



Cost Analysis for Grid-tie PV Electricity Generation System without Battery Backup Considering Panel Aging in Context of Kutubdia Island, Bangladesh

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Abstract: Grid-tie PV electricity and cost for per kWh generation are affected by solar irradiances, atmospheric conditions, PV panel and inverter's specifications etc. In this paper, Kutubdia Island, Bangladesh is selected as a site location of PV plant and solar irradiance and atmospheric conditions are considered for this island. Daily total irradiances (kWh/m² – day) are converted to hourly solar irradiances (W/m²) and these hourly irradiances are used to calculate daily generation of electricity. Specifications of PV panel model no. “Panasonic 325 watt Module 96 Cell HIT - Black Solar Panel” and grid tie inverter model no. “SolarMax 3×330TS-SV Multi MPPT-990kW” are chosen for this research investigation. This battery less PV system exports electricity to the grid during the sun shine hours in the day time only. Energy conversion efficiency reduces significantly due to aging of PV panel over its life time. Linear de-rated efficiency of PV panel due to aging effect on generation of electricity is considered in this paper. Life time average annual electricity generation is calculated for determination of cost of per kWh electricity.

Keywords: Grid-tie system, PV plant, Aging of PV panel, Maximum power point tracker (MPPT), De-rated efficiency.

NOMENCLATURE

ϕ	Latitude	NOCT	operating condition
λ	Longitude	T_A	Nominal operating cell temperature
GMT	Greenwich Mean Time	T_{ref}	Ambient temperature
θ_{Azsun}	Azimuth angle of the sun with respect to north axis	$T_C(t)$	PV panel reference temperature, 25 °C
θ_A	Altitude angle of the sun	K_v	Operating PV temperature
ρ	Ground albedo	K_i	Open circuit voltage co-efficient
GHI (t)	Global Horizontal Irradiance	E_{reqday}	Short circuit current co-efficient
DIF (t)	Diffuse Horizontal Irradiance	Mg	Daily electricity production target
DHI (t)	Direct Horizontal Irradiance	η_{inv}	Gradient for the linearly de-rated efficiency curve
β_{tilt}	Solar panel tilt angle	η_{trans}	Efficiency of inverter
$\theta_{Azpanel}$	Azimuth angle of PV panel with respect to south axis.	FF	Efficiency of transformer
G (t)	Solar irradiance on tilted surface	$f_{exploit}$	Fill factor
V_{OCSTC}	Open circuit voltage under standard test condition	Area _{grid}	Area exploitation factor
$V_{OC}(t)$	Open circuit voltage under operating condition	N_{lifepv}	Grid substation area
I_{SCSTC}	Short circuit current under standard test condition	$N_{lifeinv}$	Life time of PV panel
$I_{SC}(t)$	Short circuit current under	$N_{lifesupport}$	Life time of PV inverter
		$N_{lifesubstation}$	Life time of PV panel supports
			Life time of grid substation



$N_{lifeland}$	Life time of land
$N_{lifeproject}$	Life time of project
$Price_{purpv}$	Purchasing price of PV panels per watt
$Price_{purinv}$	Purchasing price of PV inverter per watt
$Price_{supportpv}$	Price for support of PV panels per m^2
$Price_{substation}$	Construction price of grid substation per volt-ampere
$Price_{purland}$	Purchasing price of land per acres
$Price_{landdev}$	Cost of land development per acres
$\%Salvage_{pv}$	Percentage of salvage value of PV panels, of its initial investment
$\%Salvage_{inverter}$	Percentage of salvage value of PV inverter, of its initial investment
$\%Salvage_{support}$	Percentage of salvage value of PV panel supports, of its initial investment
$\%Salvage_{substation}$	Percentage of salvage value of grid substation, of its initial investment
$\%Salvage_{land}$	Percentage of salvage value of land, of its initial investment
β	Inflation rate
γ	Interest rate
ψ	Escalation rate
$N_{techstaff}$	No. of technical staffs per MW_p
$N_{secustaff}$	No. of security staffs per MW_p
$Salary_{techstaff}$	Salary of each technical staff
$Salary_{secustaff}$	Salary of each security guard
$Price_{ompv}$	Yearly maintenance cost of PV panel per watt
$Price_{omsupport}$	Yearly maintenance cost of PV panel support per m^2
$Price_{ominv}$	Yearly maintenance cost of PV inverter per watt
$Price_{omsubstation}$	Yearly maintenance cost of grid substation per watt.
$Price_{omland}$	Yearly maintenance cost of land per acre.

I. INTRODUCTION

A grid tie PV system omitting the energy storage device like large capacity battery bank not only reduces the internal losses for charging and discharging of battery bank but also cost of the system. Maximum generation of PV power can be evacuated to grid instantly. For grid tie system, voltage wave shape of inverter’s output must be identical to the grid voltage. Since voltage wave shape of

grid is sinusoidal, so inverter should be sinusoidal wave inverter. Although sinusoidal wave inverter is little more expensive in comparison with other voltage wave inverters, but omission of large battery bank may offer more reduction of cost. Kutubdia Island has sufficient solar insolation ($3.5-5.5kWh/m^2 - day$) [1] and huge barren land. Kutubdia has not yet been connected with grid electricity, but Bangladesh Power Development Board (BPDB) has already launched a project to connect this island with grid electricity. In this research Kutubdia Island is selected as a site location for a large size PV plant (several MW_p).

II. GRID-TIE PV SYSTEM WITHOUT BATTERY BACKUP

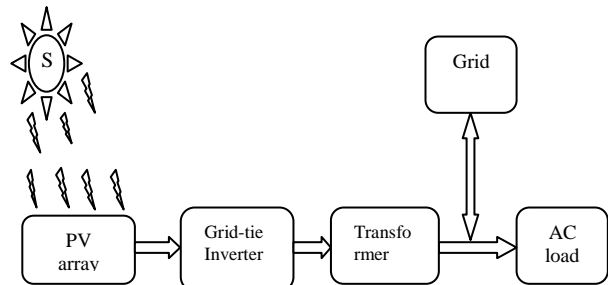


Fig.1: Block diagram for Grid-tie PV System without Battery Backup

Wattpeak (W_p) rating of PV panel is the maximum amount of power converted by PV panel under standard test conditions (STC). Under standard test condition, solar irradiance level is $1000W/m^2$, panel temperature is $25^\circ C$ and air mass (AM) is 1.5 [2]. Power conversion from panel varies for different times of a day as solar irradiance changes. Even in solar day peak time power produced from the panel is less than W_p as solar irradiance level is less than $1000W/m^2$ for the location of Kutubdia. Grid-tie inverter is a maximum power point tracker (MPPT) embedded sinusoidal wave inverter. The embedded MPPT extracts maximum power output of the PV panels and inverter converts DC voltage to sinusoidal wave AC voltage. Output voltage of inverter is stepped up using suitable turns ratio of transformer to adjust with grid voltage. Power ratings of both inverter and transformer depend on total wattpeak (W_p) rating of PV plant.

III. CONVERSION OF DAILY TOTAL IRRADIANCE TO HOURLY IRRADIANCES

Solar declination angle in degree, δ , is as [3].

$$\delta = 23.45 \times \sin\left(\frac{360(N+284)}{365}\right) \dots\dots 1$$

Where, N= Nth day of a year.

The values of the equation of time (ET) in minute as a function of the day of the year (N) can be obtained approximately from the following equation [3], [4].



$$ET = 229.18(0.0000075 + 0.001868 \cos(d) - 0.032077 \sin(d) - 0.014615 \cos(2d) - 0.040849 \sin(2d)) \dots 2$$

Where, Factor $d = \frac{2\pi(N-1)}{365}$

Relationship between local standard time (LST) and solar apparent time (AST) is given by the following equation.

$$AST = LST + \frac{ET + 4 \times (\lambda_{st} - \lambda)}{60} \dots 3$$

Where, λ_{st} = Local standard longitude and λ = Local longitude.

Expression for solar hour angle (ω) and sun set hour angle (ω_{ss}) in degree as specified in [3], [4].

$$\omega = 15 \times (AST - 12) \dots 4$$

$$\omega_{ss} = \cos^{-1}(-\tan \phi \tan \delta) \dots 5$$

Relation between hourly irradiance $G_h(t)$ and daily total irradiance G_{day} can be expressed according to Liu-Jordan correlation [5].

$$G_h(t) = \left\{ \frac{\pi}{24} \frac{(\cos \omega(t) - \cos \omega_{ss})}{\sin \omega_{ss} - \frac{2\pi \omega_{ss} \cos \omega_{ss}}{360}} \right\} \times G_{day} ; \dots 6$$

$0 \leq t \leq 24$ and t is LST in hour.

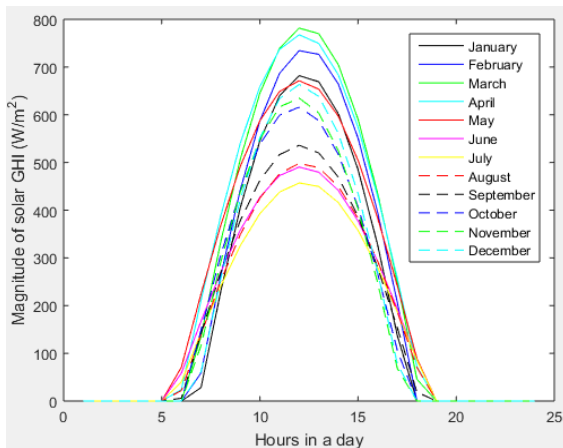


Fig. 2 Diurnal variation of GHI for January to December at location of Kutubdia Island, Bangladesh.

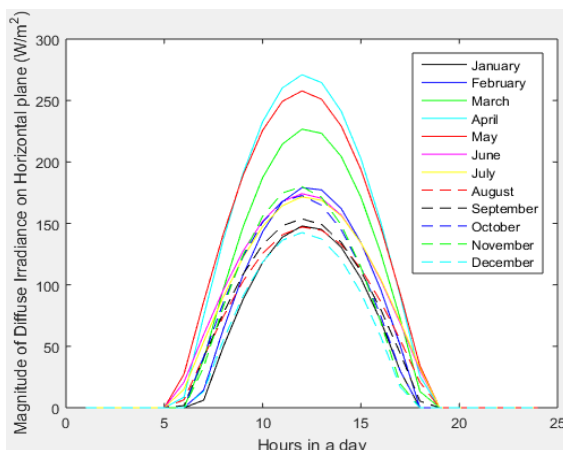


Fig. 3 Diurnal variation of DIF for January to December at location of Kutubdia Island, Bangladesh.

IV. DETERMINATION OF SOLAR IRRADIANCE ON TILTED PV PANEL

PV panels are yearly fixed to a certain tilt angle and azimuth orientation so that yearly total solar irradiances incident on PV panel surface is maximum. For Bangladesh yearly fixed tilt and azimuth angles are 21.8° (equal to latitude) and 0° [14] respectively. Solar irradiance on tilted PV panel for different hours (i.e., $0 \leq t \leq 24$) is calculated using equations as follows.

Direct Beam on Tilted Surface [6]-[7],

$$DIRT_{tilt}(t) = \max \left\{ 0, \frac{\sin \theta_A \cos \beta + \cos \theta_A \sin \beta \cos(\theta_{Azsun} - \theta_{Azpvn})}{\sin \theta_A} \right\} \times \{GHI(t) - DIF(t)\} \dots 7$$

Where, θ_{Azpvn} is the azimuth angle of PV panel with respect to north axis and so $\theta_{Azpvn} = 180^\circ + \theta_{Azpanel}$.

Diffuse beam on tilted surface is calculated by Pseudo-isotropic model proposed by authors in [8].

$$DIF_{tilt}(t) = \left(\frac{3 + \cos(2\beta_{tilt})}{4} \right) \times DIF(t) \dots 8$$

Using equation as in [9] ground reflected beam on tilted surface,

$$REF_{tilt}(t) = \rho \left(\frac{1 - \cos \beta_{tilt}}{2} \right) \times GHI(t) \dots 9$$

Solar irradiance on tilted surface,

$$G(t) = DIRT_{tilt}(t) + DIF_{tilt}(t) + REF_{tilt}(t) \dots 10$$

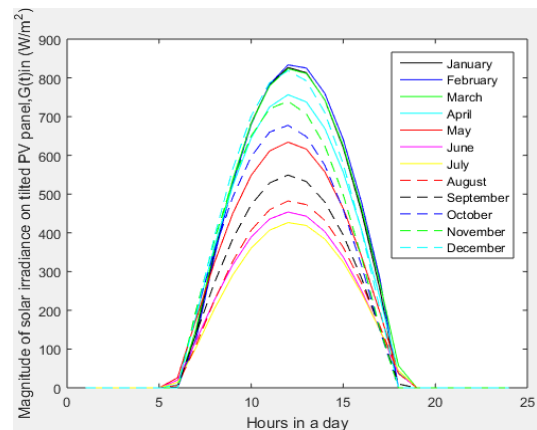


Fig. 4 Diurnal variation of $G(t)$ for January to December at location of Kutubdia Island, Bangladesh.

V. A PV SYSTEM MODEL AND CALCULATION OF PV PLANT AREA

Power produced by the PV panel can be calculated using following equations [10].

Open circuit voltage:

$$V_{OC}(t) = V_{OCSTC} + K_v (T_c(t) - T_{ref}) \dots 11$$



Short circuit current:

$$I_{SC}(t) = [I_{SCSTC} + K_i (T_C(t) - T_{ref})] \times \frac{G(t)}{1000} \dots 12$$

Where

$$T_C(t) = T_A + \frac{NOCT - 20}{800} \times G(t) \dots 13$$

Instantaneous power produced from a panel,

$$P_{Panelnew}(t) = \eta_{inv} \times \eta_{trans} \times FF \times V_{OC}(t) \times I_{SC}(t) \dots 14$$

A. Annual average electricity production by a new PV panel

Annual average electricity production by a PV panel can be calculated using following relationships.

Daily electricity production by a new panel,

$$E_{pdnew} = \sum_{t=1}^{24} P_{panelnew}(t) = \eta_{inv} \times \eta_{trans} \times FF \times \sum_{t=1}^{24} V_{OC}(t) \times I_{SC}(t) \dots 15$$

Annual electricity production by a new panel,

$$E_{pynew} = \sum_{d=1}^{365} E_{pdnew}(d) \dots 16$$

Where, d= day.

B. Consideration of aging of PV panel and life time average annual electricity production by a PV panel

Due to aging of PV panel, energy conversion efficiency reduces. Curve for de-rating of PV panel efficiency is collected from manufacturer's data sheet of PV panel. Linear de-rating of efficiency of PV panel as shown in figure below is obtained from technical specification of panel data and de-rated efficiency is represented in equation 17.

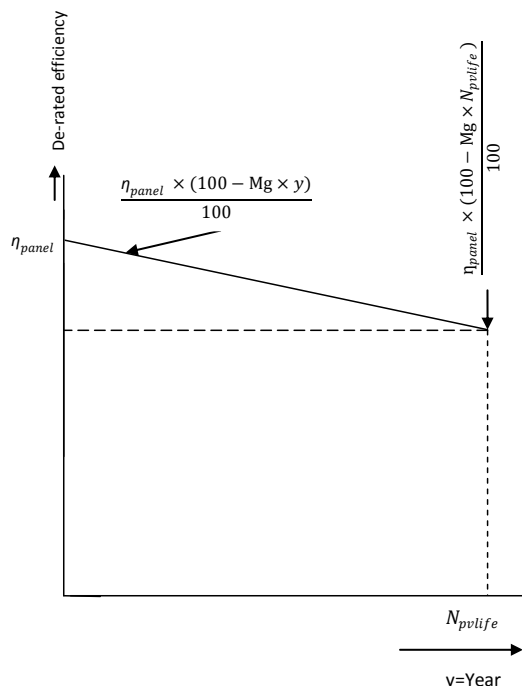


Fig. 5 Curve for de-rating of efficiency due to aging of PV panel.

$$\text{De-rated efficiency} = \frac{\eta_{panel} \times (100 - Mg \times y)}{100} \dots 17$$

Where, η_{panel} is the efficiency of a PV panel at new condition. PV panel life time average of annual electricity production by a panel,

$$E_{pyavg} = \frac{E_{pynew} \sum_{y=0}^{N_{lifepv}} - 1(100 - Mg \times y)}{N_{lifepv}} \dots 18$$

C. Area for PV plant

Annual target of electricity,

$$E_{reqyear} = 365 \times E_{reqday} \dots 19$$

Number of panels required,

$$N_{pv} = \text{Ceiling} \left(\frac{E_{reqyear}}{E_{pyavg}} \right) \dots 20$$

Watt-peak rating of PV plant,

$$W_{peakpv} = \text{Wattpeak}_{panel} \times N_{pv} \dots 21$$

Solar radiation sensitive panel area,

$$\text{Area}_{panel} = \text{Length}_{panel} \times \text{Width}_{panel} \dots 22$$

PV panel installation area in acre,

$$\text{Area}_{pv} = \frac{N_{pv} \times \text{Area}_{panel}}{f_{exploit}} \times \frac{1}{4046.8} \dots 23$$

Total PV plant area,

$$\text{Area}_{plant} = \text{Area}_{pv} + \text{Area}_{grid} \dots 24$$

VI. COST ESTIMATION FOR GRID TIE PV PLANT

A. Initial investment

Initial investment for purchasing PV panels,

$$\text{Invest}_{purpv} = \text{Price}_{purpv} \times \text{Wattpeak}_{pv} \dots 25$$

Considering record high irradiance ($G=880 \text{ W/m}^2$) on PV panel and record low temperature ($T_A = 5^\circ \text{ C}$), for Kutubdia Island, record maximum power of PV plant, P_{PVmax} is calculated as below.

$$P_{PVmax} = N_{pv} \times FF \times V_{OC}(t) \times I_{SC}(t) \dots 26$$

Power rating of inverter,

$$\text{Watt}_{inv} = P_{PVmax} \dots 27$$

Apparent power rating of transformer,

$$\text{Watt}_{substation} = \eta_{inv} \times \text{Watt}_{inv} \times \frac{1}{\text{Powerfactor}} \dots 28$$

Initial investment for purchasing PV inverter,

$$\text{Invest}_{inverter} = \text{Price}_{purinv} \times \text{Watt}_{inv} \dots 29$$

Initial investment for construction of panel supports,

$$\text{Invest}_{support} = \text{Price}_{supportpv} \times \text{Area}_{pv} \dots 30$$

Initial investment for grid substation,

$$\text{Invest}_{substation} = \text{Price}_{substation} \times \text{Watt}_{substation} \dots 31$$



Initial investment for purchasing land,
 $Invest_{land} = Price_{purland} \times Area_{plant} \dots 32$

Initial investment for land development,
 $Invest_{landdev} = Price_{landdev} \times Area_{plant} \dots 33$

B. Present worth of salvage value

Present worth of salvage value is calculated as in [11] using following equations.

Present worth of salvage value of PV panels,
 $PSV_{panel} = \%Salvage_{pv} \times Invest_{purpv} \times \left(\frac{1+\beta}{1+\gamma}\right)^{N_{lifepv}} \dots 34$

Present worth of salvage value of PV inverter,
 $PSV_{inverter} = \%Salvage_{inv} \times Invest_{purinv} \times \left(\frac{1+\beta}{1+\gamma}\right)^{N_{lifeinv}} \dots 35$

Present worth of salvage value of panel supports,
 $PSV_{support} = \%Salvage_{supprt} \times Invest_{support} \times \left(\frac{1+\beta}{1+\gamma}\right)^{N_{lifesupport}} \dots 36$

Present worth of salvage value of grid substation,
 $PSV_{substation} = \%Salvage_{substation} \times Invest_{substation} \times \left(\frac{1+\beta}{1+\gamma}\right)^{N_{lifesubstation}} \dots 37$

Present worth of salvage value of land,
 $PSV_{land} = \%Salvage_{land} \times Invest_{land} \times \left(\frac{1+\beta}{1+\gamma}\right)^{N_{lifeland}} \dots 38$

C. Present worth of maintenance cost

Present worth of maintenance cost is calculated as in [11] using following equations.

Present worth of maintenance cost of PV panels,
 $OM_{pv} = Price_{ompv} \times Watt_{peak_{pv}} \sum_{i=1}^{N_{lifepv}} \left(\frac{1+\psi}{1+\gamma}\right)^i \dots 39$

Present worth of maintenance cost of PV inverter,
 $OM_{inverter} = Price_{ominv} \times Watt_{inv} \sum_{i=1}^{N_{lifeinv}} \left(\frac{1+\psi}{1+\gamma}\right)^i \dots 40$

Present worth of maintenance cost of PV panels supports,
 $OM_{support} = Price_{omsupport} \times Area_{pv} \sum_{i=1}^{N_{lifesupport}} \left(\frac{1+\psi}{1+\gamma}\right)^i \dots 41$

Present worth of maintenance cost of grid substation,
 $OM_{substation} = Price_{omsubstation} \times Watt_{substation} \sum_{i=1}^{N_{lifesubstation}} \left(\frac{1+\psi}{1+\gamma}\right)^i \dots 42$

Present worth of maintenance cost of land development,
 $OM_{landdev} = Price_{omland} \times Area_{plant} \sum_{i=1}^{N_{lifeland}} \left(\frac{1+\psi}{1+\gamma}\right)^i \dots 43$

Present worth of operating cost (Salary of staffs),

$$OM_{salary} = (Salary_{techstaff} \times N_{techstaff} \times \frac{W_{peak_{pv}}}{10^6} + Salary_{secstaff} \times N_{secstaff} \times \frac{W_{peak_{pv}}}{10^6}) \times 14.2 \times \sum_{i=1}^{N_{lifeproject}} \left(\frac{1+\psi}{1+\gamma}\right)^i \dots 44$$

D. Total annual cost

Annual cost of PV plant is calculated using following equations [5].

Annual cost for solar panels,
 $Cost_{panels} = \frac{Invest_{purpv} - PSV_{panel} + OM_{pv}}{N_{lifepv}} \dots 45$

Annual cost for panel supports,
 $Cost_{support} = \frac{Invest_{support} - PSV_{support} + OM_{support}}{N_{lifesupport}} \dots 46$

Annual cost for PV inverter,
 $Cost_{inverter} = \frac{Invest_{inverter} - PSV_{inverter} + OM_{inverter}}{N_{lifeinverter}} \dots 47$

Annual cost for grid substation,
 $Cost_{substation} = \frac{Invest_{substation} - PSV_{substation} + OM_{substation}}{N_{lifesubstation}} \dots 48$

Annual cost for land,
 $Cost_{land} = \frac{Invest_{land} + Invest_{landdev} - PSV_{land} + OM_{land}}{N_{lifeland}} \dots 49$

Annual cost for salary of staff,
 $Cost_{salary} = \frac{OM_{salary}}{N_{lifeproject}} \dots 50$

Total Annual cost,

$$Cost_{year} = Cost_{panels} + Cost_{support} + Cost_{inverter} + Cost_{substation} + Cost_{land} + Cost_{salary} \dots 51$$

E. Per unit electricity (kWh) generation cost

Per unit electricity (kWh) generation cost in BDT,

$$kWh_{cost} = \frac{Cost_{year}}{E_{pyavg} / 1000} \dots 52$$

VII. INPUT DATA

Direct beam incident on tilted PV panel is calculated using equation 7. Altitude angle of the sun (θ_A) and azimuth angle of sun with respect to north axis (θ_{Azsun}) for middle days of every months of a year is listed in table “TABLE – I: Altitude and Azimuth angle of the sun for Kutubdia Island” in appendix. These angles are collected from online software tool (sunearthtool) [12].

Input solar data are hourly solar irradiances on titled PV panels as shown in fig.4. Prices for PV panels, inverter and transformer are collected from [13].

TABLE -1 LOCATION DATA

Latitude, ϕ	21.8°
Longitude of Kutubdia Island, λ	91.85°
Local standard longitude of Bangladesh, λ_{st}	90°



Average ambient temperature of Kutubdia Island, T_A	30°C
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TABLE -2 DESIGN SPECIFIED DATA

Daily electricity production target, E_{reqday}	24×10 ⁶ Wh
Grid substation area, $Area_{grid}$	1 acre
Area exploitation factor, $f_{exploit}$	0.6
Solar panel tilt angle, β_{tilt}	21.8° (equal to latitude) [14].
Solar panel azimuth angle, A_{zpanel}	0°

TABLE -3 DEVICE SPECIFICATION DATA

Watt-peak rating of each panel, W_p (in W)	325
Efficiency of panel at new condition, η_{panel} (in %)	19.4
Gradient of the linearly de-rated panel efficiency, M_g (in year ⁻¹)	-1
Dimension of each PV panel (Length ×Width) (in m ²)	1.590×1.053
Open circuit voltage of each panel under STC, $V_{oc.stc}$ (in V)	69.6
Short circuit current of each panel under STC, $I_{sc.stc}$ (in A)	6.03
Temperature coefficient of open circuit voltage of PV panel, K_p (in V/ °C)	-0.174
Temperature Coefficient of short circuit current of PV panel, K_i (in A/ °C)	+0.00182
Fill Factor, FF	0.774
Nominal Operating Cell Temperature of PV panel, NOCT (in °C)	49.2
Efficiency of grid tie PV inverter, η_{inv} (in%)	95
Efficiency of transformer, η_{trans} (in%)	97

TABLE -4 COST ESTIMATION DATA

N_{lifepv}	25 years
$N_{lifeinv}$	5 years
$N_{lifesupport}$	25 years
$N_{lifesubstation}$	25 years
$N_{lifeland}$	25 years
$N_{lifeproject}$	25 years
$Price_{purpv}$	BDT 110/Watt
$Price_{purinv}$	BDT 15/Watt
$Price_{supportpv}$	BDT 5000/m ²
$Price_{substation}$	BDT 10/VA
$Price_{purland}$	BDT 500 lac/acre
$Price_{landdev}$	BDT: 5 lac/acre

$\%Salvage_{pv}$	20%
$\%Salvage_{inverter}$	20%
$\%Salvage_{support}$	20%
$\%Salvage_{substation}$	20%
$\%Salvage_{land}$	100%
β	0.08
γ	0.12
ψ	0.10
$N_{techstaff}$	3 men/ MW_p
$N_{secustaff}$	3 men/ MW_p
$Salary_{techstaff}$	BDT 30000/man
$Salary_{secustaff}$	BDT 20000/man
$Price_{ompv}$	BDT 5/ Watt
$Price_{omsupport}$	BDT 200/m ²
$Price_{ominv}$	BDT 1/Watt
$Price_{omsubstation}$	BDT 1/VA
$Price_{omland}$	BDT 0.5lac /acre

VI.RESULT

Total watt peak rating of PV plant, total area of the plant and cost for per kWh PV electricity generation are calculated using equations 21, 24 and 52 respectively. Matlab software version “MATLAB R2015a” is used for these calculations. Hourly solar irradiance for a particular hour is assumed as a constant for the particular duration of an hour. For example solar irradiance at 11:30am is assumed to be same for 11:00am to 12:00pm for a particular day. Diurnal solar irradiances are determined for middle days of every months of a year and it is assumed that diurnal solar irradiance for middle of a month is identical for remaining days of that month.

TABLE -5 RESULT

Total watt peak rating of PV plant	6.53MW _p
Total area of the plant	14.85 acres
Cost for per kWh PV electricity	BDT 14.87

VIII. CONCLUSION

Cost for per kWh electricity generation is very important for planning a new power plant. Due to aging of power plant generation of electricity reduces. Reduction of generation must be taken into account to enhance the accuracy of the calculations. Battery less grid tie PV system mainly consists of PV panels, grid tie inverter and transformer. As price of inverter and transformer is significantly less than the price of PV panels, cost of PV electricity significantly depends on prices and solar performances of PV panels. Moreover de-rating of efficiencies over the lifetime of inverter and transformer is very less than that of PV panels. Consideration of de-rating of efficiency of PV panels can give significantly accurate result for calculation of cost and amount of electricity from a battery less grid tie system.



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Hamidur Rahman is currently working as an associate professor in Electrical and Electronic Engineering in Bangladesh University of Engineering and Technology. His research interests are renewable energy, power system, and control system engineering. He is currently supervising several post graduate researches on renewable energy.



Mohammad Shamsuddoha received the B.Sc in Electrical and Electronic Engineering and M.S in Nuclear Engineering from "Chittagong University of Engineering and Technology" and "University of Dhaka" respectively. He is currently working as an electrical engineer in Bangladesh Power Development Board, Dhaka. He also works as a researcher of University of Dhaka. He is currently researching on diversification of fuel sources to generate grid electricity in Bangladesh.



Nusrat Nessa received the B.Sc in Electrical and Electronic Engineering from University of Dhaka. She is pursuing the M.Sc in Electrical and Electronic Engineering from the same university. She is now working as a post graduate researcher of EEE in University of Dhaka.

BIOGRAPHIES



Md. Abubakar Talukdar received the B.Sc in Electrical and Electronic Engineering and M.S in Nuclear

APPENDIX

TABLE- I ALTITUDE AND AZIMUTH ANGLE OF THE SUN FOR KUTUBDIA ISLAND

Name of location: Kutubdia Island, Bangladesh; Latitude, $\phi = 21.82^\circ$ N, Longitude, $\text{long} = 91.85^\circ$ E, GMT = +6, Ground albedo, $\rho = 0.2$												
Hours in a day	Azimuth angle of the sun, Θ_{Azsun} / Altitude angle of the sun, Θ_A in degree for middle days of different months in a year											
	15 th Jan	14 th Feb	15 th Mar	15 th Apr	15 th May	15 th Jun	15 th Jul	15 th Aug	15 th Sep	15 th Oct	15 th Nov	15 th Dec
1:00	88.93/	48.48/	29.77/	23.65/	19.90/	16.62/	15.48/	19.01/	30.84/	55.09/	80.58/	98.76/



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	-79.77	-77.49	-67.97	-56.15	-47.20	-43.11	-45.05	-52.04	-61.22	-69.52	-73.72	-76.65
2:00	93.53/ -65.85	74.02/ -65.09	55.75/ -58.33	44.25/ -48.27	37.31/ -40.47	32.96/ -37.23	32.68/ -39.32	38.59/ -45.27	52.35/ -51.87	72.90/ -56.93	89.14/ -59.86	98.63/ -62.88
3:00	96.99/ -51.99	83.92/ -51.41	69.59/ -45.90	57.99/ -37.37	50.15/ -30.79	45.54/ -28.38	45.84/ -30.48	52.52/ -35.29	65.44/ -39.92	82.15/ -43.34	94.21/ -45.95	100.74/ -49.15
4:00	100.48/ -38.23	90.21/ -37.51	78.33/ -32.51	67.45/ -24.97	59.52/ -19.38	54.94/ -17.65	55.60/ -19.68	62.38/ -23.54	74.24/ -26.84	88.60/ -29.47	98.57/ -32.12	103.66/ -54.54
5:00	104.2/ -24.63	95.39/ -23.59	84.90/ -18.72	74.56/ -11.79	66.60/ -6.96	62.06/ -5.76	62.95/ -7.70	69.75/ -10.81	80.95/ -13.25	94.09/ -15.55	102.9/ -18.44	107.2/ -22.12
6:00	108.5/ -11.27	100.4/ -9.80	90.60/ -4.81	80.41/ 1.81	72.23/ 6.09	67.60/ 6.85	68.69/5 .01	75.67/ 2.45	86.74/ 0.59	99.45/ -1.73	107.79/ -5.02	111.52/ -8.99
7:00	113.71/ 1.725	105.83/ 3.766	96.22/9. 10	85.74/1 5.635	76.98/1 9.516	72.06/1 9.918	73.37 /18.71	80.82/1 6.112	92.34/1 4.51	105.34/ 11.86	113.53/ 8.00	116.86/ 3.714
8:00	120.19/ 14.15	112.25/ 16.94	102.46/ 22.85	91.18/2 9.56	81.26/3 3.19	75.71/3 3.30	77.33/3 1.65	85.74/2 9.94	98.48/2 8.36	112.47/ 25.03	120.76/ 20.40	123.67/ 15.75
9:00	128.65/ 25.65	120.50/ 29.43	110.28/ 36.22	97.55/4 3.45	85.49/4 7.02	78.70/4 6.88	80.84/4 5.31	91.07/4 3.85	106.21/ 41.96	121.97/ 37.43	130.35/ 31.74	132.63/ 26.71
10:00	140.04/ 35.65	131.89/ 40.71	121.46/ 48.78	106.66/ 57.07	90.39/6 0.94	80.93/6 0.58	84.08/5 9.12	98.05/5 7.72	117.74/ 54.89	135.74/ 48.31	143.53/ 41.28	144.63/ 35.95
11:00	155.35/ 43.14	148.31/ 49.71	139.64/ 59.50	124.28/ 69.73	98.69/7 4.82	81.33/7 4.35	87.35/7 2.99	111.05/ 71.23	138.66/ 65.94	156.38/ 56.16	161.36/ 47.77	160.35/ 42.42
12:00	174.48/ 46.82	170.86/ 54.66	169.74/ 65.59	171.28/ 77.71	164.78/ 86.87	49.07/8 7.71	93.73/8 6.92	158.84/ 81.80	178.00/ 71.32	183.65/ 58.61	182.81/ 49.70	179.12/ 44.93
13:00	194.68/ 45.70	195.95/ 53.83	205.00/ 63.75	228.10/ 72.50	259.70/ 76.42	279.51/ 77.80	270.91/ 79.14	237.92/ 76.28	218.74/ 66.68	209.66/ 54.53	203.62/ 46.47	198.05/ 42.82
14:00	212.23/ 40.11	216.91/ 47.56	229.58/ 55.19	250.25/ 60.14	269.01/ 62.56	278.71/ 64.04	274.45/ 65.23	257.83/ 63.27	240.87/ 55.90	228.28/ 45.68	220.21/ 39.04	214.11/ 36.66
15:00	225.67/ 31.32	231.76/ 37.79	244.12/ 43.49	260.66/ 46.93	274.08/ 48.64	280.67/ 50.31	277.65/ 51.39	266.31/ 49.47	252.88/ 43.06	240.69/ 34.30	232.32/ 28.94	226.41/ 27.62
16:00	235.59/ 20.54	242.14/ 26.10	253.55/ 30.50	267.49/ 33.08	278.35/ 34.81	283.50/ 36.69	281.02/ 37.65	272.08/ 35.55	260.81/ 29.49	249.41/ 21.65	241.19/ 17.27	235.60/ 16.78
17:00	243.05/ 8.56	249.80/ 13.39	260.55/ 16.93	273.08/ 19.17	282.61/ 21.12	286.98/ 23.26	284.75/ 24.07	277.06/ 21.67	267.01/ 15.34	256.11/ 8.34	247.95/ 4.68	242.57/ 4.82
18:00	248.88/ -4.16	255.90/ 0.084	266.44/ 3.104	278.39/ 5.32	287.30/ 7.67	291.21/ 10.10	289.07/ 10.75	282.04/ 7.93	272.611 .71	261.77/ -5.33	253.39/ -8.46	248.02/ -7.84
19:00	253.63/ -17.34	261.19/ -13.56	272.05/ -10.81	284.08/ -8.34	292.81/ -5.41	296.45/ -2.64	294.28/ -2.20	287.56/ -5.54	278.32/ -12.16	267.07/ -19.19	258.04/ -21.96	252.40/ -20.94
20:00	257.70/ -30.83	266.24/ -27.39	278.07/ -24.67	290.82/ -21.62	299.70/ -17.90	303.11/ -14.74	300.83/ -14.56	294.21/ -18.56	284.88/ -25.81	272.64/ -33.12	262.32/ -35.68	256.01/ -34.34
21:00	261.34/ -44.52	271.68/ -41.30	285.43/ -38.30	299.60/ -34.22	308.76/ -29.43	311.86/ -25.80	309.39/ -25.97	302.88/ -30.82	293.37/ -38.98	279.46/ -46.97	266.67/ -49.53	258.96/ -47.93
22:00	264.85/ -58.33	278.72/ -55.16	295.98/ -51.34	312.06/ -45.54	321.14/ -39.31	323.56/ -35.20	320.93/ -35.82	314.91/ -41.70	305.89/ -51.13	289.87/ -60.46	272.01/ -63.45	261.14/ -61.64
23:00	268.78/ -72.23	291.10/ -68.63	314.02/ -62.82	330.70/ -54.30	337.96/ -46.42	338.96/ 41.95	336.38/ -43.12	332.13/ -50.05	326.50/ -60.89	312.06/ -72.55	282.55/ -72.27	261.30/ -75.41
24:00	280.07/ 86.12	328.92/ -79.74	347.80/ -69.81	356.54/ -58.29	358.74/ -49.26	357.53/ -44.81	355.50/ -46.55	355.00/ -54.07	358.58/ -65.21	350.94/ -77.73	331.14/ -86.29	204.81/ -88.40