IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

Multi criteria Decision Analysis Algorithm based Optimal Selection of PV Panel for Grid-tie PV Electricity Generation System in context of Dhaka, Bangladesh

Md. Abubokar Talukdar[1], Hamidur Rahman[2], Pejush Chandra Sarker[3]

Research Scholar, Department of EEE, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh[1]

Associate Professor, Department of EEE, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh[2]

Lecturer, Department of EEE, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh [3]

Abstract: Solar electricity from photovoltaic (PV) panel is the important source of renewable energy and it is being popular all over the world due to enhancement of solar PV technology. There are sorts of PV panels having individually different solar performance features manufactured by different manufactures in different countries. Per watt cost, efficiency, life time etc are different for different types of PV panels. Due to difference in efficiencies, different panels require different amount of land usage for generation of same amount of electricity. Per unit electricity (kWh) generation cost is also different for different types of panels. It is an important concern to reduce land usage and per unit electricity cost. This paper deals with optimal selection of PV panel for grid tie PV power plant using multi-criteria decision analysis (MCDA) algorithm. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is adopted as MCDA tool for optimal selection of PV panel considering land usage and per kWh generation cost criteria. Several investigations are performed for different weighing of the criteria. This study could be assumed as a powerful road map for decision makers, analysts and policy makers in context of Bangladesh.

Keywords: Optimal selection, Grid tie power plant, solar PV electricity, Multi-criteria decision analysis (MCDA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

NOMENCLATURE

ø	Latitude
Long	Longitude
GMT	Greenwich Mean Time
A_{zsun}	Azimuth angle of the sun
Θ_A	Altitude angle of the sun
ρ	Ground albedo
GHI (t)	Global Horizontal Irradiance
DIF (t)	Diffuse Horizontal Irradiance
DHI (t)	Direct Horizontal Irradiance
β_{tilt}	Solar panel tilt angle
A_{zpanel}	Solar panel azimuth angle
G (t)	Solar irradiance on tilted surface
V_{OCSTC}	Open circuit voltage under standard test condition
$V_{OC}(t)$	Open circuit voltage under operating condition
I_{SCSTC}	Short circuit current under standard test condition
$I_{SC}(t)$	Short circuit current under operating condition
NOCT	Nominal operating cell temperature
T_A	Ambient temperature
T_{ref}	PV panel reference temperature, 25 °C
$T_C(t)$	Operating PV temperature
K_v	Open circuit voltage co-efficient
K_i	Short circuit current co-efficient
E_{reqday}	Daily electricity production target
Mg	Gradient for the linearly de-rated efficiency curve
η_{inv}	Inverter efficiency
FF	Fill factor
$f_{exploit}$	Area exploitation factor
$Area_{grid}$	Grid substation area
N_{lifepv}	Life time of PV panel
$N_{lifeinv}$	Life time of PV inverter
$N_{lifesupport}$	Life time of PV panel

 DOI 10.17148/IJIREEICE.2017.5214

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

	supports
$N_{lifesubstation}$	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 watt
$Price_{purland}$	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
$N_{secustaff}$	No. of security staffs
$Salary_{techstaff}$	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

The production of electricity in 2013 was 23,321 TWh. Sources of electricity were fossil fuels 67%, renewable energy 16% (mainly hydroelectric, wind, solar and biomass), and nuclear power 13%, and other sources were 4%. The majority of fossil fuel usage for the generation of electricity was coal and gas[1]. Due to depletion of fossil fuels and serious pollution occurring from usage of fossil fuels as source of energy, renewable energy sources are becoming popular for generation of electricity. Among the many other renewable energy sources solar photovoltaic (PV) electricity is more feasible due to direct conversion of electricity from solar irradiance and it requires less maintenance in comparison with other renewable electricity sources. There are several PV technologies for extraction of electricity using PV panels. Selection of PV panel is very important for optimization of PV plant design considering specified criteria.

II. PROBLEM STATEMENT

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°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 $1000W/m^2$. There are several manufacturing companies in the world which manufacture solar panels having different solar performance. Efficiency, per watt price, lifetime, and degradation of wattpeak rating over life span are widely varied with manufacturers and PV technologies. Doubly efficient panel requires half area to produce same amount of power. Highly efficient PV panel reduces the land requirement, but per watt price of high efficient panel is higher and hence per kWh electricity generation cost may be higher. Panel should be so chosen that reduces both per kWh generation electricity cost and land usage.

III. PROBLEM SOLVING APPROACH

In this paper daily electricity production capacity and location of PV plant are preliminarily determined. Few PV panels are preliminarily selected and several alternatives are formed for individual PV panel. For grid tie PV electricity system, per kWh electricity production cost and required area for PV plant are calculated for each alternative using input location data (i.e.; latitude, longitude, solar azimuth angle, sun altitude angle etc.), solar data (i.e.; temperature, diurnal solar irradiance etc), PV panel data (open circuit voltage and short circuit current under standard test condition, temperature co-efficient of open circuit voltage and short circuit current, NOCT, efficiency, physical dimension, FF, weight etc.), design data (tilt angle, azimuth orientation of panel, area exploitation factor, inter row spacing etc.).

Per kWh cost and required area for PV plant are the two criteria which are preliminarily preferred by weighing method. Now ranking of all alternatives is made using

TOPSIS multicriteria decision analysis algorithm. Panel corresponding to the best alternative is the optimal selected PV panel.

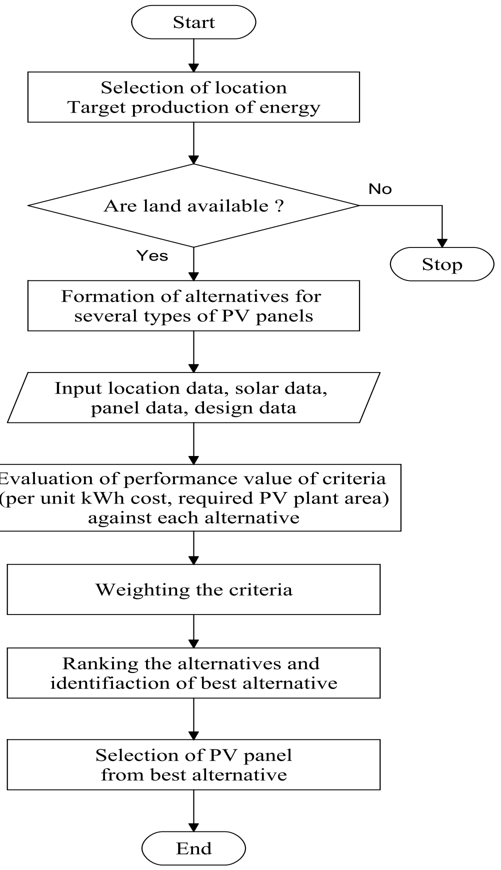

Fig.1: Flow chart for selection of PV panel.

IV. DETERMINATION OF SOLAR IRRADIANCE ON TILTED PV PANEL

Available solar data GHI and DIF are irradiance on horizontal surfaces. But PV panels are titled and panel azimuth oriented to receive maximum irradiance. In this paper, yearly fixed PV panels are considered. Solar irradiance on tilted PV panel is calculated using equations as follows. Direct beam on tilted surface [3]-[4],

$$DHI_{tilt}(t) = \max\left\{0, \frac{(\mathrm{Sin}\,\theta_A \times \mathrm{Cos}\,\beta_{tilt}) + (\mathrm{Cos}\,\theta_A \times \mathrm{Sin}\,\beta_{tilt} \times \mathrm{Cos}(A_{zsun} - A_{zpanel} - 180))}{\mathrm{Sin}\,\theta_A}\right\} \times (GHI(t) - DIF(t)) \quad \ldots\ldots 1$$

Pseudo-isotropic model proposed by authors in [5] diffuse beam on tilted surface,

$$DIF_{tilt}(t) = \left(\frac{3 + Cos(2\beta_{tilt})}{4}\right) \times DIF\ (t) \quad \ldots\ldots 2$$

Using equation as in [6] ground reflected beam on tilted surface,

$$REF_{tilt}\ (t) = \rho \left(\frac{1 - Cos\,\beta_{tilt}}{2}\right) \times GHI\ (t) \quad \ldots\ldots 3$$

Solar irradiance on tilted surface,

$$G\ (t) = DHI_{tilt}(t) + DIF_{tilt}(t) + REF_{tilt}(t) \quad \ldots\ldots 4$$

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

Power produced by the PV panel can be calculated using following equations [7].

Open circuit voltage:

$$V_{OC}(t) = V_{OCSTC} + K_v\ (T_C(t) - T_{ref}) \quad \ldots\ldots 5$$

Short circuit current:

$$I_{SC}(t) = [I_{SCSTC} + K_i\ (T_C(t) - T_{ref})] \times \frac{G(t)}{1000} \quad \ldots\ldots 6$$

Where

$$T_C(t) = T_A + \frac{NOCT - 200}{800} \times G(t) \quad \ldots\ldots 7$$

Instantaneous power produced from a panel,

$$P_{Panelnew}\ (t) = \eta_{inv} \times FF \times V_{OC}(t) \times I_{SC}(t) \quad \ldots\ldots 8$$

A. Annual average electricity production by a PV panel

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

Daily electricity production by a new panel,

$$E_{Pdnew} = \sum_{t=1}^{24} P_{Panel}\ (t) = \eta_{inv} \times FF \times \sum_{t=1}^{24} V_{OC}(t) \times I_{SC}(t) \quad \ldots\ldots 9$$

Annual electricity production by a new panel,

$$E_{Pynew} = \sum_{t=1}^{365} E_{Pdnew}\ (t) \quad \ldots\ldots 10$$

PV panel life time average of annual electricity production by a panel,

$$E_{Pyavg} = \frac{E_{Pynew} \sum_{t=0}^{N_{life}-1} \frac{(100 - Mg \times t)}{100}}{N_{life}} \quad \ldots\ldots 11$$

B. Area for PV plant

Annual target of electricity,

$$E_{reqyear} = 365 \times E_{reqday} \quad \ldots\ldots 12$$

Number of panels required,

$$N_{pv} = \frac{E_{reqyear}}{E_{Pyavg}} \quad \ldots\ldots 13$$

Watt-peak rating of PV plant,

$$Wpeak_{PV} = Wattpeak_{Panel} \times N_{PV} \quad \ldots\ldots 14$$

Solar radiation sensitive panel area,

$$Area_{Panel} = Length_{Panel} \times Width_{Panel} \quad \ldots\ldots 15$$

PV panel installation area in acre,

$Area_{PV} = \frac{N_{PV} \times Area_{Panel}}{f_{exploit}} \times \frac{1}{4046.8}$ 16

Total PV plant area,

$Area_{Plant} = Area_{PV} + Area_{grid}$ 17

VI. COST ESTIMATION FOR GRID TIE PV PLANT

A. Initial investment

Initial investment for purchasing PV panels,

$Invest_{purpv} = Price_{purpv} \times Wattpeak_{PV}$ 18

Wattage rating of both inverter and substation is 90% of Wattpeak rating of PV plant as solar irradiation does not reach 900 W/m^2 even in the sunny day peak for the site location (Dhaka, Bangladesh).

$Watt_{inv} = Watt_{substation} = 0.90 \times Wattpeak_{PV}$ 19

Initial investment for purchasing PV inverter,

$Invest_{inverter} = Price_{purinv} \times Watt_{inv}$ 20

Initial investment for construction of panel supports,

$Invest_{support} = Price_{supportpv} \times Area_{pv}$ 21

Initial investment for grid substation,

$Invest_{substation} = Price_{substation} \times Watt_{substation}$ 22

Initial investment for purchasing land,

$Invest_{land} = Price_{purland} \times Area_{plant}$ 23

Initial investment for land development,

$Invest_{landdev} = Price_{landdev} \times Area_{plant}$ 24

B. Present worth of salvage value

Present worth of salvage value is calculated as in [8] using following equations.

Present worth of salvage value of PV panels,

$PSV_{panel} = \%Salvage_{pv} \times Invest_{purpv} \times (\frac{1+\beta}{1+\gamma})^{N_{lifepv}}$ 25

Present worth of salvage value of PV inverter,

$PSV_{inverter} = \%Salvage_{inv} \times Invest_{purinv} \times \left(\frac{1+\beta}{1+\gamma}\right)^{N_{lifeinv}}$ ...26

Present worth of salvage value of panel supports,

$PSV_{support} = \%Salvage_{suppprt} \times Invest_{support} \times (\frac{1+\beta}{1+\gamma})^{N_{lifesupport}}$ ...27

Present worth of salvage value of grid substation,

$PSV_{substation} = \%Salvage_{support} \times Invest_{support} \times (\frac{1+\beta}{1+\gamma})^{N_{lifesubstation}}$ ...28

Present worth of salvage value of land,

$PSV_{land} = \%Salvage_{land} \times Invest_{land} \times (\frac{1+\beta}{1+\gamma})^{N_{lifeland}}$ ...29

C. Present worth of maintenance cost

Present worth of maintenance cost is calculated as in [8] using following equations.

Present worth of maintenance cost of PV panels,

$OM_{pv} = Price_{ompv} \times Wattpeak_{pv} \sum_{i=1}^{N_{lifepv}} (\frac{1+\psi}{1+\gamma})^{i}$ 30

Present worth of maintenance cost of PV inverter,

$OM_{inverter} = Price_{ominv} \times Watt_{inv} \sum_{i=1}^{N_{lifeinv}} \left(\frac{1+\psi}{1+\gamma}\right)^{i}$ ... 31

Present worth of maintenance cost of PV panels supports,

$OM_{support} = Price_{omsuppv} \times Area_{pv} \sum_{i=1}^{N_{lifesupport}} \left(\frac{1+\psi}{1+\gamma}\right)^{i}$ ... .32

Present worth of maintenance cost of grid substation,

$OM_{substation} = Price_{omsubs} \times Watt_{substation} \sum_{i=1}^{N_{lifesubstation}} \left(\frac{1+\psi}{1+\gamma}\right)^{i}$ 33

Present worth of maintenance cost of land development,

$OM_{landdev} = Price_{omland} \times Area_{plant} \cdot \sum_{i=1}^{N_{lifeland}} (\frac{1+\psi}{1+\gamma})^{i}$ ...34

Present worth of operating cost (Salary of staffs),

$OM_{salary} = (Salary_{techstaff} \times N_{techstaff} + Salary_{secustaff} \times N_{secustaff}) \times 14.2 \times \sum_{i=1}^{N_{lifeproject}} (\frac{1+\psi}{1+\gamma})^{i}$ 35

D. Total annual cost

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

Annual cost for solar panels,

$Cost_{panels} = \frac{Invest_{purpv} - PSV_{panel} + OM_{pv}}{N_{lifepv}}$ ...36

Annual cost for panel supports,

$Cost_{support} = \frac{Invest_{support} - PSV_{support} + OM_{support}}{N_{lifesupport}}$ ...37

Annual cost for PV inverter,

$Cost_{inverter} = \frac{Invest_{inverter} - PSV_{inverter} + OM_{inverter}}{N_{lifeinverter}}$ ... 38

Annual cost for grid substation,

$Cost_{substation} = \frac{Invest_{substation} - PSV_{substation} + OM_{substation}}{N_{lifesubstation}}$ .39

Annual cost for land,

$Cost_{land} = \frac{Invest_{land} + Invest_{landdev} - PSV_{land} + OM_{land}}{N_{lifeland}}$ ...40

Annual cost for salary of staff,

$Cost_{salary} = \frac{OM_{salary}}{N_{lifeproject}}$ 41

Total Annual cost,

$Cost_{year} = Cost_{panels} + Cost_{support} + Cost_{inverter} + Cost_{substation} + Cost_{land} + Cost_{salary}$ ...42

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

E. Per unit electricity (kWh) generation cost

Per unit electricity (kWh) generation cost in BDT,

$$kWh_{cost} = \frac{Cost_{year}}{E_{Pyavg}\ /1000} \quad .....43$$

VII. COST ESTIMATION FOR GRID TIE PV PLANT

Multiple criteria decision analysis (MCDA) refers to making decisions in the presence of multiple, usually conflicting, criteria. In general, there exist two distinctive types of MCDA problems due to different problem settings: one type having a finite number of alternative solutions and the other an infinite number of solutions [9]. Normally in problems associated with selection and assessment, the number of alternative solutions is limited. In problems related to design, an attribute may take any value in a range. Therefore the potential alternative solutions could be infinite. If this is the case, the problem is referred to as multiple objective optimization problems instead of multiple attribute decision problems. In this paper research focus will be on the problems with a finite number of alternatives. Among many other MCDA algorithms TOPSIS is a powerful MCDA algorithm and it is used in this research investigation for optimal selection of PV panel.

A. TOPSIS: MCDA TOOL

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multicriteria decision analysis tool, based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution (PIS) and the longest geometric distance from the negative ideal solution (NIS) [10]. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. TOPSIS is used for ranking the alternatives as follows. A performance matrix is formed which consists of m number of alternatives and n number of alternatives, with the intersection of each alternative and criterion given as X_{ij}.

$$(A_i)_{m\times 1} = (X_{ij})_{m\times n}$$

Where, $(A_i)_{m\times 1}$ = Matrix for alternatives $= \begin{bmatrix} A1 \\ A2 \\ \vdots \\ \vdots \\ Am \end{bmatrix}$

Performance matrix =

$$(X_{ij})_{m\times n} = \begin{bmatrix} X_{11} & X_{12} & \cdots & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & \cdots & X_{2n} \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ X_{m1} & X_{m2} & \cdots & \cdots & X_{mn} \end{bmatrix}$$

Where, i={$1, 2, \dots \dots \dots, m$} and j={$1, 2, \dots \dots \dots, n$}

$$\text{Alternatives, } A = \begin{bmatrix} A1 \\ A2 \\ \vdots \\ \vdots \\ Am \end{bmatrix} = \begin{bmatrix} X_{11} & X_{12} & \cdots & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & \cdots & X_{2n} \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ X_{m1} & X_{m2} & \cdots & \cdots & X_{mn} \end{bmatrix}$$

Step 1 : Normalization of performance matrix:

a) Determination of $\sqrt{\sum_{i=1}^{m} X_{ij}^2}$

b) Normalized performance matrix is given by:

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$$

Step 2 : Determination of the weighted normalized decision matrix:

a) Weight of criteria is given by $W_j = [\ W_1\ W_2\ \dots \dots\ W_n\ ]$

b) Weighted normalized decision matrix, $V_{ij} = W_j \times r_{ij}$

Step 3 : Determination of ideal solution and negative ideal solution

a) Set of criteria having benefit attributes (i.e.; larger value is better) $= J_+$

b) Set of criteria having negative attributes (i.e.; smaller value is better) $= J_-$

c) Ideal solution:

$V_j^* = \{ \langle max(V_{ij} | i = 1,2, \dots .m) | j \epsilon J_+ \rangle, \langle min(V_{ij} | i = 1,2, \dots .m) j \epsilon J - $

d) Negative ideal solution:

$V_j^{'} = \{ \langle min(V_{ij} | i = 1,2, \dots .m) | j \epsilon J_+ \rangle, \langle max(V_{ij} | i = 1,2, \dots .m) j \epsilon J - $

Step 4 : Determination of separation of a target alternative from ideal solution .

Separation of a target alternative from ideal solution is given by $S_i^* = \sqrt{\sum_{j=1}^{n} (V_j^* - V_{ij}\ )^2}$

Step 5 : Determination of separation of target alternative from negative ideal solution.

Separation of a target alternative from negative ideal solution is given by $S_i^{'} = \sqrt{\sum_{j=1}^{n} (V_j^{'} - V_{ij}\ )^2}$

Step 6: Determination of the relative closeness of alternatives (similarity of alternative) to the ideal solution

Relative closeness of alternatives to the ideal solution is given by $C_i^* = \frac{S_i^*}{(S_i^* + S_i^{'})}$

Step 7: Identification of the best alternative (TOPSIS optimal solution).

Matrix for degree of closeness, $C_i^* = \begin{bmatrix} C_1 \\ C_2 \\ \vdots \\ \vdots \\ C_m \end{bmatrix}$

IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 2, February 2017

Best alternative is one, for which $C_i^* = \max(C_i^*)$
index = index of $\max(C_i^*)$
Best alternative = A_{index} .

VIII. CASE STUDY

The proposed method of optimal selection of PV panel has been applied to real data. Dhaka, Bangladesh is selected as PV plant location. Location data are collected from [11] using online software and data are listed in Table-I (Appendix). Solar data [12] of that location are listed in Table-II (Appendix). 15 no. of PV panels are selected and market price is collected from [13] on date 30th November 2016 and 15 no. of alternatives are generated for these PV panels. Alternatives and panel data are listed in Table-III (Appendix). Design specified data are listed in Table-1.

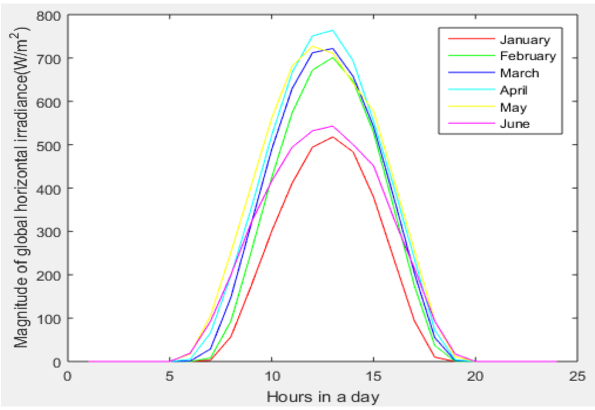

Fig. 2 Diurnal variation of global horizontal irradiance for January to June in the location of Dhaka, Bangladesh.

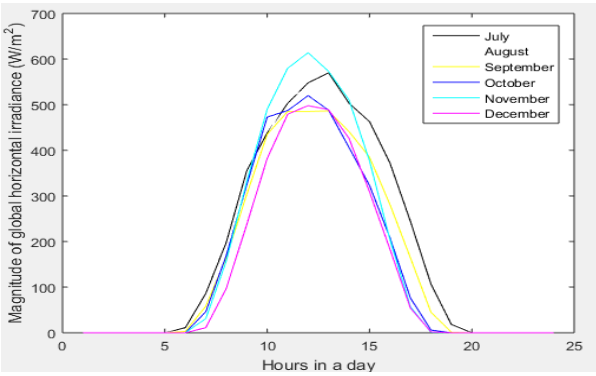

Fig. 3 Diurnal variation of global horizontal irradiance for July to December in the location of Dhaka, Bangladesh.

Using data which is listed in "Appendix" per unit electricity generation cost and required area of land are calculated for the PV electricity generation system as mentioned in diagram Fig.4.

Cost estimation data are listed in Table-2. Matlab@version2015a software is used for calculation in this case study. In this study, it is assumed that per unit prices of all items except PV panel for different alternatives are same.

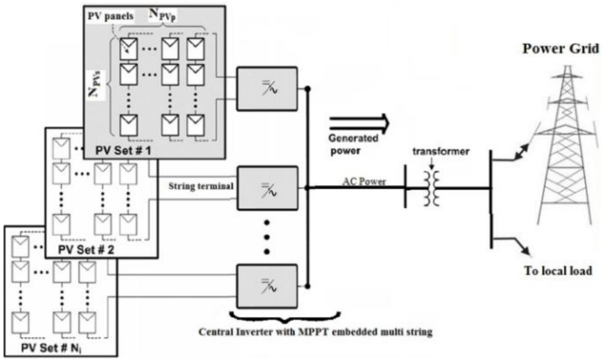

Fig.4 Battery less grid tie PV electricity generation system.

TABLE -1 DESIGN SPECIFIED DATA

Daily electricity production target, E_{reqday}	10×10^5 Wh
Grid substation area, $Area_{grid}$	1 acre
Area exploitation factor, $f_{exploit}$	0.56
Solar panel tilt angle, β_{tilt}	23.5° (equal to latitude) [14].
Solar panel azimuth angle, A_{zpanel}	0°

TABLE -2 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
$Price_{purinv}$	BDT 5/Watt
$Price_{supportpv}$	BDT 3000/m^2
$Price_{substation}$	BDT 15/Watt
$Price_{purland}$	BDT 300 lac/acre
$Price_{landdev}$	BDT:0.4 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
$N_{techstaff}$	9 men
$N_{secus\ taff}$	9 men
$Salary_{techstaff}$	BDT 30000/man
$Salary_{secustaff}$	BDT 20000/man
$Price_{ompv}$	BDT 5/ Watt
$Price_{omsupport}$	BDT 150/m^2
$Price_{ominv}$	BDT 1/Watt
$Price_{omsubstation}$	BDT 2/Watt
$Price_{omland}$	BDT 0.5lac /acre

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

Applying equations (1) to (8) monthly average daily production of electricity by each panel are calculated for every month and then annual average energy production are calculated considering degradation of panel efficiency over life span by using equations (9) to (11). Applying equations (12) to (16) required PV plant area for generation of target PV electricity are calculated for each alternative. Using equations (17) to (43) per kWh electricity generation cost are calculated for each alternative. Performance values of criteria (Area of PV plant and per kWh cost) are obtained for every alternative. Performance values of criteria for all alternatives are listed in Table-3.

TABLE-3 PERFORMANCE VALUES OF CRITERIA

Alternatives	Model of Solar Panels	Required area (in acres) (Criterion-1)	Per kWh electricity cost (in BDT) (Criterion-2)
1	Astronergy VIOLIN CHSM6610P-260 Silver Poly Solar Panel	8.6732	15.2940
2	Astronergy ASM6612P-315 Silver Poly Solar Panel	8.5896	15.3608
3	SolarWorld SW285 Plus Black Mono Solar Panel	7.8154	14.4884
4	SolarWorld SW320 XL Silver Mono Solar Panel	8.3034	14.7438
5	Suniva OPT280-60-4-100 Silver Mono Solar Panel	8.5082	15.7380
6	Suniva OPT285-60-4-100 Silver Mono Solar Panel	8.1636	15.2945
7	Topoint JTM190-72M Silver Mono Solar Panel	9.3624	15.8155
8	Panasonic 325 watt Module 96 Cell HIT - Black Solar Panel	7.1501	14.6727
9	Hyundai HiS-M260RG Black Frame, White Backsheet Poly Solar Panel	8.7669	15.4547
10	LG 320 NeON, Mono, Black Frame - LG320N1C-G4 Solar Panel	7.2045	14.8358
11	LG 315N1C Black Mono Solar Panel	7.3022	14.8452
12	LG 310N1C Black Mono Solar Panel	7.3786	14.7873
13	LG 300N1K Black on Black Mono Solar Panel	7.6490	14.9964
14	Solarland SLP160S-12 Silver Mono Solar Panel	8.8952	16.2725
15	Solarland SLP150-12 Silver Poly Solar Panel	9.4369	16.6277

IX. RESULT

Performance values of two criteria which are required land area and per kWh electricity generation cost are listed for each alternative and a performance matrix is formed. Row of this matrix is the performance value for a particular alternative. Weighting of criteria is adopted to give preference of the criteria. The TOPSIS which is a MCDA algorithm is applied for ranking the alternatives. Best alternative has higher degree of closeness to the ideal solution and corresponding to the best alternative is the optimal PV panel. Result for ranking of alternatives considering equal weight of both criteria is shown in Fig. 5. Result for different weighing of criteria is given in appendix.

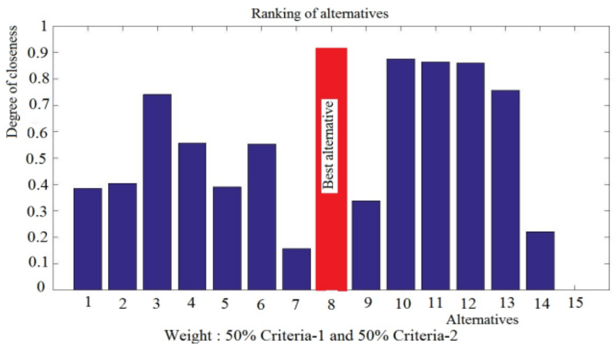

Fig. 5 Ranking of alternatives for 50% preference of criterion-1, and 50% preference of criterion-2.

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

TABLE-4 RESULT FOR BEST ALTERNATIVE

Best alternative	Model of Solar Panels	Required area (in acres) Criterion-1)	Per kWh electricity cost (in BDT) (Criterion-2)
8	Panasonic 325 watt Module 96 Cell HIT - Black Solar Panel	7.1501	14.6727

X. CONCLUSION

Optimal selection of PV panel for grid tie PV power plant can be achieved by performing the proposed approach. In a highly dense country, land availability is a crisis and hence land usage should be reduced. Per unit electricity generation cost should be minimized for saving of revenue.

To install a large scale PV plant, these two major concerns should be taken into account. This proposed method is capable to reduce both land usage and electricity generation cost for a PV plant. This method gives decision makers and designer flexibility to insert new criteria and also allows inserting special weighing preference for specified criteria. The proposed method can be considered a viable guidance in the design process or policy making process.

REFERENCES

[1] The Organization for Economic Co-operation and Development, “OECD Factbook 2015-2016,’’ Economic, Environmental and Social Statistics 2015-16. [Online]. Available:http://www.oecd.org/publications/oecd-factbook-18147364.htm
[2] Wohlgemuth,John H., “Standards for PV Modules and Components – Recent Developments and Challenges,” 27th European Photovoltaic Solar Energy Conference and Exhibition, Frankfurt, Germany, September 24–28, 2012.
[3] M. Gulin, M. Vaˇsak, and N. Peri´c, “Dynamical optimal positioning of a photovoltaic panel in all weather conditions,” Applied Energy, vol. 108, no. 0, pp. 429–438, August 2013.
[4] Gulin, Marko, Mario Vašak, and Mato Baotic. "Estimation of the global solar irradiance on tilted surfaces." 17th International Conference on Electrical Drives and Power Electronics (EDPE 2013). 2013.
[5] V. Badescu, “3D isotropic approximation for solar diffuse irradiance ontilted surfaces,” Renewable Energy, vol. 26, no. 2, pp. 221–233, June 2002.
[6] H.R. Ghosh, N.C. Bhowmik and M. Hussain, “Determining seasonal optimum tilt angles, solar radiations on variously oriented, single and double axis tracking surfaces at Dhaka, Renewable Energy, Volume 35, Issue 6, June 2010, Pages 1292-1297
[7] Alsayed, M., Cacciato, M., Scarcella, G. and Scelba, G., “Multicriteria Optimal Sizing of Photovoltaic-Wind Turbine Grid Connected Systems ,’’ IEEE Transactions on Energy Conversion ,Vol.28 , Issue. 2 , pp. 370-379,2013.
[8] Wang, Lingfeng and Singh, Chanan, “Multicriteria Design of Hybrid Power Generation Systems Based on a Modified Particle Swarm Optimization Algorithm,’’ IEEE Transactions on Energy Conversion, Vol.24, Issue 1, pp. 163 – 172, 2009.
[9] Dr. Ling Xu and Dr. Jian-Bo Yang, “Introduction to Multi-Criteria Decision Making and the Evidential Reasoning Approach’’ Manchester School of Management, University of Manchester Institute of Science and Technology, Working Paper No. 0106,May 2001
[10] Assari, A., Mahesh, T., and Assari, E., “Role of public participation in sustainability of historical city: usage of TOPSIS method,’’Indian Journal of Science and Technology, Vol.5, Issue. 3, pp. 2289-2294, 2012.
[11] http://www.sunearthtools.com/dp/tools/pos_sun.php?lang=en
[12] Prof. (retd) Muhtasham Hussain, Md. Shafiuzzaman Khan Khadem and Himangshu Ranjan Ghosh, “Country Report of Solar and Wind Energy Resource Assessment (SWERA) – Bangladesh,’’ Supported by, United Nations Environment Programme (UNEP) and Global Environment Facility (GEF),2007.
[13] http://www.wholesalesolar.com/
[14] Md. Saifur Rahman et al., “Solar Energy and Solar Electricity,’’ Solar Home System, first edition, Dhaka, Bangladesh: Department of Electrical and Electronic Engineering, BUET, 2013, ch. 1, sec. 1.14, pp. 45-46.

BIOGRAPHIES

Md. Abubokar Talukdar 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 perusing M.Sc in Electrical and Electronic Engineering in Bangladesh University of Engineering and Technology. He worked as a lecturer in Electrical, Electronics and Telecommunication Engineering at Dhaka International University, Bangladesh from 2011 to 2013. He is currently working as an electrical engineer in Bangladesh Power Development Board, Dhaka.

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.

Pejush Chandra Sarker is currently working as a lecturer in Electrical and Electronic Engineering in Rajshahi University of Engineering and Technology, Bangladesh. His research interests are Electrical Machines, Control System, Power System and Renewable Energy. He is an author of several international journal papers. He was awarded with “Prime Minister Gold Medal-2010” by the government of Bangladesh for his academic excellence.

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

APPENDIX

TABLE I LOCATION DATA

Name of location: Dhaka, Bangladesh; Latitude, ø = 23.81° N, Longitude, long = 90.41° E, GMT = +6, Ground albedo, ρ =0.2												
Hours in a day	Sun Azimuth angle, A_{zsun} / Sun Altitude angle, Θ_A in degree for middle day 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	80.91/-77.59	49.10/-74.66	32.37/-64.86	25.87/-53.21	21.86/-44.45	18.60/-40.6	17.72/-42.69	21.68/-49.66	33.25/-58.69	52.99/-66.29	77.15/-71.28	91.31/-74.73
2:00	90.08/-63.92	72.40/-62.54	55.66/-55.18	44.98/-45.16	38.32/-37.51	34.18/-34.45	34.10/-36.66	40.10/-42.56	53.19/-49.21	70.52/-54.14	87.19/-57.68	95.41/-61.04
3:00	95.17/-50.22	82.82/-49.12	69.12/-42.97	58.19/34.36	50.70/-27.85	46.34/-25.55	46.80/-27.73	53.45/-32.53	65.88/-37.36	80.40/-40.86	93.23/-43.97	99.09/-47.43
4:00	99.57/-36.61	89.71/-35.43	78.06/29.8	67.63/-22.13	59.98/-16.54	55.61/-14.87	56.41/-16.96	63.19/-20.85	74.77/-24.44	87.49/-27.22	98.28/-30.33	102.91/-33.9
5:00	104.0/-23.18	95.44/-21.72	84.99/-16.22	74.94/-9.12	67.18/-4.24	62.81/-3.07	63.83/-5.05	70.69/-8.22	81.76/-11.01	93.54/-13.51	103.25/-16.9	107.15/-20.7
6:00	108.9/-10.02	100.98/-8.14	91.14/-2.45	81.13/4.31	73.07/8.67	68.58/9.44	69.8/-7.56	76.9/4.95	87.95/2.65	99.46/0.12	108.66/-3.67	112.06/-7.80
7:00	114.69/2.72	106.97/5.18	97.29/11.19	86.92/17.96	78.21/21.97	73.38/22.41	74.84/20.64	82.48/18.45	94.1/16.36	105.92/13.5	114.99/9.07	117.98/4.64
8:00	121.8/14.82	114.03/18.05	104.19/24.68	92.99/31.69	83.05/35.51	77.54/35.69	79.34/34.01	88.04/32.12	100.97/29.95	113.72/26.41	122.88/21.08	125.4/16.32
9:00	130.9/25.90	123.05/30.12	112.91/37.7	100.32/45.32	88.16/49.19	81.31/49.18	83.68/47.57	94.38/45.83	109.79/43.18	124.04/38.43	133.21/31.9	135.01/26.82
10:00	142.9/35.31	135.33/40.80	125.4/49.73	111.17/58.55	94.75/62.90	84.94/62.80	88.46/61.26	103.25/59.38	123.04/55.5	138.84/48.76	147.08/40.73	147.59/35.43
11:00	158.6/42.06	152.51/48.95	145.31/59.48	132.47/70.34	108.2/76.38	89.09/76.5	95.84/74.96	120.9/72.16	146.30/65.38	160.35/55.77	165.95/46.32	163.58/41.44
12:00	177.5/44.94	174.93/52.87	175.84/64.18	181.67/76.12	194.47/85.02	207.11/89.46	156.57/87.43	176.01/80.07	184.52/68.97	187.27/57.27	185.95/47.39	182.0/42.88
13:00	196.9/43.21	198.64/51.23	208.3/61.24	229.28/69.80	255.50/74.08	271.11/76.0	262.26/76.96	233.24/73.24	219.94/63.57	211.92/52.57	205.56/43.61	200.09/40.22
14:00	213.5/37.32	218.20/44.65	230.72/52.41	249.69/57.88	266.71/60.51	275.20/62.31	270.67/63.26	255.54/66.62	240.32/52.93	229.63/43.53	221.23/36	215.37/24.7
15:00	226.5/28.48	232.37/34.86	244.63/40.78	260.25/44.63	272.88/46.8	278.84/48.69	275.61/49.57	264.83/47.09	252.26/40.33	241.74/32.15	232.94/25.91	227.25/24.70
16:00	236.2/17.75	242.59/23.28	254.06/27.94	267.49/30.99	277.89/33.14	282.62/35.2	279.96/35.97	271.29/33.38	260.49/26.98	250.52/19.59	241.74/14.34	236.32/14.90
17:00	243.8/5.86	250.37/10.70	261.30/14.94	273.54/17.28	282.76/19.65	286.80/21.94	284.34/22.56	276.87/19.69	267.11/13.33	257.46/6.39	248.64/1.88	243.37/2.03
18:00	249.8/-6.75	256.75/-2.45	267.58/0.89	279.35/3.65	288.06/6.42	291.63/8.98	289.34/9.43	282.42/6.15	273.18/-0.39	263.52/-7.15	254.36/-11.1	249.04/-10.5
19:00	254.9/-19.82	262.44/-15.9	273.7/-12.82	285.61/-9.74	294.10/-6.38	297.44/-3.5	295.13/-3.28	288.52/-7.08	279.44/-14.0	269.38/-20.9	259.43/24.51	253.77/-23.5
20:00	259.5/-19.82	268.06/-29.6	280.41/-26.4	293.04/-22.7	301.61/-18.5	304.7/-15.26	302.3/-15.33	295.84/-19.8	286.69/-27.4	275.77/-34.6	264.32/-38.1	257.89/-36.8
21:00	263.9/-46.76	274.38/-43.3	288.77/-39.7	302.67/-34.8	311.36/-29.6	314.07/-25.9	311.52/-26.3	305.29/-31.6	296.13/-40.2	283.91/-48.1	269.66/-51.8	261.64/-50.3
22:00	268.8/-60.45	282.97/-56.9	300.86/-52.2	316.16/-45.5	324.4/-38.80	326.3/-34.70	323.72/-35.6	318.23/-41.9	309.99/-51.8	296.7/-60.99	277.05/-65.5	265.3/-63.96
23:00	276.4/-74.15	298.88/-69.7	231.14/-62.6	335.57/-53.2	341.54/-45.1	342.03/-40.7	339.6/-42.18	336.19/-49.4	332.08/-60.5	323.04/-71.7	294.87/-78.8	269.6/-77.66
0:00	325.5/-86.98	343.55/-79.4	355.01/68.26	0.67/-56.43	1.84/47.31	0.37/-42.88	358.58/-44.7	358.84/-52.1	3.48/-63.11	14.5/-74.24	37.51/-83.34	70.53/-88.38

TABLE II SOLAR GHI AND DHI DATA

Monthly average hourly solar GHI (W/m^2) data												
Hours in a day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0

DOI 10.17148/IJIREEICE.2017.5214

2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	5	17	19	11	7	3	0	0	0
7	3	8	29	66	106	93	86	66	58	46	31	11
8	57	93	148	198	252	200	198	180	165	169	157	97
9	175	254	318	354	406	321	355	288	303	324	331	237
10	300	424	489	521	561	416	438	433	435	473	490	382
11	411	573	629	666	681	494	503	514	485	487	580	479
12	494	672	712	751	727	532	548	537	485	520	614	498
13	518	701	722	764	711	543	570	535	486	488	573	489
14	483	646	657	693	641	500	503	482	441	406	510	426
15	379	528	541	553	577	451	463	453	385	323	377	309
16	236	353	377	402	419	329	372	356	281	208	204	183
17	94	175	204	237	257	215	244	231	164	76	57	54
18	10	37	55	72	93	93	107	89	45	6	1	2
19	0	0	2	4	11	17	18	8	1	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Monthly average hourly solar DIF (W/m^2) data

Hours in a day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	5	16	18	11	6	3	0	0	0
7	3	7	27	58	90	80	70	58	55	37	23	10
8	47	70	109	147	183	156	145	140	137	108	87	59
9	117	146	189	238	253	228	226	217	229	172	137	109
10	172	205	244	308	322	281	287	292	279	238	176	145
11	220	250	281	350	356	325	318	343	327	248	205	171
12	250	274	297	372	381	339	349	350	333	263	223	194
13	257	264	306	367	375	348	356	342	304	268	217	208
14	240	254	276	339	345	317	295	319	269	219	206	193
15	199	221	245	284	303	282	250	270	259	173	167	156
16	139	170	191	217	238	215	211	224	187	122	110	105
17	69	104	127	151	164	152	149	157	115	55	43	40
18	9	30	46	60	77	75	82	68	38	5	1	2
19	0	0	1	4	12	15	16	7	1	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

12:00 represents the period between 11:00 to 12:00.

IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 2, February 2017

TABLE III ALTERNATIVES AND PV PANEL DATA

Alternatives	Model of Solar Panel	Brand Name of Panel	Watt-peak rating, Wp (in W)	Life Time, $N_{Lifepanel}$ (in Year)	Efficiency at new condition, $\eta_{Panelnew}$ (in %)	Gradient of linearly de-rated efficiency, m_{panel}	Dimension (Length ×Width) in sq. meter	Open Circuit Voltage under STC, Voc.stc (in V)	Short Circuit Current Under STC, Isc.stc (in A)	Temperature coefficient of Voc (in V/ °C)	Temperature Coefficient of Isc ((in A/ °C)	Fill Factor, FF	Nominal Operating Cell Temperature, NOCT(in °C)	Weight of Panel (in Kg)	Price per Watt in BDT, $Price_{purpv}$ (1 USD= BDT 80)
1	Astronergy VIOLIN CHSM6610 P-260 Silver Poly Solar Panel	Astronergy Solar, Germany	260	25	15.94	-0.7	1.648×0.990	38.53	8.72	-0.1194	+0.00427	0.774	45	18.4	69.6
2	Astronergy ASM6612P -315 Silver Poly Solar Panel	Astronergy Solar, Germany	315	25	16.20	-0.7	1.956×0.994	45.55	9.02	-0.14166	+0.00451	0.766	48	23.5	71.2
3	SolarWorld SW285 Plus Black Mono Solar Panel	Solar World, Germany	285	25	17.0	-0.7	1.675×1.001	39.7	9.84	-0.0305	+0.00433	0.729	48	18.0	85.6
4	SolarWorld SW320 XL Silver Mono Solar Panel	Solar World, Germany	320	25	16.04	-0.7	1.993×1.001	45.9	9.81	-0.1395	+0.00412	0.741	46	21.6	75.20
5	Suniva OPT280-60-4-100 Silver Mono Solar Panel	Suniva, America	280	25	17.04	-0.7	1.660×0.990	38.8	9.57	-0.129	+0.00497	0.754	46	17.9	84.0
6	Suniva OPT285-60-4-100 Silver Mono Solar Panel	Suniva, America	285	25	17.34	-0.7	1.660×0.990	38.9	9.71	-0.129	+0.00497	0.754	46	17.9	84.0
7	Topoint JTM190-72M Silver Mono Solar Panel	Topoint, China	190	25	14.9	0.7	1.580×.808	43.8	5.83	-0.139	+0.0019	0.744	49	15.5	67.20
8	Panasonic 325 watt Module 96 Cell HIT - Black Solar Panel	Panasonic, Japan	325	25	19.4	-1	1.590×1.053	69.6	6.03	-0.174	+0.00182	0.774	49.2	18.5	112

IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified

Vol. 5, Issue 2, February 2017

9	Hyundai HiS-M260RG Black Frame, White Backsheet Poly Solar Panel	Hyundai, South Korea	260	25	15.94	-0.8	1.64×0.998	37.7	8.9	-0.121	+0.00427	0.774	48	17.2	80
10	LG 320 NeON, Mono, Black Frame - LG320N1C-G4 Solar Panel	LG, Korea	320	25	19.50	-0.7	1.64×1.0	40.9	10.05	-0.114	+0.00301	0.778	49	17.5	115
11	LG 315N1C Black Mono Solar Panel	LG, Korea	315	25	19.20	-0.65	1.64×1.00	40.60	10.02	-0.1136	+0.0030	0.775	49	17.0	112.5
12	LG 310N1C Black Mono Solar Panel	LG, Korea	310	25	18.90	-0.70	1.64×1.00	40.40	9.96	-0.1134	+0.00298	0.770	49	17.0	105.03
13	LG 300N1K Black on Black Mono Solar Panel	LG, Korea	300	25	18.29	-0.70	1.64×1.00	39.70	9.70	-0.1111	+0.00291	0.779	49	17.0	106.40
14	Solarland SLP160S-12 Silver Mono Solar Panel	Solarland, China	160	25	15.8	-0.70	1.50×0.675	21.9	9.60	-0.08	+0.00624	0.760	49	12.0	162.4
15	Solarland SLP150-12 Silver Poly Solar Panel	Solarland, China	150	25	14.8	-0.70	1.50×0.675	22.2	8.68	-0.08	+0.00564	0.778	49	12.1	173.38

MCDA OPTIMIZATION FOR DIFFERENT WEIGHING OF CRITERIA

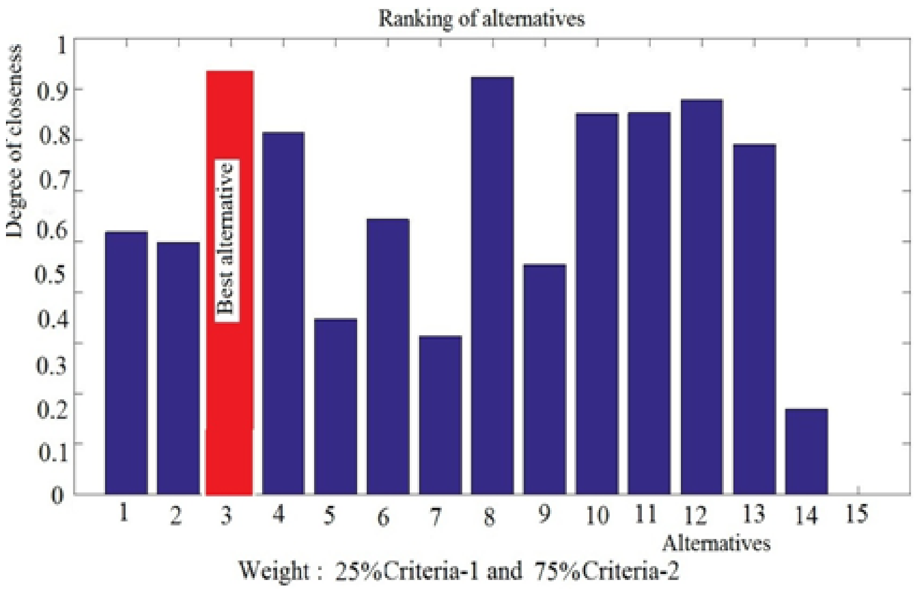

Fig.I Ranking of alternative for 25% preference of criteria-1, and 75% preference of criteria-2

IJIREEICE
ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
International Journal of Innovative Research in
Electrical, Electronics, Instrumentation and Control Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 2, February 2017

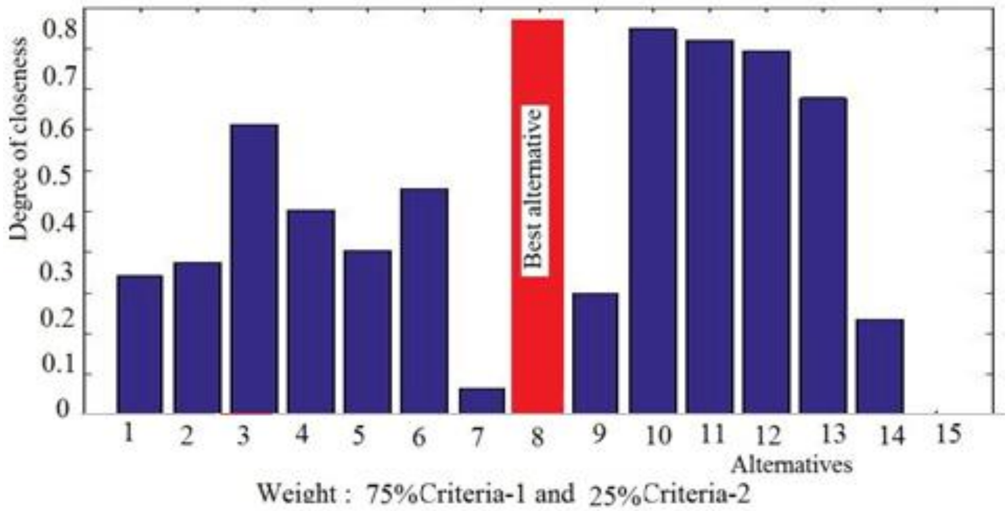

Fig.II Ranking of alternative for 75% preference of criteria-1, and 25% preference of criteria-2

TABLE IV MCDA OPTIMIZED RESULT FOR DIFFERENT WEIGHING OF CRITERIA

Weighting of Criteria-1	Weighting of Criteria-1	Best Alternative	Optimal Selection of Panel	Requirement of area	Per kWh Cost
25%	75%	3	SolarWorld SW285 Plus Black Mono Solar Panel	7.81 acres	BDT 14.88
75%	25%	8	Panasonic 325 watt Module 96 Cell HIT - Black Solar Panel	7.15 acres	BDT 15.32