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Research Article

An allusive realization on the performance analysis of glass to glass, glass to tedlar and aluminum base flexible photovoltaic (PV) module

Vivek CHOPRA[1], Rajeev Kumar MISHRA[2,*], Vijay Kumar DWIVEDI[3], Baibaswata MOHAPATRA[4]

[1]*Department of Kellogg School of Management, Northwestern University, Illinois, 60208, USA*
[2]*Galgotias College of Engineering and Technology, Hi-Tech Institute of Engineering and Technology, Indian Institute of Technology Delhi, 201310, India*
[3]*Department of Mechanical Engineering, Institute of Engineering & Technology, GLA University, Mathura, 281406, India*
[4]*Department of Electrical, Electronics and Communication Engineering, Galgotias University, Uttar Pradesh, 201310, India*

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ABSTRACT

The photovoltaic effect plays a significant role in power generation by using solar PV modules. The two most popular types of PV panels majorly available in the market: Glass-to-Tedlar (G-T) and Glass-to-Glass (G-G) type. Both G-T and G-G type of modules are rigid in structure due to the involvement of transparent glass cover on the top of the module. In order to have non rigid or flexible type of module, a module structure with aluminum as base and transparent plastic sheet at the top has been taken which is known as flexible type of PV module (F-Al). The use of plastic and aluminum makes these modules more flexible and lighter in weight as compared with G-T and G-G type of PV modules. The advantage of using F-Al PV module is that it can easily be modified into desired shapes. Initially, the mathematical modeling of F-Al PV module has been developed on Simulink. The different set of data for these three types of modules has been taken for analyzing the performance of these modules. The performance analysis of G-T type, G-G type and F-Al type of PV modules have been compared in terms of efficiency, cell temperature, daily energy production. The maximum electrical efficiency has been observed with G-G PV module. It is also observed that being with flexible nature, efficiencies of F-Al PV modules are almost comparable with G-T modules. The cell temperature of F-Al PV module and G-T PV module is found to be larger than G-G module. The daily electrical energy production was found to be more with G-G module in comparison to G-T and F-Al PV modules for a typical day in the month of April, 2019. It is also observed that due to flexible nature of F-Al module, efficiency is also converging faster towards regression line in comparison to G-G and G-T module. Further, efficiency and daily energy consumption of all three modules of PV panel are realized through artificial neural network (ANN). It is observed that least mean square error (MSE) is obtained with F-Al in comparison to G-G and G-T under the implication of ANN. Therefore, additional feature of least MSE for F-Al makes its preferable over others.

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*Corresponding author.
*E-mail address: bhu.rajeev@gmail.com

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INTRODUCTION

Energy demand in present scenario is pretty much high as compared to last five years that effects directly on the fossil fuels, which rapidly decreasing the sources of non-renewable energy. The use of renewable energy sources not only shared the burden of energy demand but also decelerate global warming and reduces the pollution, smog etc. Photovoltaic (PV) solar energy is the key role in renewable energy sources. In last five years solar energy generation is raised to three to four times. In 2013 generation of solar energy was 139.03TWh /year where as in 2018 it was 584.63TWh/year [7]. This technology emerged as a major source of generation of electrical energy. This energy is not only limited to urban areas only but has a wide scope in rural areas too. Wide range of application in various areas like agriculture, households' appliances, transport system and different sectors of industries. BIPVT (Building integrated photovoltaic thermal) technology has innumerable of household and industrial applications [1, 2]. This hybrid technology not only produces electricity but also participate in transferring of thermal energy. PV modules are used in different areas yet it has many anomalies too, like it's efficiency, price, processing is cumbersome etc. [24, 25] To minimize these anomalies, it's necessary to analyze the performance of different type of PV modules. Whillier [3] describe the performance on solar house heating and collection of solar energy using flat plate collector was also analyzed on their performance and economical basis by.Stultz, J. W. and Wen, L. C. [4] presented the electrical deterioration of modules because of the combined effect of thermal and PV system. Author also evaluated and demonstrated on the basis of nominal operating cell temperature (NOCT). E. C. Kern, Jr., and M. C. Russell [5, 26] proposed the hybrid systems which are incorporated with thermal system. Authors evaluated in terms of energy savings and their cost and system performance was calculated for both house hold and office buildings. Evans [6, 27] has developed to a simplified procedure for predicting PV array output with a smaller number of input information. Author adopted this procedure to discuss mean monthly array efficiency. Nameplate rating of PV systems was discussed by K. Firor et al. [8], and the author also mentioned the significance of capacity factor in PV plants. H. P. Garg et al. [9] engineered a device called thermosyphon, in which the hybrid solar water heater's thermal and electrical efficiencies are 33.5 and 3.35 percent, respectively. This author adhered solar cells to the absorber plate directly. K. Sopian et al. 10] discussed the analysis of single-pass and double – pass air flow hybrid PV systems. In this author determined experimentally coefficient of heat transfer of tank, overall heat loss of the collector. Author also validated experimental readings with the theoretical model equations. Lee et al. [11, 28] discussed the modelling and thermal analysis of PVT system incorporated with the building and the outcomes of hybrid PVT are magnificent. Tiwari, A., and Sodha [12] If the PVT system is properly used, the thermal efficiency can be increased. The efficiency of a PV/T air collector was evaluated by Sarhaddi et al. [16, 30]. For a set of climatic operating and design parameters, the thermal efficiency is found to be 17.18%, electrical efficiency is found to be 45% for PV/T air collector respectively. Tyagi et al. [19, 29] shed light on comprehensive research work aimed at improving the solar cells performance of commercial use. The efficiency of monocrystalline silicon solar cells has been enhanced from 15% in the 1950s to 28% today, according to the author. In this paper apart from growth in PV technologies other aspects like material for solar cells, efficiency of module, factor effecting the PV module performance, overall PV module cost analysis are discussed. Kapsis, K. & Athien it is, A. K. [20]proposed the minimum annual final electricity consumption (as small as 5 kW h/m^2/yr) was accomplished by creating a semi-transparent photovoltaic module with 10% clear active transmittance.Tiwari et al. [21] proposed and implemented the design of PVT green housedryers. Hussain, Alaa, A.F et al. [22] reviewed paper which states From 2007 onwards, all new transparent photovoltaic technologies with at least a 20% average transmission rate have been registered. The authors also illustrated each technology's process (including materials and methods) and addressed its benefits and drawbacks in terms of efficiency, aesthetics, and cost.In this paper a PV module which is flexible aluminum (F-Al) having the base aluminum and top is plastic one, which enables this module a flexible one and light weighted as compared to conventional G-G and G-T type of PV module. It starts with mathematical modeling of solar PV module of all three types. Thereafter electrical parameters like efficiency, cell temperature,daily energy production of different modules are analyzed and compared.In terms of maximum electrical efficiency all the three modules, G-G is having higher electrical efficiency while F-Al and G-T module has comparable efficiency.However, F-Al PV module is more advantageous than other two modules due to flexible nature.So,it can easily be modified into desired shapes. The other result like daily produced electrical energy was found to be 408.727Wh, 392.27Wh & 392.19Wh for G-G, G-T and F-Al PV modules for a typical day in the month of April, 2019 which shows that G-G produces maximum electrical energy in comparison with G-T and F-Al PV modules. The F-Al module is also converging faster towards regression line due to its flexible nature.Thereafter efficiency and daily energy consumption of three modules is realized by using ANN. It is observed that MSE value is least for F-Al in comparison to G-G, G-T module for estimation of efficiency and daily energy consumption.Therefore, solar F-Al module is preferred. This paper consists of different sections. Sections II consist of Methodology, Section III consist of mathematical modeling, Section IV consist of performance characteristics of solar PV modules, Section V consist of linear regression analysis,Section VI consist of performance analysis of efficiency and daily energy consumption using

ANN, Section VII consist of Conclusion,Section VIII consist of acknowledgement, Section IX consists of references.

SYSTEM DESCRIPTION

The general structure of the rigid type of solar PV module is shown with Figure.1. Basically, these types of structures are being represented by G-G and G-T type of modules.

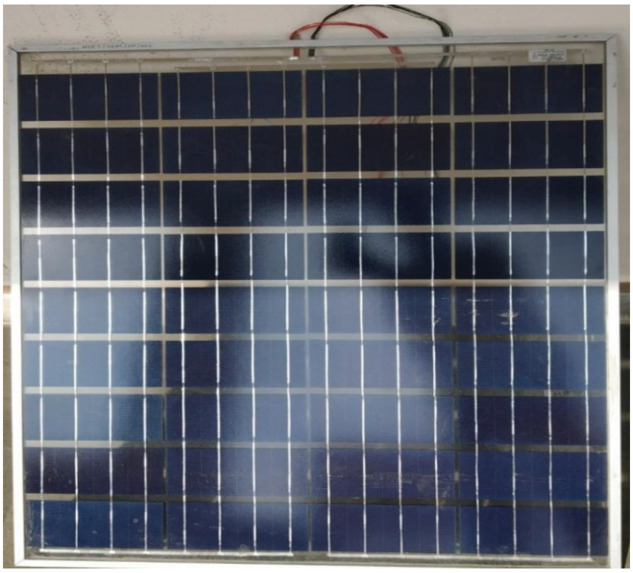

Figure 1. Rigid structure of PV module.

The flexible nature of solar PV module is being represented by F-Al module which is shown in Figure 2. Such flexible nature is adjusted in nature and can be arranged to different shapes at different angles.

Figure 2. Flexible structure of PV module.

The logic behind to select the F-Al PV module is already clear. But it is good to realize in terms of electrical parameters like efficiency, temperature, daily energy production. For attain this mathematical modeling of such system is design which is discussed in next section.

MATHEMATICAL MODELING

PV cell energy balance equations are used to estimate the temperature and electrical efficiency of the module's cells. The assumptions for the energy balance equation have been mentioned in order to accomplish this:

- For the purposes of this analysis, one-dimensional heat conduction will be used as an approximation.
- At a constant temperature, the glass cover should be considered.
- The encapsulate ethylene vinyl acetate (EVA) is completely transparent.
- The system is assumed to be in pseudo-steady state.
- For PV module,ohmic losses are assumed to be negligible.

The modeling of three types of solar PV module is discussed as

MODELING OF FLEXIBLE ALUMINIUM(F-AL) BASE SOLAR MODULE

The energy balance equation for Flexible aluminum base PV modules [14, 17]can be written as shown in Eq.(1)

$$\alpha_c\beta_c\tau_p I(t)bdx + \alpha_{al}\tau_p(1-\beta_c)I(t)bdx = U_{tca}(T_c - T_a)bdx + U_b(T_c - T_a)bdx + (\eta_m)I(t)bdx \quad (1)$$

Eq.1 shows that the amount of thermal energy loss per hour from solar cells to the surrounding via the top panel side and thermal energy loss per hour from solar cells to surrounding via lower panel surface along with electrical energy lossper hour from solar cells is equal to absorbed solar radiation received per hour by solar cells and also absorbed solar radiation received per hour by aluminum.

Now U_{tca} and U_b are explained as

$$U_{tca} = \left[\frac{L_p}{K_p} + \frac{1}{h_o}\right]^{-1},$$

$$U_b = \left[\frac{L_{al}}{K_{al}} + \frac{1}{h_i}\right]^{-1}$$

From Eq.1, the temperature of cell is given below as:

$$T_c = \frac{T_a(U_b + U_{tca}) + I(t)\alpha_c\beta_c\tau_p - I(t)\eta_m + \alpha_{al}\tau_p(1-\beta_c)I(t)}{U_b + U_{tca}} \quad (2)$$

Now the electrical efficiency of the F-Al module is given below as:

$$\eta_c = \eta_o[1 - \beta_{ref}(T_c - T_{ref})] \quad (3)$$

Put the value of Eq.(2) in Eq.(3) and Eq.(4) is obtained as

$$\eta_c = \eta_o[1 - \beta_{ref}(T_a + (I(t)\alpha_c\beta_c\tau_p)/(U_b + U_{tca}) - (I(t)\eta_m)/(U_b + U_{tca}) + (\alpha_{al}\tau_p(1-\beta_c)I(t))/(U_b + U_{tca}) - T_{ref})] \quad (4)$$

The electrical energy of PV modules on hourly basis [13, 15] can be given in Eq.(5)

$$E_{hourly} = \eta_c A_m I(t) \quad (5)$$

The daily electrical energy in KWh is calculated by

$$E_{daily} = \sum_{i=1}^{N}(E_{hourly,i}/1000) \quad (6)$$

where N is the number of solar sunshine hours in a day.

MODELING OF GLASS TO GLASS(G-G) SOLAR MODULE

The energy balance equation for Glass to Glass PV modules [12][17]can be written in Eq.7

$$\alpha_c\beta_c\tau_g I(t)bdx = U_{tca}(T_c - T_a)bdx + U_b(T_c - T_a)bdx + (\eta_m)I(t)bdx \quad (7)$$

Eq.(7) shows that thermal energy loss per hour from solar cells to surrounding via the top surface of the panel plus thermal energy loss per hour from solar cells to the environment via the bottom part of the panel gives absorbed solar radiation per hour received by solar cells determines electrical energy produced per hour by solar cells in a PV module..

Now U_{tca} and U_b are explained as

$$U_{tca} = \left[\frac{L_g}{K_g} + \frac{1}{h_o}\right]^{-1}$$

$$U_b = \left[\frac{L_g}{K_g} + \frac{1}{h_i}\right]^{-1}$$

Now from equation (7), the cell temperature is shown as Eq.(8)

$$T_c = \frac{T_a(U_b + U_{tca}) + I(t)\alpha_c\beta_c\tau_g - I(t)\eta_m}{U_b + U_{tca}} \quad (8)$$

Use Eq. 3, electrical efficiency of the glass to glass module is modified as Eq.(9)

$$\eta_c = \eta_o[1 - \beta_{ref}(T_a + (I(t)\alpha_c\beta_c\tau_g)/(U_b + U_{tca}) - (I(t)\eta_m)/(U_b + U_{tca}) - T_{ref})] \quad (9)$$

Using equations (5) and (6) Electrical energy on hourly basis and total electrical energy in a day in KWh is evaluated.

MODELING OF GLASS TO TEDLAR (G-T) SOLAR MODULE

The energy balance equation for Glass to TedlarPV[12] modules is given in Eq.(10)

$$\alpha_c\beta_c\tau_g I(t)bdx + \alpha_t\tau_g(1 - \beta_c)I(t)bdx = U_{tca}(T_c - T_a)bdx + U_b(T_c - T_a)bdx + (\eta_m)I(t)bd \quad (10)$$

where as

$$U_{tca} = \left[\frac{L_g}{K_g} + \frac{1}{h_o}\right]^{-1}$$

$$U_b = \left[\frac{L_t}{K_t} + \frac{1}{h_i}\right]^{-1}$$

From Eq.10, the cell temperature of the module is expressed as in Eq.(11)

$$T_c = \frac{T_a(U_b + U_{tca}) + I(t)\alpha_c\beta_c\tau_g - I(t)\eta_m + \alpha_t\tau_g(1-\beta_c)I(t)}{U_b + U_{tca}} \quad (11)$$

Using Eq.3, theelectrical efficiency of the glass to tedlar module become Eq.(12)

$$\eta_c = \eta_o[1 - \beta_{ref}(T_a + (I(t)\alpha_c\beta_c\tau_g)/(U_b + U_{tca}) - (I(t)\eta_m)/(U_b + U_{tca}) + (\alpha_t\tau_g(1-\beta_c)I(t))/(U_b + U_{tca}) - T_{ref})] \quad (12)$$

Again using Eq.5 and Eq.6, Electrical energy on hourly basis and total electrical energy in a day in KWh is evaluated. The design parameters of three modules is shown in Table 1.

The overall process of evaluating the daily energy production is examined by following the 4 steps.

EVALUATING PROCESS

Step 1: The planned parameters used in the calculation of various modules are mentioned in the Table 1. [19]

Step 2:PV modules Mathematical modeling has been design and done by using MATLAB R2018a

Step 3: For the known climatic data and designed parameters, temperature of the cell and electrical efficiency has been checked for F-Al module using Eq. (2) and (4) respectively. Similarly for G-G module Eq.8 and Eq.9 are used and for G-T Eq.11 and Eq.12 are used.

Step 4: The electrical energy generation on daily basis has been estimated for all the modules using Eq.6

The complete evaluating process is explained through flowchart in Figure 3 in which convergence will be checked for all three module after estimating the parameters. The convergence rate will be checked through linear regression analysis.

Table 1. Design parameters of Glass to Glass(G-G), Glass to Tedlar(G-T) and Flexible Aluminum (F-Al)

S.No.	Nomenclature	Specifications
1.	Area of Module (Am)	0.5332 m^2
2.	Absorptivity Solar cell (a_c)	0.9
3.	Packing factor Solar cell (b_c)	0.81
4.	Absorptivity Aluminium (a_{al})	0.6
5.	Absorptivity Tedlar (a_t)	0.5
6.	Transmissivity of Glass (t_g)	0.95
7.	Transmissivity of Plastic (t_p)	0.9
8.	Refrence Temperature (T_{ref})	25^0C
9.	Efficiency module (h_m)	12%
10.	Efficiency of Solar cell at standard test condition (h_o)	14%
11.	Heat loss Coefficient from bottom (h_i)	2.8+3v; v=0.2m/sec
12.	Heat loss coefficient from top (h_0)	5.7+3.8v; v=0.5m/sec
13.	Length of Glass (Lg)	0.02m
14.	Length of Plastic (Lp)	0.002m
15.	Length of Tedlar (Lt)	0.001m
16.	Length of Tedlar (Lal)	0.001m
17.	Thermal Conductivity of Glass (Kg)	1.1(W/(m.K))
18.	Thermal Conductivity of Plastic(Kp)	0.2(W/(m.K))
19.	Thermal Conductivity of Tedlar(Kt)	0.369(W/(m.K))
20.	Thermal Conductivity of Aluminium (Kal)	205(W(m.K))

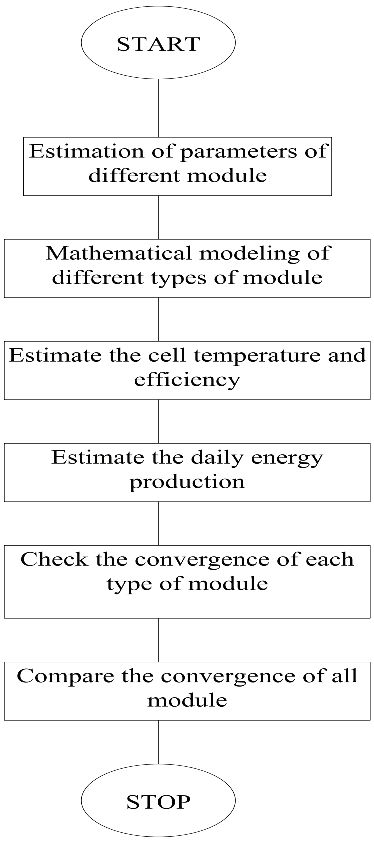

Figure 3. Flowchart for evaluation process of three modules.

PERFORMANCE CHARACTERISTICS OF SOLAR PV MODULES

IMDPune[23] provides the climatic data, intensity of solar I(t), and temperature of ambient (Ta). The electrical performance parameters like temperature of the cell and electrical energy of PV modules were evaluated using the following methodology.

1) Solar intensity variation on hour basis and ambient temperature for a day in the June month have been shown in Table 2 and also plot in Figure 4.
2) Temperature of the cell on hour basis and electrical efficiency of considered three types of PV modules have been presented in Figure 5 and Table 3.
3) Figure 5 shows that minimum cell temperature has been observed in case of G-G PV module among all three cases.
4) Figure 5 also depicts that G-G PV module gives better electrical efficiency as compared with G-T and F-Al PV modules.
5) Daily electrical energy gain for all three types of PV modules have been plotted in Figure 6 and Table 4
6) The daily electrical energy was found to be 420.63Wh in case of G-G PV modules whereas it was 418.9Wh and 414.75Wh in case of G-T and F-Al modules respectively.
7) It has been concluded that for electrical energy point of view the G-G PV modules gives best performance among three cases. F-Al PV modules can be used in desired shapes because of the flexibility of aluminum base.

Table 2. Hourly variation of solar radiation with temperature

Time (hour)	I(t) in W/m²	T(a) in degree Celsius
8	374	31.6
9	523	32.5
10	797	35.5
11	947	36.9
12	1032	37.3
13	1047	37.3
14	867	36.8
15	785	37.4
16	520	37.3
17	341	36.9

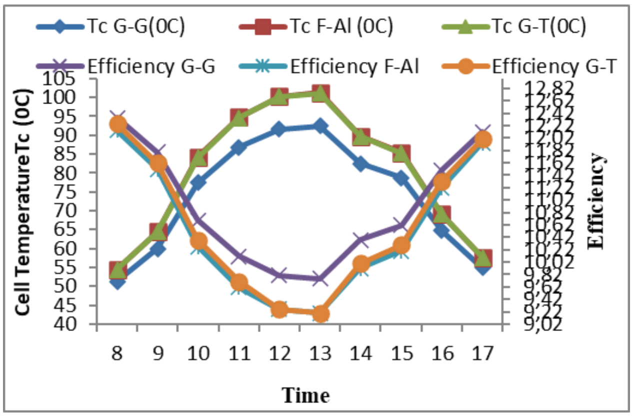

Figure 5. Hourly variation of cell temperature, T_c, and electrical efficiency, η_o, for F-Al, G-G & G-T modules.

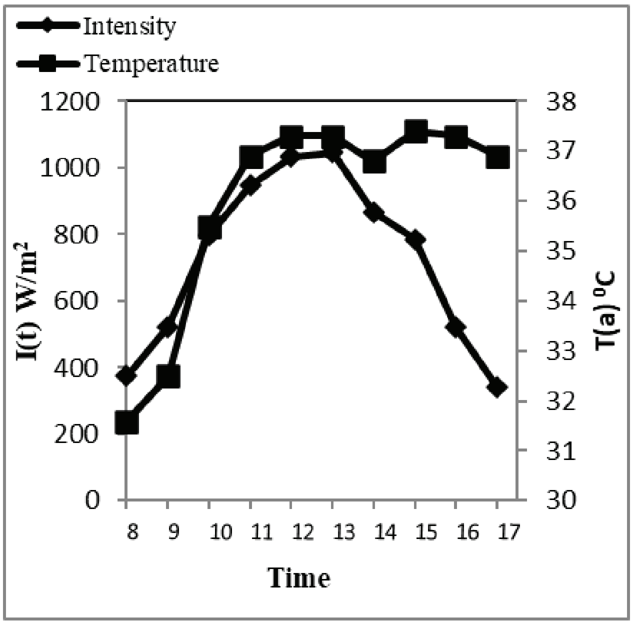

Figure 4. Hourly variation of solar intensity, I(t), and ambient temperature, T_a.

Table 4. Daily electrical energy production comparison of all three modules

DifferentType of Modules	Daily Electrical Energy (Wh)
G-G	420.63
G-T	418.9
F-Al	414.75

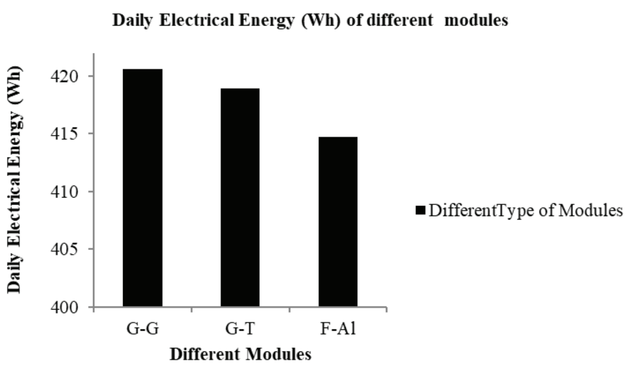

Figure 6. Daily electrical energy gain for F-Al, G-G & G-T modules.

Table 3. Efficiency comparison of all three modules

Time	Tc G-G(°C)	Efficiency G-G	Tc F-Al (°C)	Efficiency F-Al	Tc G-T (°C)	Efficiency G-T
8	49.03	12.49	50.14	12.42	49.36	12.47
9	56.87	11.99	58.43	11.89	57.33	11.96
10	72.64	11.00	75.02	10.85	73.34	10.95
11	81.03	10.47	83.85	10.29	81.86	10.42
12	85.39	10.20	88.47	10.00	86.30	10.14
13	86.09	10.15	89.21	9.95	87.01	10.09
14	77.20	10.71	79.79	10.55	77.96	10.66
15	73.98	10.91	76.32	10.77	74.67	10.87
16	61.53	11.70	63.08	11.60	61.99	11.67
17	52.79	12.25	53.81	12.19	53.09	12.23

REGRESSION ANALYSIS

It is used to check the convergence rate of three types of module. The linear regression analysis for the three types of modules has been assessed by extended the Eq. (4, 9, 12)

In generalize way relationship among efficiency,temperature and intensitycan be expressed as in Eq. (13) after taken logarithm on both side of Eq. (4, 9, 12) with certain approximation.

$$\log(\eta_c) = A\log(\tau) + B\log(I(t) + C \quad (13)$$

where $A = \frac{\beta_c \tau}{U_b + U_{ca}}$, $B = \frac{U_b + U_{ca}}{\alpha_l \tau(1-\beta_c \tau)}$, $C = \frac{\beta_{ref}(U_b + U_{ca})}{T_{ref} + 1}$

where A, B and C are constant and its values varies with the types of modules.

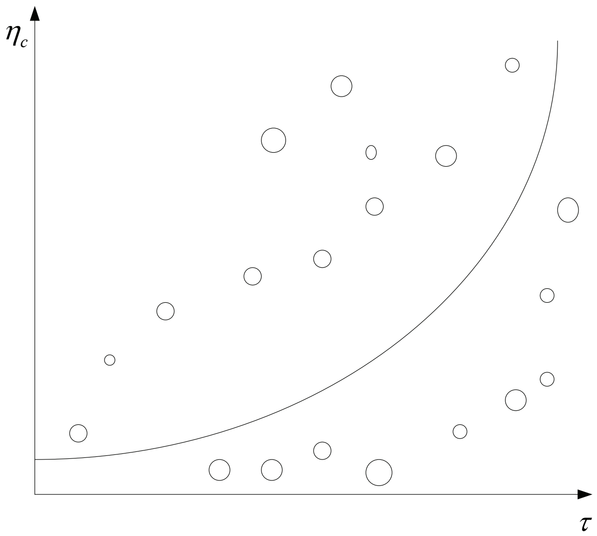

Figure 7. Regression analysis for G-T module.

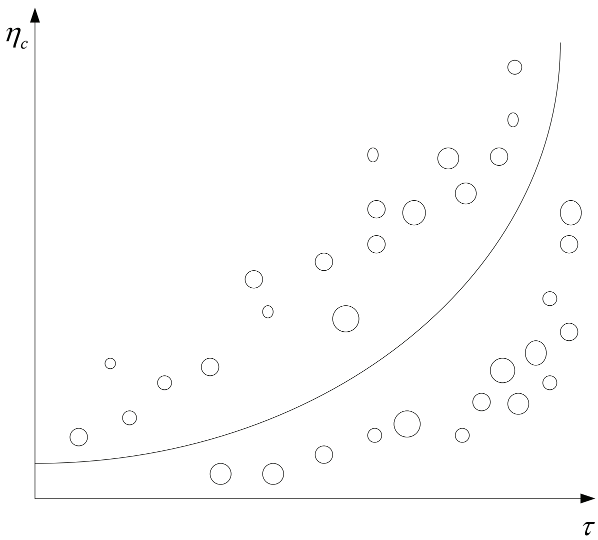

Figure 8. Regression analysis for G-G module.

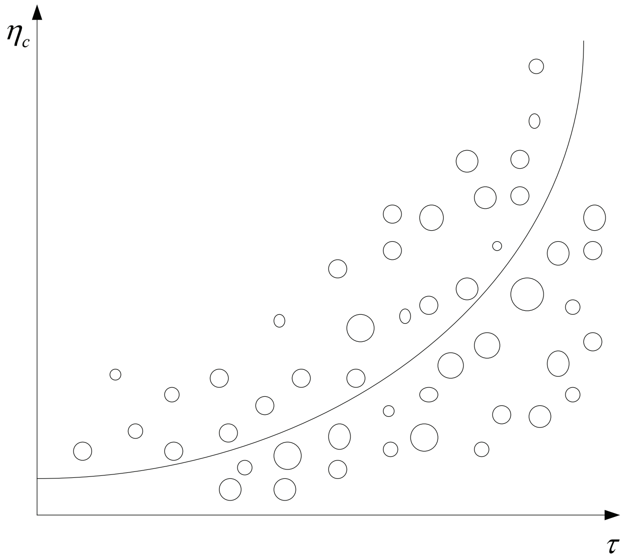

Figure 9. Regression analysis for F-Al module.

In the Figure 7, efficiency of the G-T module is weakly converging towards the regression line with respect to the τ as per the designed Eq.13. It is all due to property of G-T module. In order to overcome such issue, another material G-G module is used, In this module, efficiency of the G-G module is slightly more converging towards the regression line with respect to the τ as shown in Figure 8 but still this is not sufficient. In order to have highly convergence around regression line, efficiency of the F-Al module is used for the converging towards regression line with respect to the τ as shown in Figure 9.

From the above graphs represented by Figure 7, Figure 8 and Figure 9. It can be realized that efficiency of F-Al module is converging faster towards the regression line due to its flexible nature in comparison to other G-G and G-T module. Although the efficiency of F-Al module is lesser than G-G module in terms of magnitude.

PERFORMANCE ANALYSIS OF EFFICIENCY & DAILY ENERGY CONSUMPTION USING ANN

The performance analysis of efficiency and daily energy consumption of different module of solar PV array is assessed by using artificial neural network(ANN).

The design aspects of ANN is done by extended the Eq.13 in the form as Eq.14

$$Y = W_1 X_1 + W_2 X_2 + b \quad (14)$$

Compare Eq.14 with Eq.13 and following parameters are obtained

$Y = \log(\eta_c)$, $W_1 = A$, $X_1 = \log(\tau)$, $W_2 = B$, $X_2 = \log(I(t)$, $C = b$

The diagram representation of the Eq.14 is shown in Figure 10.

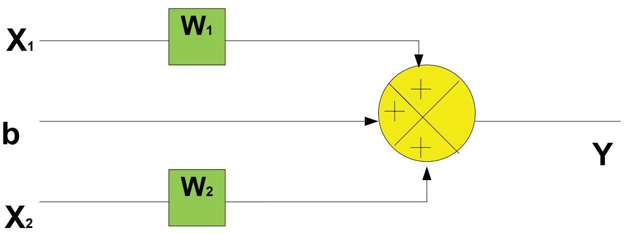

Figure 10. Schematic representation of ANN equation.

ANN is used to train the weights in the closed mechanism by using feed forward method with back propagation delay. The structure of feed forward method is shown in Figure 11.

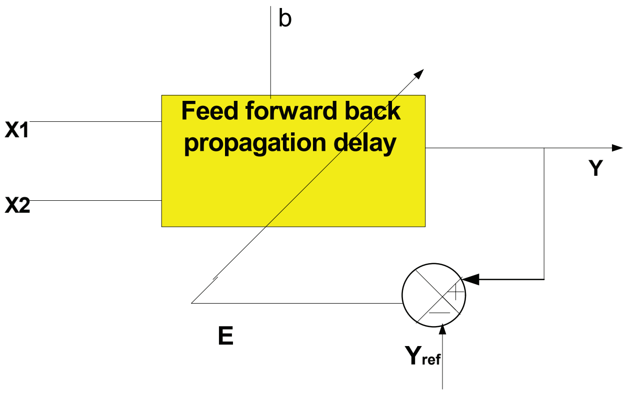

Figure 11. Structure of ANN with feed forward based back propagation delay.

The design aspects of ANN begins with the selection of efficiency, temperature and intensity. The relationship among these variables are shown in Eq.13 which is ultimately the logarithm non linearity representation. The final expression of ANN is always linear in nature that's why Eq.13 is represented as Eq.14 with proper well defined symbols. In Eq.14, output is a combination of inputs, weights and bias. It is complete open loop equation in which output(efficiency) can't be controlled. In order to have desired output, a closed loop feedback control based on feed forward method using back propagation delay is used. In the feed forward back propagation day method, output is compared with its reference value, then generated error is readjusted in back propagation delay method. The error has been trained in the closed loop mechanism accordingly new weights are updated as shown in Eq.16. In Eq.16, new weights are dependent on previous or old weights and error. Initially selection of the old weights and bias is being decided on the basis of PV rating. The value of the old weights for Eq.16 is shown in Table 5.

Table 5. Old weights used in ANN & bias

Parameters	Value
W_1	44.98
W_2	67.98
b	11.65

Use steepest descent algorithm for calculating error E for training the weights in closed mechanism is shown in Eq.15.

$$E = \frac{(Y - Y_{ref})^2}{2} \tag{15}$$

By using the above equation, weights will be upgraded with Eq.16

$$W_j(new) = W_j(old) - \eta \frac{\partial(E)}{\partial W_j} \tag{16}$$

η is learning rate which is equal to 0.5

From the Eq.16, derivative of error with respect to weight is shown in Eq.17

$$\frac{\partial(E)}{\partial W_j} = \frac{\partial(E)}{\partial Y}\frac{\partial Y}{\partial W_j} \tag{17}$$

In the above equations, following values are obtained by using Eq.14 and Eq.15 then Eq.18 and Eq.19 are obtained

$$\frac{\partial(E)}{\partial Y} = Y - Y_{ref} \tag{18}$$

$$\frac{\partial Y}{\partial W_j} = X_j \tag{19}$$

Substitute the value of Eq.18 and Eq.19 in Eq.17 and Eq.20 is obtained

$$\frac{\partial(E)}{\partial W_j} = X_j(Y - Y_{ref}) \tag{20}$$

Substitute value of Eq.20 in Eq.17 then Eq.21 is obtained

$$W_j(new) = W_j(old) - \eta X_j(Y - Y_{ref}) \tag{21}$$

The upgraded value of weights is shown in Table 6 & η=0.85

Once the old values of weights is decided as shown in Table 5 after new or upgraded value of weights is estimated from Eq. 16 .The upgraded or new value of weights is shown in Table 6 with η=0.85

Table 6. Upgraded weights used in ANN & bias

Parameters	Value
W_1	41.32
W_2	26.98
b	42.65

$$\text{Mean square error, MSE} = \frac{\sum_{i=1}^{3}(Y-\bar{Y})}{n} \quad (22)$$

where n is the number of modules (n=3)

After analyzing the output using ANN for different modules, it is observed that MSE for the output or efficiency is found to be least with F-Al. The MSE value of efficiency for solar G-G module, solar F-Al module, solar G-T module are shown in Figure 12, Figure 13 and Figure 14.

After design the ANN structure in the closed loop structure, Mean square error (MSE) corresponding to output is estimated. In Figure 12, MSE for the efficiency for solar GG

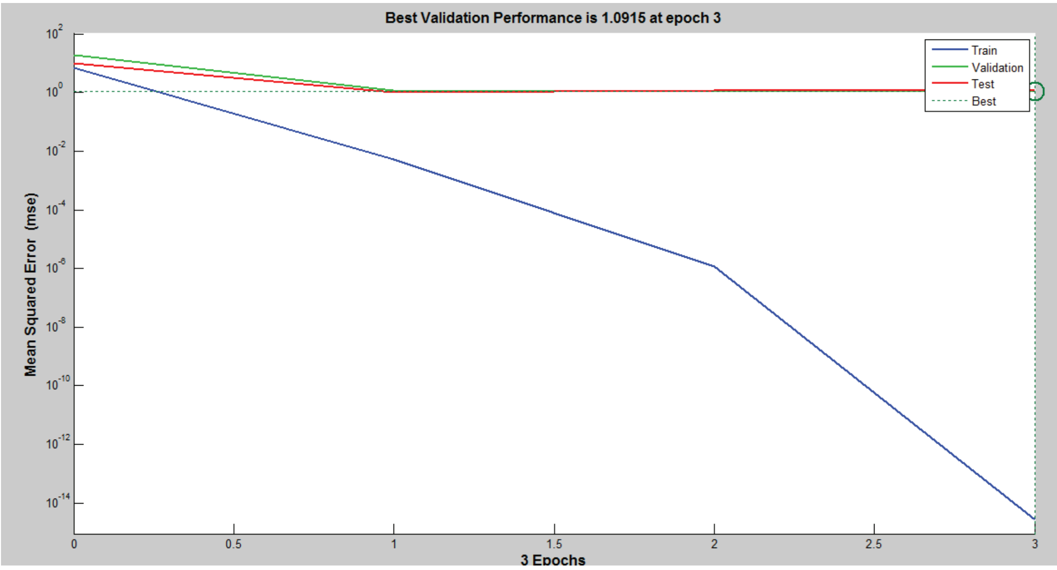

Figure 12. MSE value for the output(or efficiency) for the solar G-G module.

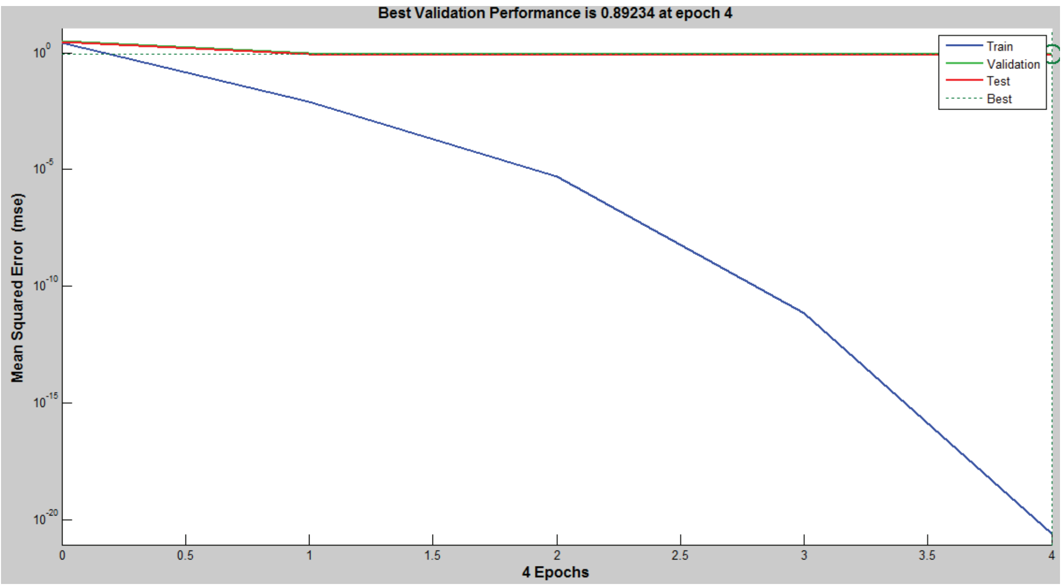

Figure 13. MSE value for the output(or efficiency) for the solar F-Al module.

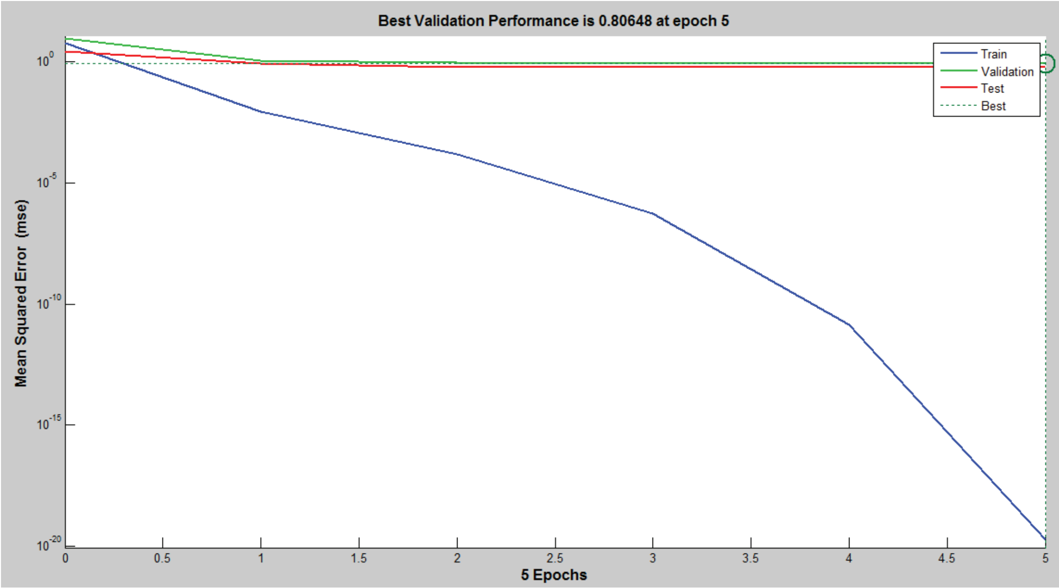

Figure 14. MSE value for the output(or efficiency) for the solar G-T module.

module is shown for parameter like train, validation, test type of output. All these parameters are approaching to its best value. It can be realized that trained, validation and test value lie in the range of 0.01 which approach to its best value.

Similary In Figure 13, MSE for the efficiency for solar F-Al module is shown for parameter like train, validation, test type of output. All these parameters are approaching to its best value. It can be realized that trained, validation and test value lie in the range of 0.02 which is quite close to its best value.

Similary In Figure 14,MSE for the efficiency for solar G-T module is shown for parameter like train, validation, test type of output. All these parameters are approaching to its best value. It can be realized that trained, validation and test value lie in the range of 0.002 which resembles to its best value. The brief comparison of above data is shown in Table 9.

The comparative performance of efficiency output for three module is shown in Table 7.

Table 7. Comparison of MSE of efficiency of three module

Solar module	MSE value of efficiency
G-G	10^{-16}
F-Al	10^{-22}
G-G	10^{-20}

It is quite clear from Eq.5 that daily energy consumption is directly proportional to efficiency. By considering this and use Eq.13 and Eq.14 for estimating the MSE of daily energy consumption of three modules. Such comparison is shown in Table 8.

Table 8. Comparison of MSE of daily energy consumption of three module

Solar module	MSE value of daily energy consumption
G-G	10^{-12}
F-Al	10^{-26}
G-G	10^{-21}

Table 9. Comparison of three module on the basis of train, validation & test

Solar module	Train	Validation	Test
G-G	10^{-1}	10^{-2}	10^{-1}
F-Al	10^{-2}	10^{-3}	10^{-3}
G-G	10^{-1}	10^{-1}	10^{-2}

CONCLUSION

This paper shows the design aspects of different kind of solar module namely G-G,G-T,F-Al module. The structure wise G-G and G-T module are of rigid type while F-Al is a flexible type of module. Due to its flexible nature , regression line of Figure 7, 8 and 9, F-Al module is converging faster in comparison to G-G, G-T module. Although the efficiency with G-G is found to be larger with G-G module in comparison to G-T,F-Al module as from the Table 3, where at 13:00hrs efficiency of G-G is 10.15%, G-T is 10.09% and F-Al is 9.95%. Whereas the cell temperature at thesame time i.e at 13:00hrs of F-Al module is observed as

89.21⁰C is largest than G-G module and G-T module whose temperature is 86.09⁰C and 87.01⁰C respectively. Even the G-G module produces the maximum daily energy production of 420.63Wh in comparison to G-T whose is 418.9 Wh and F-Al module has 414.75 Wh. The analysis of three modules for optimal value of efficiency and daily energy consumption is assessed through ANN. It is observed that least value of MSE is attained with solar F-Al module in comparison to others and additional characteristic of F-Al creates lot of chances for selection.

NOMENCLATURE

A_m	area of the module (m^2)
L	length of the module (m)
b	breadth of the module (m)
lg	glass length (m)
dx	elemental length (m)
$\dot{m}_f$	mass flow rate of fluid (kg/ m^2)
C_f	specific heat of fluid (J/kg K)
I(t)	irradiation of sun(W/m^2)
h	loss coefficient of the heat(W/m^2)
K	thermal conductivity (W/mK)
h_o	loss coefficient at top in form of heat (W/m^2)
T	temperature (^{0}C)
h_i	loss coefficient at bottom in form of heat (W/m^2)
U_{tca}	overall solar cell to ambient heat loss conversion coefficient from the top (W/m^2 K)
U_b	overall solar cell to ambient heat loss conversion coefficient from the bottom (W/m^2 K).
G-T	Glass to Tedlar
G-G	Glass to Glass
Wp	System Power(Watt –Peak)
F-Al	Flexible aluminum
v	air velocity (m/s)
η_o	efficiency of solar cell at standard test condition (STC)

Subscripts

a	ambient
c	solar cell
al	aluminium
p	plastic
m	module
g	glass
t	tedlar

Greek letter

α	absorptivity
β	packing factor
β_o	temperature coefficient of the material
τ	transmissivity
η	efficiency

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AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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