises in Bangladesh have become crucial because of its sole dependence on hydro power generation. Currently, only one major hydro power plant (kaptai) is generating electricity but their capacity is much lower than the growing needs for electricity in the country. In view of current energy crisis, it is necessary to be more focused on renewable energy source [1]. Solar energy is one of the cheapest energy types that are currently used in modern world. The purpose of this study is to explore the areas in Bangladesh having a reasonable solar energy potential based on temporal and spatial analysis of meteorological parameters. Angstrom equation and Hargreaves formula were used to calculate monthly solar energy potential by utilizing monthly weather data of bright sunshine hours, mean maximum and minimum temperature.

Extraterrestrial radiation, Ra, defined as the short-wave solar radiation in the absence of an atmosphere can be used in the calculation of Clear-sky solar radiation (Rs or Rso), is a well behaved function of the day of the year, time of the day, and latitude [2]. The sunshine duration was recorded by a sun-dial 10.16 cm in diameter through which the sun's rays are focused upon a sensitized card graduated in hours. Solar radiation intensity was estimated from the actual sunshine duration. Sunshine duration for a given period is defined as the sum of that sub-period for which the direct solar irradiance exceeds 120Wm^{-2}.Solar radiations (Rs) intensity is taken as incoming short-wave radiation measured in MJ/m^2/day.

With the increase in industries and automobiles, the global energy utilization has reached the value of 4.1×1020 J per year or equivalently the annual rate of utilization is 13×1012 W [3]. The current and projected growth rates indicate that the energy consumption would be double by 21st century and triple in 2100 requiring high rates of energy supply from sustainable and renewable sources. It is also emphasized these days that energy should be produced without carbon emissions. This emphasizes the importance of using renewable energy sources for power generation without destroying the natural ecosystem [4].

2. MATERIALS AND METHODS

This study was conducted in different climatic regions of Bangladesh during the year 2012. Climatic data on sunshine duration (n), mean maximum and mean minimum temperature, and extraterrestrial radiation (Ra) from different meteorological stations of Bangladesh were used for a period of 30 years (1981–2010) (Table:1). Solar radiation intensity was calculated from the actual bright sunshine hours [5]. Mean monthly maximum and mean monthly minimum temperatures were used to calculate solar radiations intensity where the sunshine data was not available by Hargreaves method [6]. To calculate solar radiation intensity (MJ/m^2/day) for the fifty eight meteorological stations covering the entire country, we used the following formula [7]

$$Ra = [a + b(n/M)]Ra \quad (1)$$

Where,
Rs=incoming solar radiation (insolation) or global radiation intensity (MJ/ m^2/day)
n=actual measured sunshine hours
N=day-length or the maximum possible sunshine (N) duration (h).

TABLE 1. Daily extraterrestrial radiation (Ra) for different latitudes in the Northern region for the 15th day of the month [6] (values for Ra on the 15th day of the month provide a good estimate (error < 1%) of Ra averaged over all days within the month. Only for high latitudes, greater than 55° (N or S), during winter months may deviations be more than 1%).

Degree	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
50	9	14	22	32	39	42	40	34	26	17	10	8
48	10	16	23	32	39	42	40	35	27	18	11	9
46	11	18	24	33	39	42	41	36	28	19	12	10
44	12	19	25	34	39	42	41	36	28	20	13	11
42	13	20	26	34	40	42	41	37	29	21	14	12
40	14	22	27	35	40	42	41	37	30	23	15	14
38	15	23	28	35	40	42	41	37	31	24	16	15
36	16	24	29	36	40	42	41	38	32	25	18	16
34	18	25	30	36	40	42	41	38	32	26	19	17
32	19	26	31	37	40	41	41	38	33	27	20	19
30	20	27	32	37	40	41	41	38	33	28	21	20
28	21	28	33	37	40	41	40	38	34	29	22	21
26	22	29	34	38	40	41	40	38	35	29	23	22
24	23	30	34	38	40	40	40	38	35	30	25	23
22	25	31	35	38	40	40	40	38	35	31	26	25
20	26	32	36	38	40	40	39	38	36	32	27	26
18	27	33	36	38	39	39	39	38	36	33	28	27
16	28	34	37	38	39	39	39	38	36	33	29	28
14	29	35	37	38	39	39	38	38	37	34	30	29
12	30	36	38	38	38	38	38	38	37	35	31	30
10	31	37	38	38	38	38	37	38	37	35	32	31
0	32	38	38	37	35	35	34	36	37	37	36	36

TABLE 2. Mean daily duration of maximum possible sunshine hours (N) for different months and latitudes.

North latitude	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
South latitude	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
50	9	10	12	14	15	16	16	14	13	11	9	8
48	9	10	12	14	15	16	16	14	13	11	9	8
46	9	10	12	14	15	16	15	15	13	11	10	9
44	9	11	12	13	15	15	15	14	13	11	10	9
42	9	11	12	13	15	15	15	14	13	11	10	9
40	10	11	12	13	14	15	15	14	13	11	10	9
35	10	11	12	13	14	15	14	13	12	11	10	10
30	10	11	12	13	14	14	14	13	12	12	10	10
25	11	11	12	13	13	14	13	13	12	12	10	11
20	11	12	12	13	13	13	13	13	12	12	11	11
15	11	12	12	13	13	13	13	13	12	12	11	11
10	12	12	12	12	13	13	13	12	12	12	11	12
5	12	12	12	12	13	12	13	12	12	12	11	12
0	12	12	12	12	12	12	12	12	12	12	12	12

Ra=extraterrestrial radiation MJ/m2/day. (Table 2)
A=constant expressing the fraction of extraterrestrial radiation reaching the earth's surface on completely overcast days. (Table 3)
b=constant expressing the additional fraction of extraterrestrial radiation reaching the earth's surface on a

clear day (Table III).

At sea level for clear-sky periods, Angstrom's formula [8] describing incoming solar radiations or global radiation intensity Rs (Rso) becomes

$$\mathrm{Rso} = (a+b)\mathrm{Ra} \quad \text{or} \quad \mathrm{Rso} = \mathrm{Kab} \times \mathrm{Ra} \qquad (2)$$

Where Kab=a+b represents the fraction of extraterrestrial radiation reaching the earth on clear-sky days.

Solar radiation may also be calculated by using the maximum and minimum temperature with extraterrestrial radiations (Ra) by De Wit method [9] as shown below,

$$\mathrm{Rs} = \mathrm{Krs} \times (\mathrm{Tmax} - \mathrm{Tmin})\hat{}0.5 \qquad (3)$$

Where,

Rs= incoming solar radiations (M.J/m^2/day)

Krs= adjustment coefficient based on monthly mean relative humidity. 0.16 for interior region not influence by large water bodies and 0.19 for coastal locations.

Ra= extraterrestrial radiation MJ/ m^2/day.

Tmax= mean monthly maximum temperature (°C)

Tmin= mean monthly minimum temperature (°C)

TABLE 3. The fraction of extraterrestrial radiation reaching the earth's surface on completely overcast and clear days

Constant values for a and b					
Altitude	Constant	Dec, Jan Feb	Mar, Apr May	June, July, Aug	Sept, Oct, Nov
Up to 300m	a	0.18	0.21	0.25	0.25
	b	0.51	0.49	0.51	0.51
300 to 1000m	a	0.22	0.25	0.25	0.27
	B	0.48	0.49	0.51	0.51
Greater then 1000m	A	0.23	0.25	0.25	0.27
	B	0.51	0.48	0.53	0.53

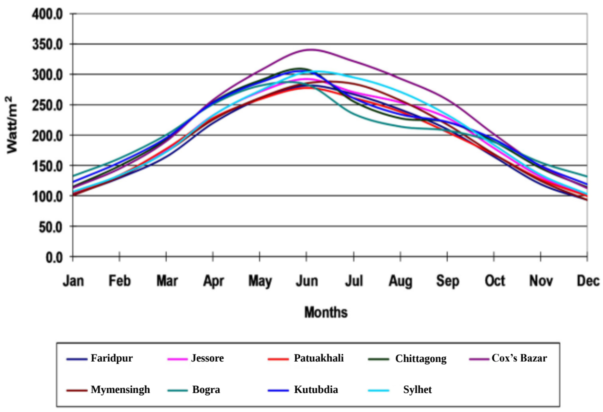

Fig. 1.Solar radiation intensity (W/ m^2) in Northern areas and Bogra during (1981–2010).

3. RESULTS AND DISCUSSIONS

Annual Solar radiations were calculated and plotted throughout the country. The results are discussed here on regional bases. In Rajshahi and Northern Areas, lowest incoming solar radiation intensity was 92.38 W/ m^2 in December at Dinajpurand highest 339.25 W/ m^2 at Madaripurin June. Solar radiation intensity greater than 150W/ m^2 was observed at most humid zones of Rajshahi during February to October while greater than 200 W/m^2observed in whole Northern and eastern regions during April to September. In these areas, monthly average solar radiations remain from 107.1 to 297.0 W/ m^2 during the year as shown in Figure 1.

In Tangail, lowest (76.49W/ m^2) incoming solar radiation intensity was observed at Comilla in December and highest (319.33W/ m^2) at Dinajpur in June. As shown in Figure 2, from March to October solar radiation intensity was greater than 150W/ m^2 in the province except for eastern parts where it extends from February to November.

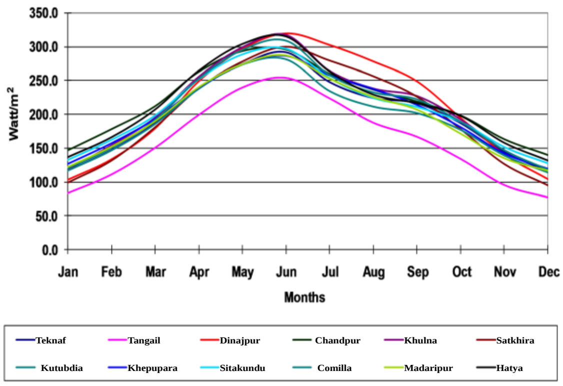

Fig. 2. Solar radiation intensity (W/ m^2) in the tropic of Capricorn part during (1981–2010).

Figure 2 also indicates that the radiation intensity greater than 200W/ m^2 is persistent in all northern regions from April to September except Tangail. Monthly average solar radiations vary from 113.91 to 295.75W/ m^2. It has been observed that the southern part of Tangail has a reasonable potential for solar energy than the northern part of the province.

In Chadpur, minimum solar radiation intensity (96.11W/ m^2) was observed in December arid zone of northeastern region and highest (315.14 W/ m^2) in southern part in May (Figure 3). Solar radiation intensity greater than 150W/m^2 observed from February to November in upper Raojan except Lohagora while lower southern parts of province like Feni, Dhaka and Rangamati have still greater potential throughout the year. It has been observed that radiation intensitymgreater than 200W/m^2 is available in most upper parts of Dinajpur during March to September (like inKhepupara, Rangpur, Ishwardi). Average monthly solar radiation remains from 138.73 to 286.81W/m^2 during the year (Figure 3).

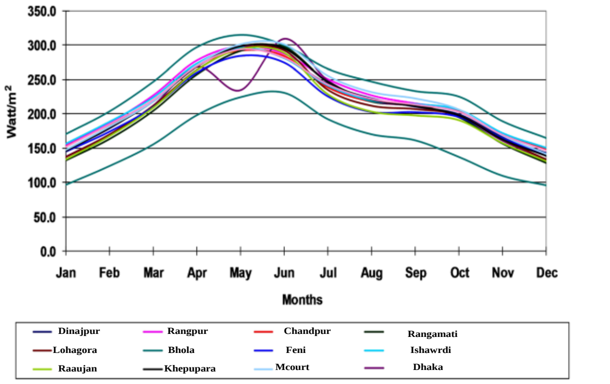

Fig 3. Solar radiation intensity (W/m^2) in Middle part and Rangamati during (1981–2010).

In Chuadanga, lowest solar radiation intensity 135.73 W/ m^2 observed in December at Kishoregonjand highest 329.05 W/ m^2 at Potuakhali during June. Solar radiation intensity is greater than 150W/m^2 is observed throughout the year except in some of the northern and south western parts of the country, where this condition is persistent only from February to November. Solar radiation intensity is larger than 200W/m^2 was observed from March to October. Monthly average solar radiations vary from 153.61 to 281.94 W/ m^2 during the year (Figure 4).

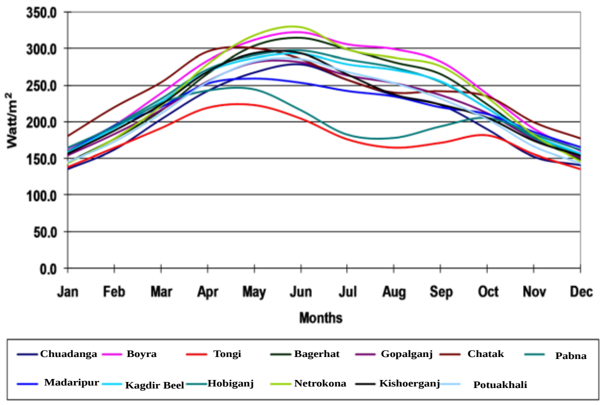

Fig. 4.Solar radiation intensity (W/m^2) in Jossore to Kishoregonj region during (1971–2000).

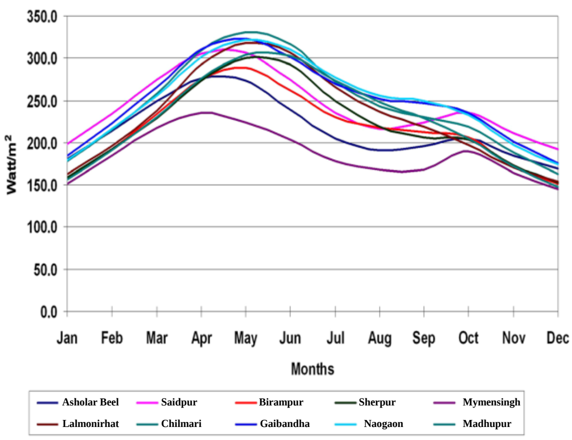

Fig. 5.Solar radiation intensity (W/m^2) in Western Part during (1981–2010).

Like Asorer Beel province also has a lot of solar energy potential than other parts of the country. Solar radiation intensity remained 145.29W/m^2 (lowest) in December in coastal areas and highest 331.27W/m^2 in central regions of Laalmonirhat during June. Solar radiation intensity is greater than 150W/m^2 was observed throughout the province, except Mymensingh, where intensity was less than 150W/m^2 in December. The radiation intensity greater than 200 W/m^2 was observed from February to October in the province except in northwestern parts and coastal areas of Saidpur. Monthly average solar radiation intensity remained from 162.44 to 299.31W/ m^2 during the year (Figure 5).

Annual solar radiation intensity greater than 200 W/m^2 was observed in almost every part of the country except some of the coastal and northern regions. In summer, day length ranges from 12 to14 h and in winter 8 to10 h in Bangladesh. Normally, 10 to 12 average day-length hour have been observed in Bangladesh during the year. In most parts of the country, for a 10 h day, average solar radiation intensity ranging from 1500W/m^2/day to 2750W/m^2/day (Figure 6).

This has been observed especially in Chilmari, Birampur and Sherpurduring one year. Depending upon the area and capacity of solar panel, large amounts of power can be generated, that is, in an area of 100 m^2 and 45MW to 83MW power can be generated in amonth.

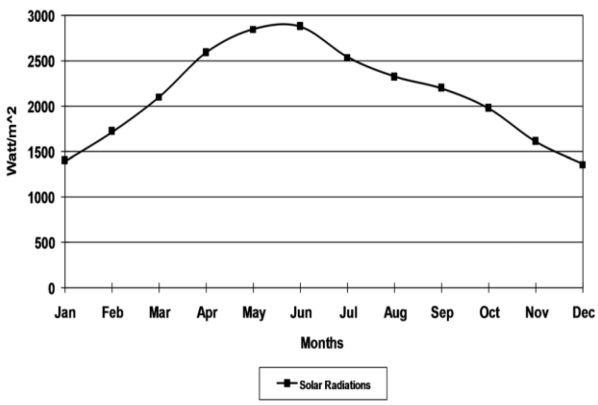

Fig. 6.Average annual solar radiation intensity (W/m2/day) in Bangladesh during (1971–2000).

This has been observed especially in Chittagong, Cox's Bazar and North Bengal during one year. Depending upon the area and capacity of solar panel, large amounts of power can be generated, that is, in an area of 100 m^2; 45MW to 83MW power can be generated in a month.

4.CONCLUSION

From this study, it can be concluded that solar radiation intensity remains favorable from March to October throughout the country. The analysis shows that solar radiation intensity greater than 200W/ m^2 was observed, from February to October in Rajshahi, from March to October in North Bengal region, from April to September in Southern region. In most parts of eastern part, there is an encouraging potential for solar power generation throughout the year. In an area of 100 m^2, 45MW to 83MW power can be generated during a month in these regions. It has been observed that southern part of Bangladesh where annual solar direct normal irradiance is above 5kWh/m^2/day is ideally suitable for photovoltaic technologies.

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