Evaluation of Thin Film Amorphous Silicon Solar Energy System

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Abstract
This paper focus on the evaluation of thin film amorphous silicon solar panel and one model which is based on mathematical equations of generating photovoltaic current and efficiency of solar energy system . This model have been developed with the help of LabVIEW software. The developed model allows the prediction of generating photovoltaic current under different solar radiation, Efficiency of solar panel, efficiency of solar water pump & the efficiency of total energy system. In order to validate the developed model, an experimental test setup was built and the results are found to be in close agreement with the observed reading of current shown by solar power conditioning unit. The analysis of graph shows that the difference between predicated current and actual current error does not exceed 5%.
Keywords: Amorphous silicon solar panel, LabVIEW, photovoltaic current, solar radiation.

INTRODUCTION
The increasing energy demand and decrease in conventional energy resources orientates researches to be in tendency to continuously increase the output of alternative energy resources. [Drfan Guney, et al., (2008)], [L. A. Dobrzański , et al.,(2009)], [Ron Swenson, (2004)] One of the commonly used renewable energy sources is the sun and the use of photovoltaic cells to convert solar radiation into electricity is rapidly expanding throughout the world.[Joseph Minutillo, et al.,(2008), WU, et al.] The primary objective of the worldwide photovoltaic (PV) solar cell research and development is to reduce the cost of PV cells and modules to a level that will be competitive with conventional ways of generating power.[Satyen K. Deb, (2000)], [Vivian E. Ferry, et al.,(2008)] The recent boom in the demand for photovoltaic modules has created a silicon supply shortage, providing an opportunity for thin-film photovoltaic modules to enter the market in significant quantities. [Greg P. Smestad, (2008)], [Martin A. Green, (2007)] In fact, the demand for solar energy has increased by 20% to 25% over the past 20 years. The market for PV systems is growing worldwide. In fact, nowadays, solar PV provides around 4800 GW. [Tarak Salmi, Mounir Bouzguenda (2012)]

With no pollutant emission, Photovoltaic cells convert sunlight directly to electricity. They are basically made up of a PN junction. [Savita Nema, R.K.Nema (2010)] Fig. 1 shows the photocurrent generation principle of PV cells. In fact, when sunlight hits the cell, the photons are absorbed by the semiconductor atoms, freeing electrons from the negative layer. This free electron finds its path through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one. [Tarak Salmi, Mounir Bouzguenda (2012)] For monocrystalline silicon solar cell the photon generated current Iph is in fact related with solar insolation λ as

$$Iph = [Isc + Ki(T - 298)]\frac{\lambda}{100}$$

K_i= 0.0017 A/ºC is cell's short-circuit current temperature coefficient, I_{SC} is cells short circuit current at 25ºC, T is the cell's temperature and λ is the solar insolation in kW/m^2 . [Savita Nema, R.K.Nema (2010)]

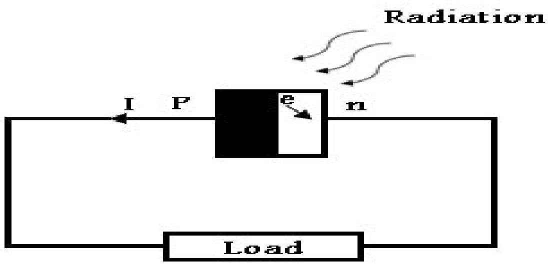

Fig.1. Photocurrent generation principle

EXPERIMENTAL SETUP

This study was undertaken with main objectives was to predict the generating photovoltaic current of thin film amorphous silicon solar panel which were installed as at Energy Park, RGPV. , Bhopal.

Location of Energy Park, RGPV, Bhopal:
Latitude : +23.24 (23°14'24"N)
Longitude : +77.4 (77°24'00"E)
Time zone : UTC+5:30 hours
Local time : 01:15:10
Altitude : ~ 490 m

The measurements were carried out on a rectangular shaped thin film amorphous silicon solar panel. The incident solar radiation on the solar cell & air temperature measured by weather monitor-SpecWare 7 (watch dog). Current & voltage measurement are done by solar power conditioning unit.

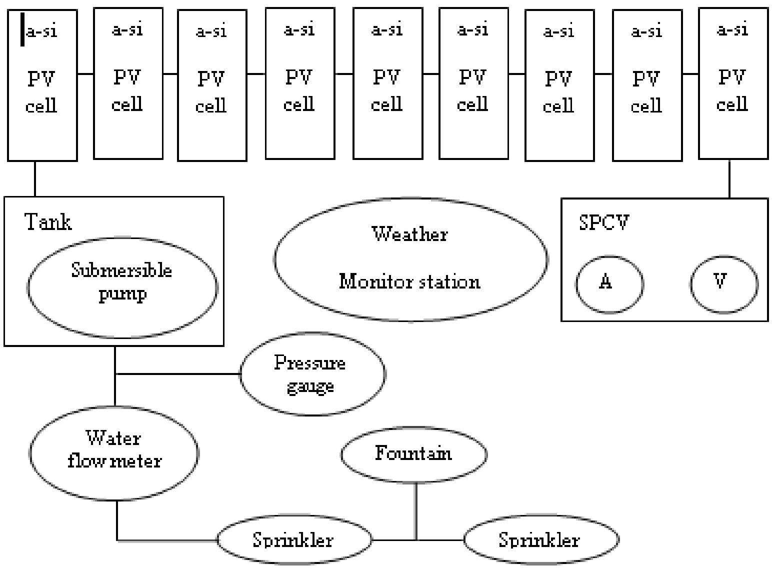

Fig.2. Experimental setup

The experimental setup used, as shown in Fig. 2. [9 Nos. of thin film amorphous silicon PV panel (each rated 100 W)], The solar panel was made up of amorphous silicon cells; The dimensions of the panel are 1308 mm by 1108 mm , thickness is 50mm. Weight of each panel is 18 Kg. All 9 a-Si Solar panels are connected in series as shown in Fig.3. For the measurements of voltage and current, solar power conditioning unit are connected with the thin film amorphous silicon solar panel as shown in Fig.4. Submersible pump is situated in under the water tank. Submersible pump used the generated PV current for pumping the water. 1 inch of water pipe line connects with submersible pump to 2 nos. of sprinklers and 1 no. of fountain. Pressure gauge (range is 0 to 2.1Kg/cm^2) (as shown in figure 5.) is attached vertically in 1 inch of water pipe line which is connect with submersible pump (range is 0 to 2 Kg/cm^2). Just after the pressure gauge water flow meter is attached in 1 inch of water pipe line which is connect with submersible pump to sprinklers & fountain as shown in Fig.5. Weather monitor-SpecWare 7 (Watch dog, as shown in fig.6) is placed in front of solar energy system as shown in fig 2. For measuring solar radiation, wind speed, wind direction, humidity & air temperature

Fig.3. Nine Nos. of thin film amorphous silicon PV panel

Fig.4. Solar power conditioning unit

Fig.5. Pressure gauge and water flow meter

Fig.6. Weather monitor-SpecWare 7

Effect of solar radiation variation

A solar cell is generally tested at STC i.e. 1000 W/m^2 & at 25^0C. For Indian conditions at different geographical places temperature varies from 4^0C to 52^0C which means a solar photovoltaic installation will give out put in terms of generation of units, which will vary affecting the economics of solar photovoltaic installation which will give maximum output optimizing generation cost .Therefore it is very important to study the effect of temperature on performance of solar photovoltaic installation.

The LabVIEW model calculates the PV cell photocurrent for thin film amorphous silicon solar panel which depends on the solar radiation and the temperature of air according to following equation below.

$$I_{ph} = [I_{sc} - K_i(t_{air} - t_{amb})]\frac{\beta}{A*100} \qquad [1]$$

Where,

I_{sc} = short circuit current = 6.79 A

K_i= 0.0008 A/◦C is the cell's short circuit current temperature coefficient

β = the solar radiation (W/m^2)

t_{air}= Actual temperature of air in ^0C

t_{amb}= Ambient temperature of air in $^0C = 25^0C$

A= Area of solar cell =$13.043m^2$

For the evaluation of amorphous silicon solar energy system

- To find the efficiency of amorphous silicon solar cell using following formula

$$\eta = \frac{IV}{\beta * A} \qquad [2]$$

- To find the power of solar pump using below formula

  Power of amorphous silicon solar pump = m ρ g h [3]

- To find the efficiency of solar pump using following formula

  Efficiency of solar pump $\eta_2 = \frac{m\rho gh}{IV}$ [4]

  Where m = mass of water Kg/s
  ρ = Density Kg/m^3
  g = Gravitational Constant m^3/Kgs^2
  h = Height of water column m

I = Photovoltaic Current A
V = Voltage V

- To find the total efficiency of solar energy system

$$\eta = \eta_1 \times \eta_2 \quad [5]$$

MODELING WITH LabVIEW

The development of modeling with LabVIEW is computer based implementation with high priests performing mysterious rites. The term LabVIEW is stats that "Laboratory Virtual Engineering Workbench" by National instruments of Austin, Texas, USA. It is graphical programming paradigm. In LabVIEW, the user interaction takes place through the front panel while the code itself resides on the block diagram.

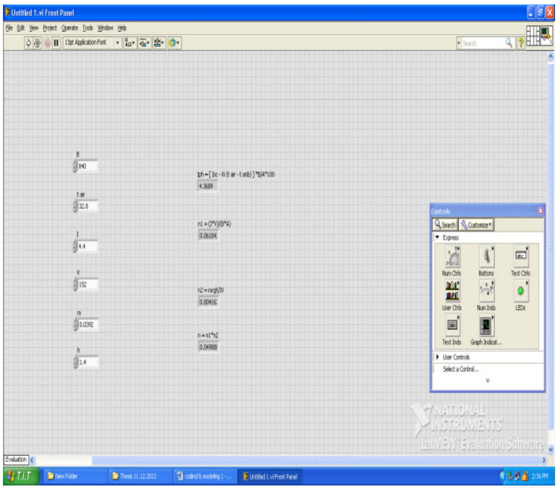
Fig.7 **F**ront panel of modeling

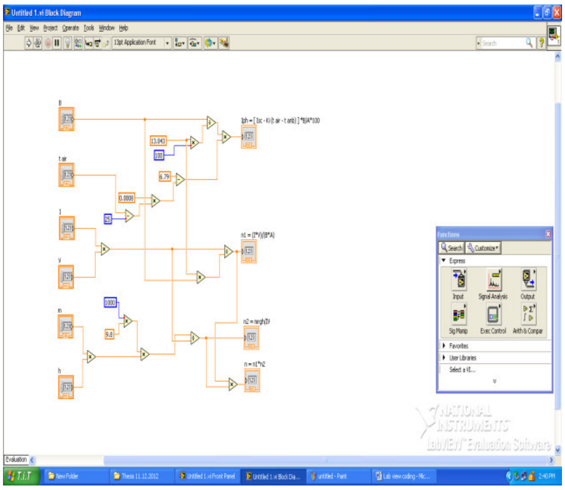
Fig.8 Block diagram of modeling

OBSERVATIONS

In India the weather conditions are changes with the climatic regions, to find out exact the effect of temperature on the performance of amorphous silicon Solar panel, the solar panels were tested on the field for 40 days in the month of September, October and November 2012. By using the data of 24.09.2012, 15.10.2012 & 19.11.2012 we can find out the formulated photovoltaic current of thin film amorphous silicon solar panel, efficiency of solar cell, efficiency of pump and efficiency of total energy system

Table 1. Observation of the experiment on thin film amorphous silicon solar panel on Date 24.09.2012

Time	Current I (A)	Voltage V(V)	Solar Radiation W/m^2	Air Temp ^{0}C	Wind direction	Wind Speed m/s	Relative Humidity %	Discharge Of water Kg/s	Pressure of water in Kg/cm^2
12.55 Hrs	4.3	167	850	34.2	S-W	0	43	0.0411	0.15
13.25 Hrs	4.2	168	800	34.4	W	2	43	0.0382	0.15
13.55 Hrs	4.3	159	830	34.4	N-W	2	41	0.0392	0.15
14.25 Hrs	4.4	153	860	34.4	N-W	1	42	0.0384	0.15
14.45 Hrs	4.4	156	850	34.4	W	0	39	0.0411	0.15
15.00 Hrs	4.2	160	790	31.0	N	3	40	0.0373	0.15

Table 2. Observation of the experiment on thin film amorphous silicon solar panel on Date15.10.2012

Time	Current I (A)	Voltage V(V)	Solar Radiation W/m^2	Air Temp ^{0}C	Wind direction	Wind Speed m/s	Relative Humidity %	Discharge Of water Kg/s	Pressure of water in Kg/cm^2
11.00 Hrs	4.4	160	820	32.8	NW	1	10	0.0492	0.13
11.40 Hrs	4.4	164	860	34.0	N	2	10	0.0500	0.13
12.20 Hrs	4.3	170	850	34.4	E	1	10	0.0500	0.13
13.00 Hrs	4.3	169	810	34.0	NW	2	10	0.0492	0.13
13.40 Hrs	4.3	166	790	36.5	S	0	10	0.0500	0.13
14.20 Hrs	4.2	166	780	34.0	N	2	10	0.0483	0.12
15.00 Hrs	3.9	158	740	34.4	NE	3	10	0.0467	0.11
15.40 Hrs	3.6	154	670	33.3	NW	1	10	0.0417	0.11

Table 3. Observation of the experiment on thin film amorphous silicon solar panel on Date19.11.2012

Time	Current I (A)	Voltage V(V)	Solar Radiation W/m^2	Air Temp ^{0}C	Wind direction	Wind Speed m/s	Relative Humidity %	Discharge Of water Kg/s	Pressure of water in Kg/cm^2
10.10 Hrs	4.2	152	780	27.8	N	2	10	0.0475	0.13
10.40 Hrs	4.3	160	800	28.9	E	0	10	0.0483	0.13
11.10 Hrs	4.3	164	810	28.9	N	1	10	0.0492	0.13
11.40 Hrs	4.4	166	830	30.0	W	3	10	0.0500	0.13
12.10 Hrs	4.3	165	810	30.6	SE	1	10	0.0500	0.13
12.40 Hrs	4.2	165	790	31.1	SE	1	10	0.0493	0.13
13.10 Hrs	4.3	163	800	32.2	SW	2	10	0.0483	0.13
13.40 Hrs	4.1	163	760	30.6	E	0	10	0.0458	0.12
14.10 Hrs	3.9	164	720	30.6	SE	2	10	0.0450	0.12
14.40 Hrs	3.7	163	690	30.6	SE	0	10	0.0433	0.12

RESULT AND DISCUSSION

Table 4. Result of the experiment on thin film amorphous silicon solar panel on Date 24.09.2012

Time	Efficiency of Solar cell η_1 in %	Theoretical Photovoltaic current I_{ph} (A)	Water head of Fountain In m	Efficiency of pump η_2 in %	Total efficiency of system $\eta=\eta_1 x \eta_2$ in %
12:55 Hrs	6.47	4.4201	1.5	84.13	5.45
13:5 Hrs	6.76	4.1600	1.5	79.58	5.38
13:55 Hrs	6.31	4.3160	1.5	84.28	5.32
14:25 Hrs	6.00	4.4720	1.5	83.85	5.03
14:45 Hrs	6.19	4.4720	1.5	88.02	5.45
15:00 Hrs	6.52	4.1097	1.5	81.59	5.32

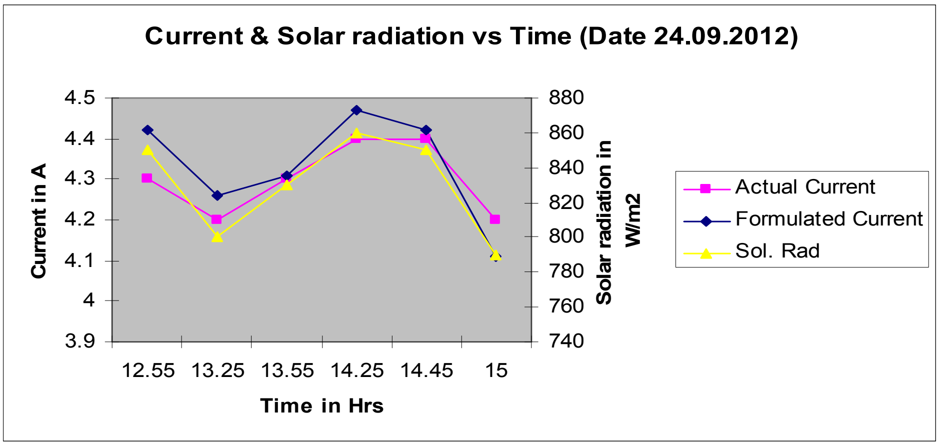

Fig.9 (a) Graph of Current & Solar radiation with respect to time (Date 24.09.2012)

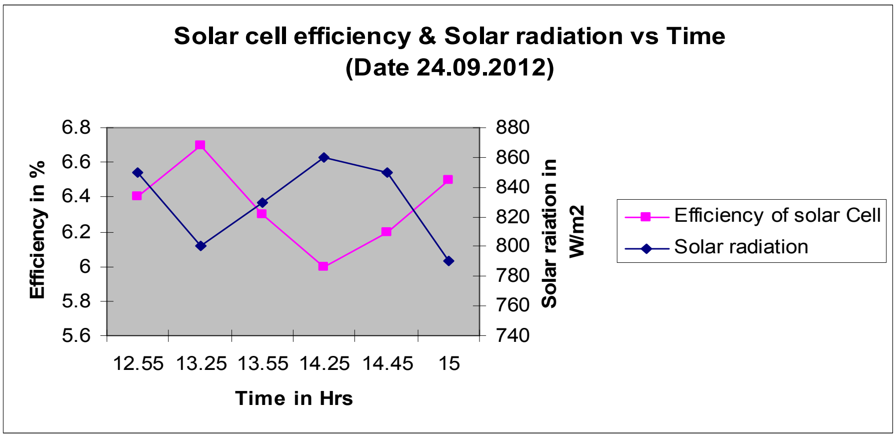

Fig. 9 (b) Graph of Solar cell efficiency & solar radiation with respect to time (Date 24.09.2012)

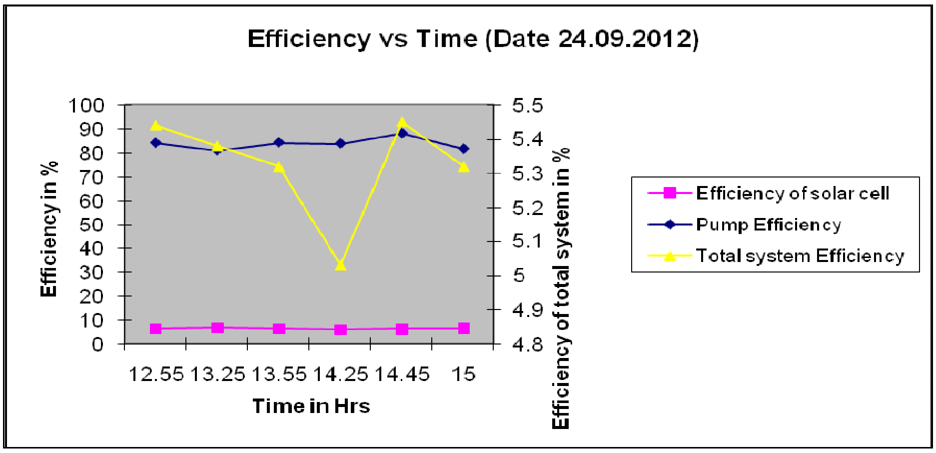

Fig.9 (c) Graph of Solar cell efficiency, Pump efficiency & total energy system with respect to time (Date 24.09.2012)

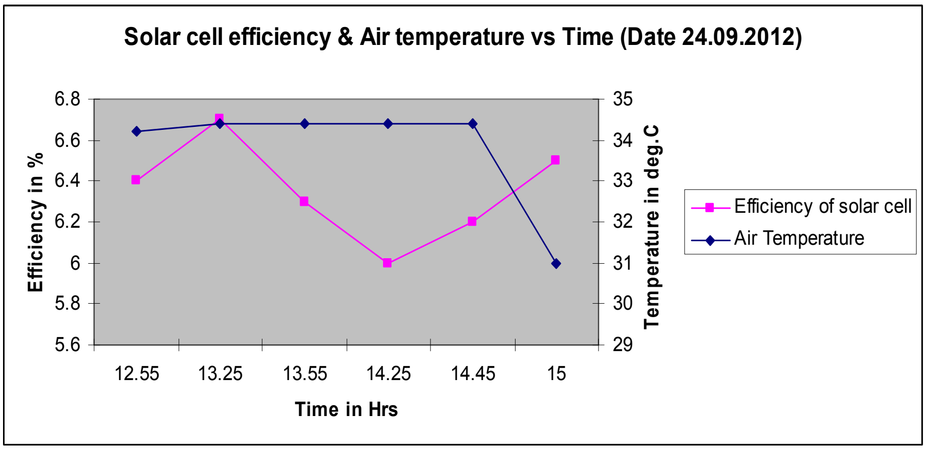

Fig. 9 (d) Graph of Solar cell efficiency & Air temperature with respect to time (Date 24.09.2012)

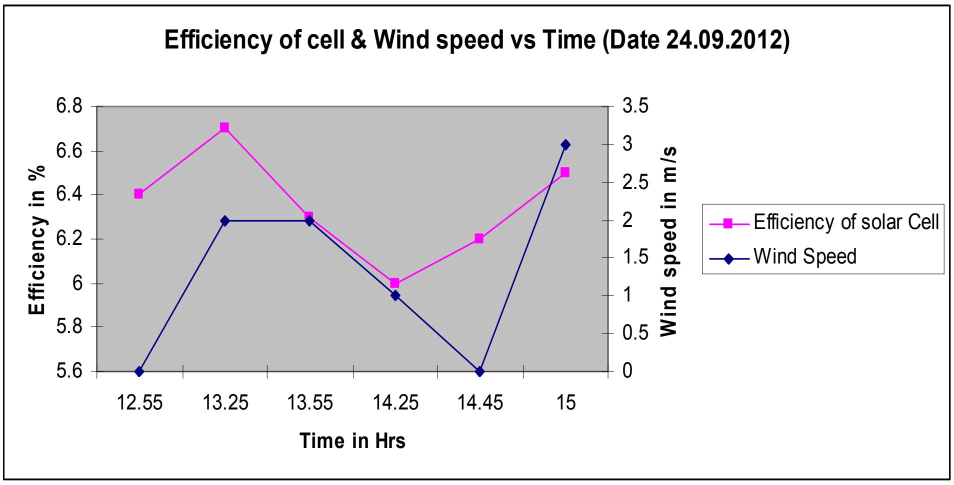

Fig. 9 (e) Graph of Solar cell efficiency & Wind speed with respect to time (Date24.09.2012)

Table 5. Result of the experiment on thin film amorphous silicon solar panel on Date 15.10.2012

Time	Efficiency of Solar cell η_1 in %	Theoretical Photovoltaic current I_{ph} (A)	Water head of Fountain In m	Efficiency of pump η_2 in %	Total efficiency of system $\eta=\eta_1 x \eta_2$ in %
11:00 Hrs	6.58	4.2648	1.3	89.00	5.86
11:40 Hrs	6.43	4.4723	1.3	88.27	5.67
12:20 Hrs	6.59	4.4201	1.3	87.14	5.74
13:00 Hrs	6.87	4.2122	1.3	86.25	5.93
13:40 Hrs	6.93	4.1071	1.3	89.24	6.18
14:20 Hrs	6.85	4.0562	1.2	81.46	5.68
15:00 Hrs	6.38	3.8481	1.1	81.69	5.21
15:40 Hrs	6.34	3.4851	1.1	81.08	5.14

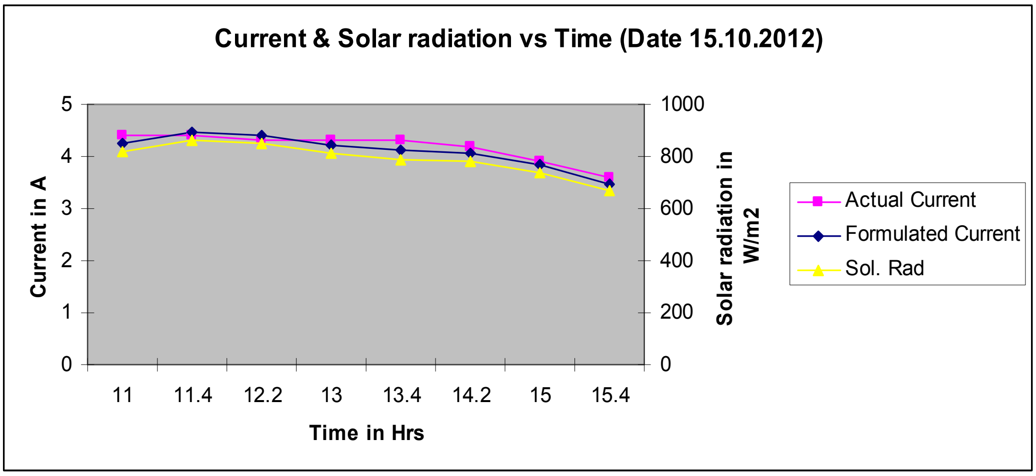

Fig.10 (a) Graph of Current & Solar radiation with respect to time (Date 15.10.2012)

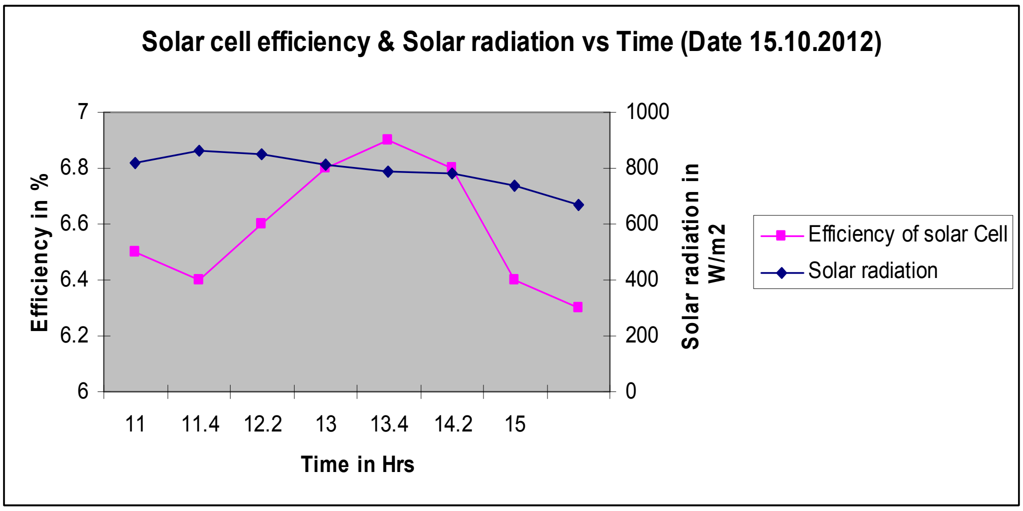

Fig. 10 (b) Graph of Solar cell efficiency & solar radiation with respect to time (Date 15.10.2012)

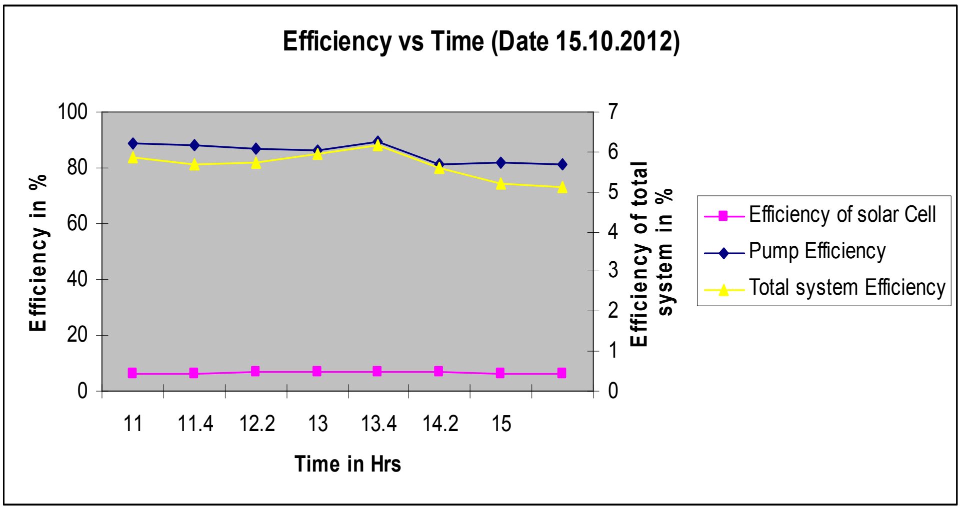

Fig.10 (c) Graph of Solar cell efficiency, Pump efficiency & total energy system with respect to time (Date 15.10.2012)

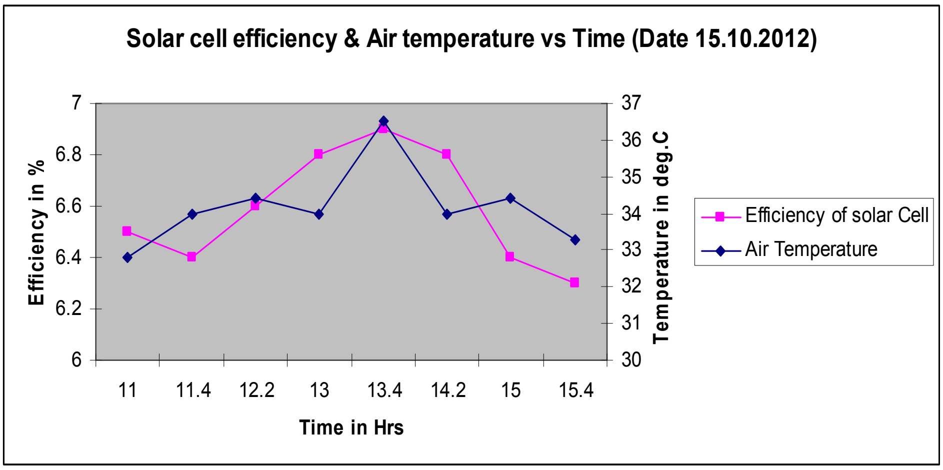

Fig.10 (d) Graph of Solar cell efficiency & Air temperature with respect to time (Date 15.10.2012)

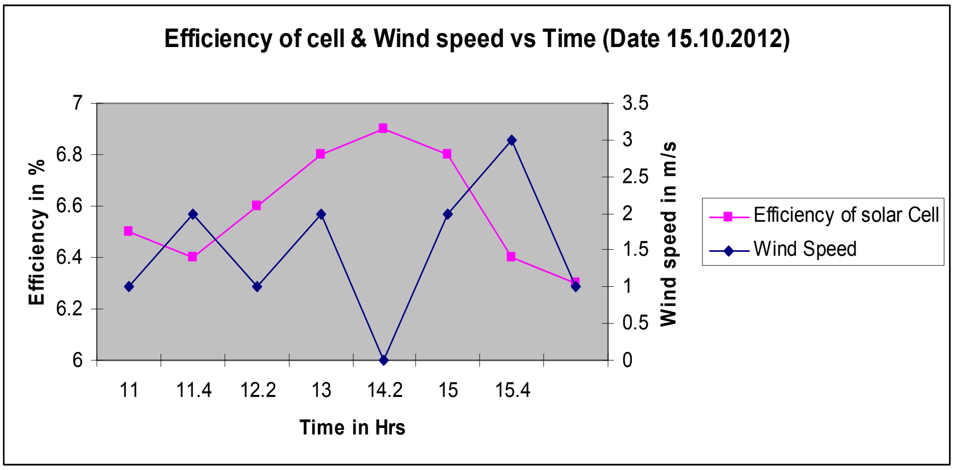

Fig. 10 (e) Graph of Solar cell efficiency & Wind speed with respect to time (Date15.10.2012)

Table 6. Result of the experiment on thin film amorphous silicon solar panel on Date 19.11.2012

Time	Efficiency of Solar cell η_1 in %	Theoretical Photovoltaic current I_{ph} (A)	Water head of Fountain In m	Efficiency of pump η_2 in %	Total efficiency of system $\eta=\eta_1 x \eta_2$ in %
10:10 Hrs	6.27	4.0592	1.3	94.79	5.95
10:40 Hrs	6.59	4.1627	1.3	89.44	5.89
11:10 Hrs	6.67	4.2148	1.3	88.88	5.93
11:40 Hrs	6.74	4.3183	1.3	87.21	5.88
12:10 Hrs	6.71	4.2139	1.3	89.78	6.03
12:40 Hrs	6.72	4.1097	1.3	90.63	6.09
13:10 Hrs	6.72	4.1612	1.3	87.79	5.89
13:40 Hrs	6.74	3.9538	1.2	80.59	5.43
14:10 Hrs	6.81	3.7457	1.2	82.74	5.63
14:40 Hrs	6.70	3.5896	1.2	84.43	5.66

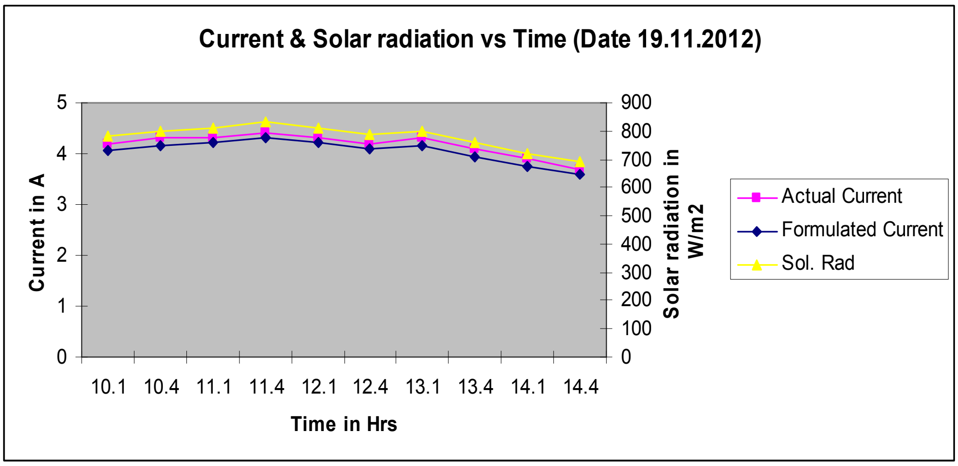

Fig.11 (a) Graph of Current & Solar radiation with respect to time (Date 19.11.2012)

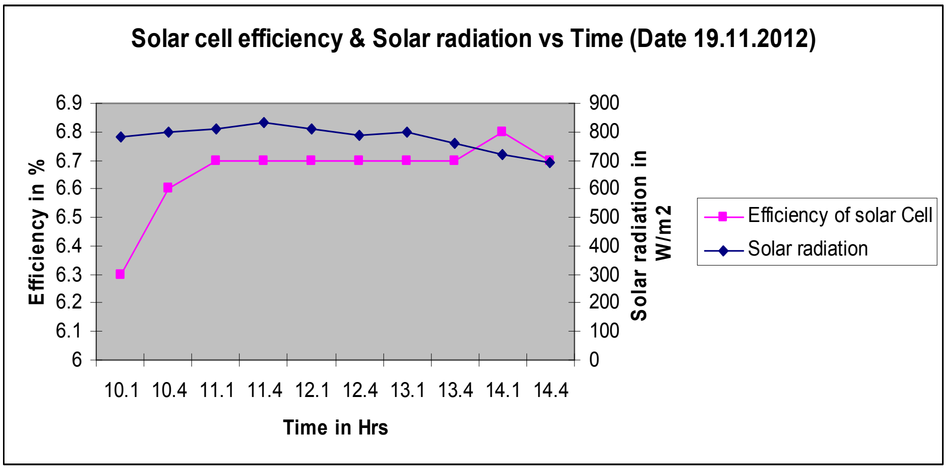

Fig. 11 (b) Graph of Solar cell efficiency & solar radiation with respect to time (Date 19.11.2012)

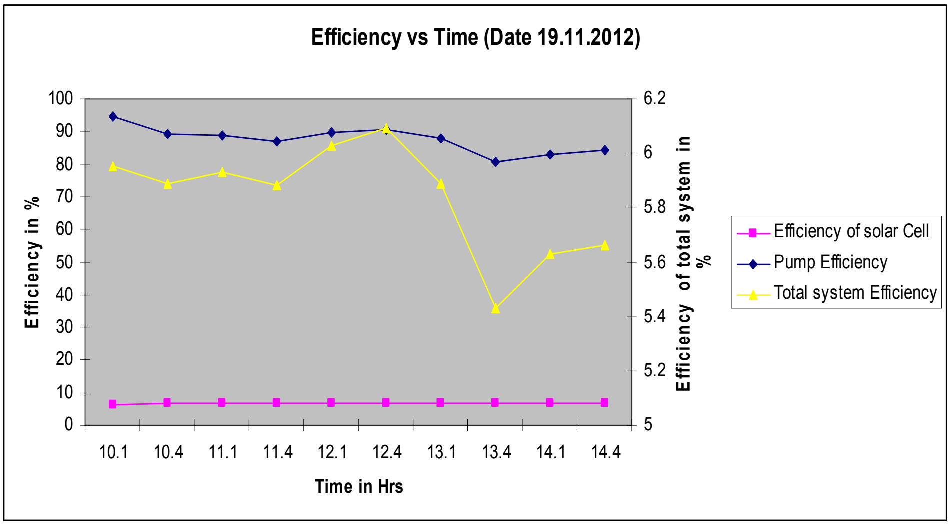

Fig.11 (c) Graph of Solar cell efficiency, Pump efficiency & total energy system with respect to time (Date 19.11.2012)

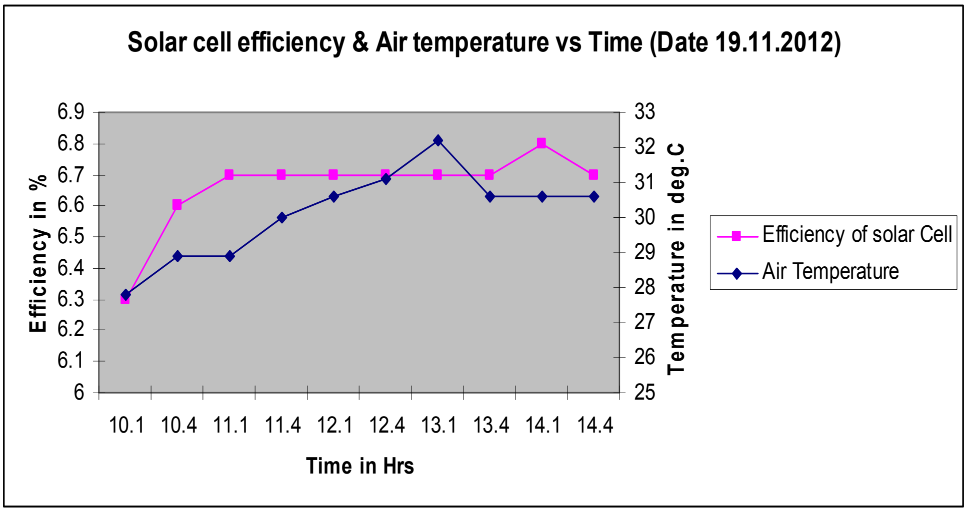

Fig.11 (d) Graph of Solar cell efficiency & Air temperature with respect to time (Date 19.11.2012)

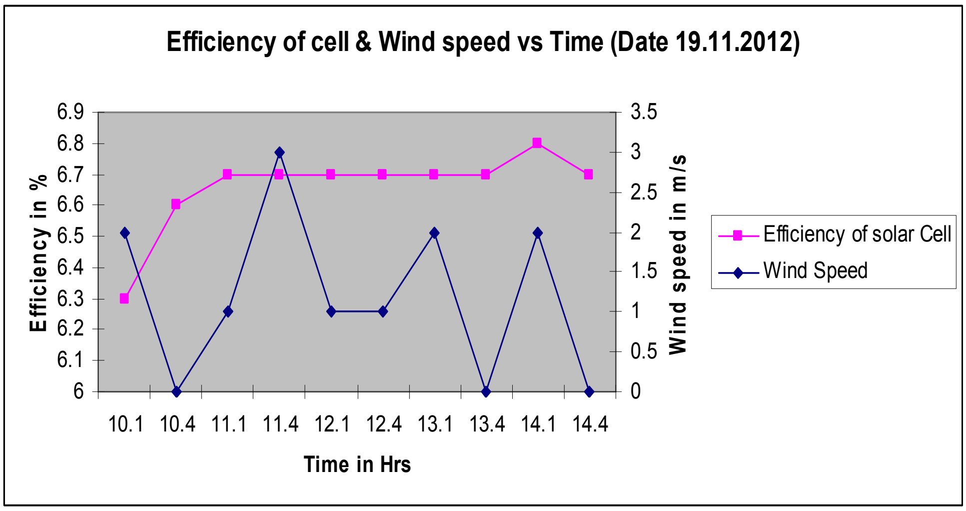

Fig. 11 (e) Graph of Solar cell efficiency & Wind speed with respect to time (Date19.11.2012)

Solar panel output current is proportional to solar flux or solar radiation. This means that when solar flux increases solar panel output current increases that is when there is less clouds cover, less dust, haze and low air pollution. Fig.9(a) , 10(a) & 11 (a) shows that current increases with increases the solar radiation & current decreases with decreases the solar radiation . The value of actual current which was measured by solar power conditioning unit and predicted generated photocurrent (formulated current by using mathematical formula [1]) were almost same and the difference is less than 5%.

As per the observation table 1 to 3 increase in solar flux has little effect on output voltage of solar panel. When current increases, relative humidity drops which means low water vapors in the atmosphere, resulting to high flux which enhances high current production. Humidity reduced the amount of visible solar radiation reception. Efficiency is high during low relative humidity.

Solar flux is also proportional to efficiency. This means that when solar flux increases solar panel efficiency increases Fig.9(b) , 10(b) & 11 (b) shows that efficiency of solar panels increases with increases the solar radiation & efficiency decreases with decreases the solar radiation.

Fig.9(c) , 10(c) & 11 (c) shows the efficiency of thin film amorphous silicon solar panels, efficiency of submersible pump and the total efficiency of solar energy system with respect to time.

The effect of air temperature on the efficiency of thin film amorphous silicon solar panel is very less . Fig. 9(d) , 10(d) & 11 (d) shows that the efficiency of thin film solar panels increase with decrease the air temperature i.e. efficiency of solar panel is inversely proportional to air temperature.

The effect of wind speed on the efficiency of thin film amorphous silicon solar panel is less. Fig.9(e) , 10(e) & 11 (e) shows that efficiency of solar panels increases with increases the speed of wind & efficiency decreases with decreases the wind speed.

Conclusion

In this paper a model of amorphous Silicon solar panel based on mathematical equations of generating photovoltaic current and efficiency of solar energy system is proposed. The developed model find out the generating photovoltaic current under different solar radiation , efficiency of solar panel varies between 6.0 - 6.93%, efficiency of pump varies between 79.58-94.79% and the total efficiency of solar energy system varies between 5.03-6.18%which also have one solar fountain with two sprinklers. In order to validate the developed model, an experimental test setup was built and the results are found to be in close agreement with the observed reading of current shown by solar power conditioning unit. The current mismatch analysis indicates that the difference between formulated current & actual current error does not exceed 5%. It is cautioned that this conclusion may be applicable only to our amorphous Silicon solar panel and it may or may not be applicable to with other different solar panel.

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