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Abstract: Energy sources are very important for the development of a country. Due to global warming and other environmental effects there is an urgent need for clean energy. The study and research on solar photovoltaic systems is increasing to get the electricity on the electric power grid as well as on local domestic load level. This technology development nowadays focuses on the improvement related to the enhancement in the performance of these solar PV modules with factors dependent on the conditions at the installation sites. The present work is based on the experimentation that is conducted on a laboratory set made as per the hot and dry climate zone of India. Its experimental set up consists of two solar cell array PV modules with similar electrical and mechanical parameters under the experimental sets. Work is focused on the analysis of the real time performance records and measurements by high quality standard instruments at the time zone of different months in the year without and with the presence of effect of cooling due to artificial wind. The experimental observation describes that due to increase in the module temperature because of heating by solar irradiance degrades the performance of the solar PV module in terms of net energy output but by the inclusion of the controlled artificial wind based cooling mechanism helps in supporting the process of bringing down the solar cell PV module temperature as a result the gain of a net energy is increased for similar time constraints and irradiance. Performance measure ratio is also consequently observed to be improved. Finally the experimental and simulated energy by the artificial neural network (ANN) is observed for both of the wind cooled module and without the wind cooled module experimental and simulated energy. ANN based simulated model related estimated values of energy is observed to be closer to experimental values for both modules. ANN is helpful in finding the accurate estimation of the performance ration of solar as that of experimental results.

Keywords: PV solar, ANN, Energy

1. Introduction

Vitality and ecological issues are normal worries on the planet today [1, 2]. Solar energy is a renewable form of energy & potential solution to the population growth and industrialization pertaining to the energy crisis and environmental concerns [3-4]. PV modules convert solar radiation into electricity through photovoltaic effect and also have the highest power density among all renewable energy resources [5-6]. The solar irradiation, ambient temperature, humidity, wind effect and cleanliness of the surface affect the performance and efficiency of photovoltaic modules [7-11]. The efficiency of solar PV modules has correlation between temperature; decreases with increasing temperature [12-13]. The positive wind effect improves the performance and efficiency of the PV module by decreasing the temperature of a module [14-15]. In [16– 20] ANN have been used for modeling the behavior of PV cells. The effectiveness of the sunlight-based cell is professed to be 30% for the ideal band gap of 1.1 eV [21]. The ANN model was developed to analyze the exit temperature of a parabolic solar collector through irradiation as input parameter [22]. A relationship has been developed for the single and double diode PV model output with irradiance and temperature as input and found that the efficiency and maximum power were increased with increasing value of solar irradiance [23-25].

As referenced over, the vitality dispersion measure is huge in the photoelectric change cycle of PV modules. Up until this point, a great deal of work has been given to it. In any case, in a genuine sun powered PV module, the vitality circulation is reliant on the cell band gap, temperature, strong edges, recombination components and parasitic opposition. This is more muddled than the models that have been given [9]. To examine the entire vitality change systems and the commonplace exhibition, this paper proposes a coordinated vitality dissemination model for PV modules, offering a decent trade off among exactness and straightforwardness. In view of the guideline of sun powered cells, the vitality dissemination model for PV modules is created, to figure the electrical yield and warmth source age. The extent involved by various misfortune components and the circulation of episode sun powered radiation in genuine PV modules are examined and some encouraging relief arrangements are dissected. In this paper the performance ratio of PV modules with varying radiation, temperature, and wind effects was studied. The PV cell energy output by developing artificial network models was also studied.

2. Experimental Setup

Figure 1 shows the photo of the experimental set up. In this setup the artificial irradiation using the filament light bulbs is casted on the solar PV module. The number of lamps ON at a time can be varied from the rotatory switch placed under the lamp panels. By rotating the switch, the number of lamps increased and the irradiance falling on the PV panels increased. In this set up two modules of solar PV panels are fitted under the lamp. The module is placed in the lab hence no natural solar light is falling on the module and only this artificial irradiation of lamp falls on the modules.

The modules produce the electric current and voltage on receiving the artificial light from the lamps. Due to high intensity light the photovoltaic effect produces DC electric current and voltage. As the number of lamps in ON condition is increased the voltage output of the solar cell panel increases.

Fig.1: Solar PV module experimental setup (IET, Lucknow)

The voltage and current produced by the solar cells was observed on the measurement panel. The readings were taken in different months to incorporate the effect of heating of the solar module due to environmental temperature along with the heating due to light falling by the lamps at different intensity.

3. Observation data

The experiments were conducted during sunshine hours in the month of February, March, August and September in the year 2020. The artificial irradiance was varying from 50 Watt/m2 to 500 Watt/m2 while wind speed is taken 2.5 m/sec in case of wind cooling.

Table 1. Experimental Data record for PV module

Sample record	Month	Irradiation (Watt/m2)	Time	Ambient Temperature (oC)	Energy (W-hr)	
					Without cooling	With cooling
1	February	50	11:30	20	1.5	2.2
2		100	12:00	22	4	5.8
3		150	12:30	25	6	7.9
4		200	1:00	26	7.5	9.7
5		250	1:30	24	9	12
6		300	2:00	23	11.5	14
7		350	2:30	21	13	17
8		400	3:00	20	14.8	19
9		450	3:30	19	16	20
10		500	4:00	19	18	22
11	March	50	11:30	15	1.6	2
12		100	12:00	17	3.8	4.6
13		150	12:30	19	6	7.8
14		200	1:00	20	7.7	10
15		250	1:30	24	9.2	12
16		300	2:00	23	11.8	14
17		350	2:30	23	13.3	17
18		400	3:00	22	14.4	18
19		450	3:30	22	15.9	19
20		500	4:00	22	18	22
21	August	50	11:30	18	1.5	2
22		100	12:00	19	4	5.8
23		150	12:30	20	6	7.6
24		200	1:00	22	7.5	9.6
25		250	1:30	22	9	11
26		300	2:00	21	11.5	15
27		350	2:30	20	13	16
28		400	3:00	19	14.8	19
29		450	3:30	19	16	20
30		500	4:00	18	18	22
31	September	50	11:30	24	1.5	2.3
32		100	12:00	24	4	4.9
33		150	12:30	25	6	7.5
34		200	1:00	26	7.5	10
35		250	1:30	28	9	11
36		300	2:00	29	11.5	15

37		350	2:30	30	13	16
38		400	3:00	30	14.8	19
39		450	3:30	29	16	19
40		500	4:00	28	18	22

I_m= the current of solar panel when maximum power is drawn from panel =2.21 A

P_m = the maximum power =40 W

NOCT = Nominal operating cell temperature = 47 ^{0}C

Operating Range of the temperature safe working of solar panel=-20 ^{0}C to 90 ^{0}C

Bstc=temperature coefficient of power = -0.43

Fan rating = 3 W

INOCT =800 W/m^2

TaNOCT= 20◦C

τα = transmittivity and absorptivity product = 0.9

η_{stc} =11.3%

Module Area = 0.353 m^2

4. Results and Discussion

The irradiation, ambient temperature and wind speed as input variables are used to form a neural network model of the order of 3 x 40 as shown in table-1. The neural network follows an approach that can develop a mathematical equation from a given data and determine the output energy at any arbitrary value of these three inputs. The output matrix of order 1× 40, the neural network is trained with these new values ensuring that 70% data for training, 15% for validation and 15% for test. The energy output was calculated with or without wind cooling by using the value of solar cell module voltage and current. The observations in this setup are plotted to observe the energy output of solar panels with and without the wind cooling effect. The solar panel is made up of semiconductors and the voltage and current depends upon the valence electrons. As the temperature varies the number of electrons in and out of the valence bands varies. The response of semiconductors to solar cells can be improved by knowing the impact of temperature control during the power generation in presence of different irradiance.

The recorded values of ambient temperature at different artificial irradiance are plotted in Fig. 2. In this figure the irradiance may be observed to be varied from 50 to 500W/m2 and the readings were taken for a fixed value of wind speed kept at 2.5 m/sec in case of wind cooling otherwise wind effect is zero. The ambient temperature is observed to be varying as per the day time from 11:30am to 4:00 pm. Figure 3 shows the variations of the module temperature with or without cooling. It may be observed that the module temperature under wind cooling condition is lower under similar irradiance, time slots and ambient temperature. After recording the module temperature at different artificial irradiance the electrical efficiency is calculated using the sample records of Tmb and Ta.

Electrical efficiency:

$\eta_{el} = \eta_{stc} \quad 1- \beta_{stc}(T_{mb} - T_a))$

η_{el} (without wind cooling): 14%

η_{el} (with wind cooling):25%

It is observed that the electrical efficiency is improved under the effect of wind cooling as compared to without the wind cooling.

Electrical Energy:

$$\sum_{j=1}^{n} E = \eta_{elj} I_j t_j A$$

Electrical Energy (without wind cooling) =273W-hr

Electrical Energy (with wind cooling) =495W-hr

Since the time stamps, irradiance and panel area are same but the electrical efficiency is increased under the wind cooling condition hence the net energy output is also increased.

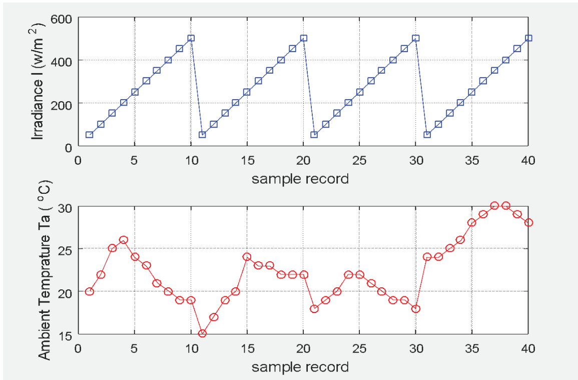

Fig.2: Variation in artificial irradiation and ambient temperature

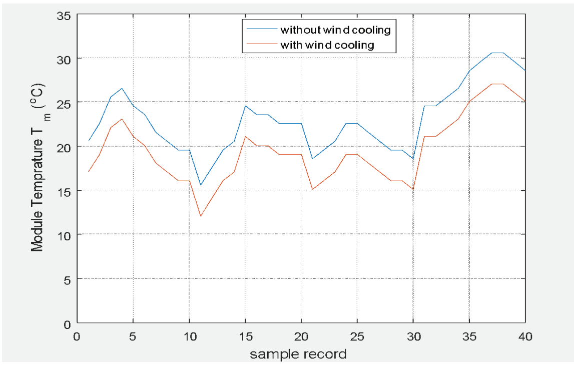

Fig.3: Variation in module temperature without and with wind cooling

Figure 4 shows the value of percentage performance ratio obtained using the observed energy in watt hour and expected energy that could be obtained at maximum power output loading condition. The %PR is plotted as a bar chart for both conditions i.e. without the wind cooling and under the wind cooling effect. The %PR is high and lies in between 80 to 100% under the wind cooling condition.

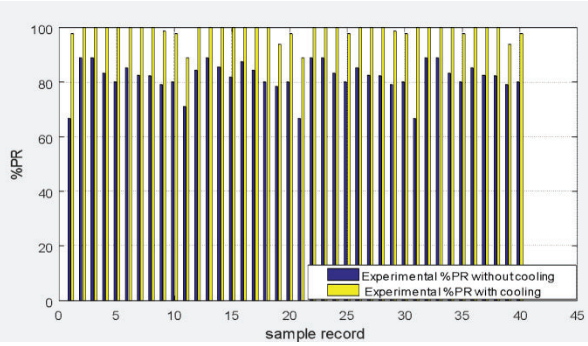

Fig.4: Instantaneous values of performance ratio

After getting the experimental and theoretical values, the ANN model is developed using the irradiance, ambient temperature and wind speed as input and the energy as the output variable. The model is developed by using the neural network toolbox in MATLAB. This toolbox separates the data records in training, testing and validation samples randomly. The training part is used to develop the ANN equation using available values of output and input. The accuracy and updates in the equation is performed using the validation data and finally all the developed equations under different instants were checked using the testing data. The ANN results are shown in the Fig. 5-11.

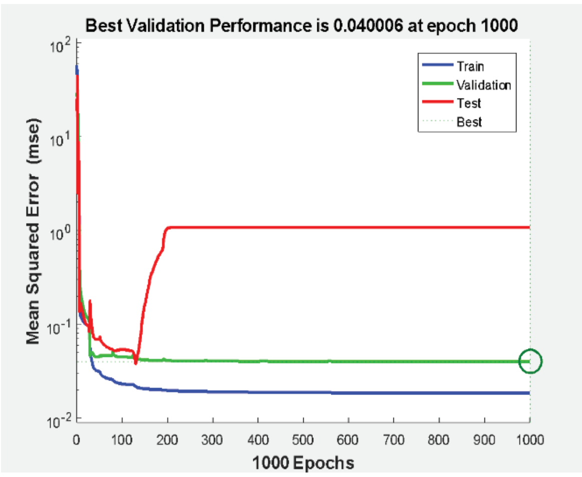

Fig.5: Mean square error for without wind cooling.

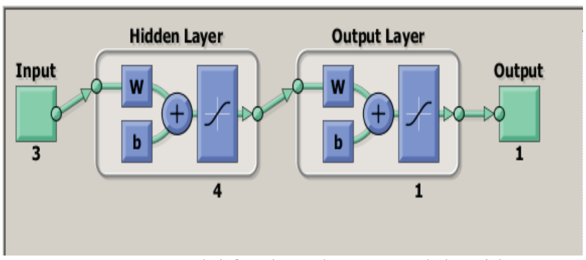

Fig.6: ANN model for the solar PV module without consideration of the effect of wind cooling.

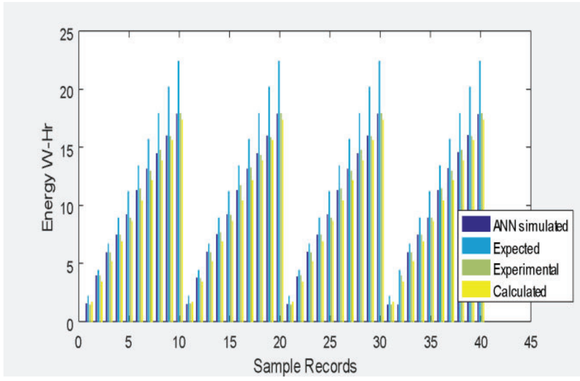

Fig.7: Energy output in different months without considering the wind cooling effect.

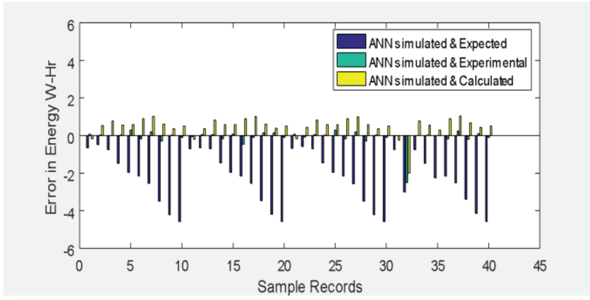

Fig.8: Error in the value of energy without wind cooling effect.

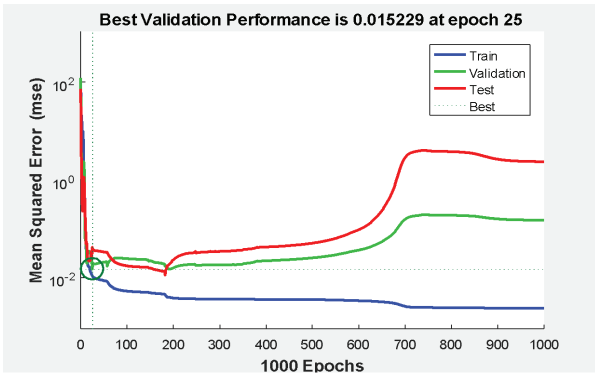

Fig.9: Mean square error for with wind cooling.

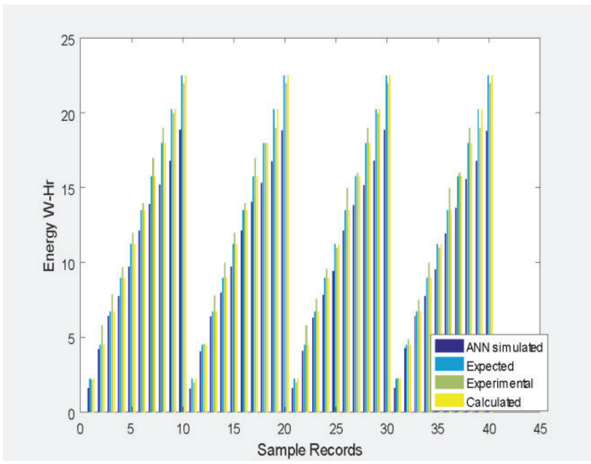

Fig.10: Energy output in different months with considering of the cooling effect.

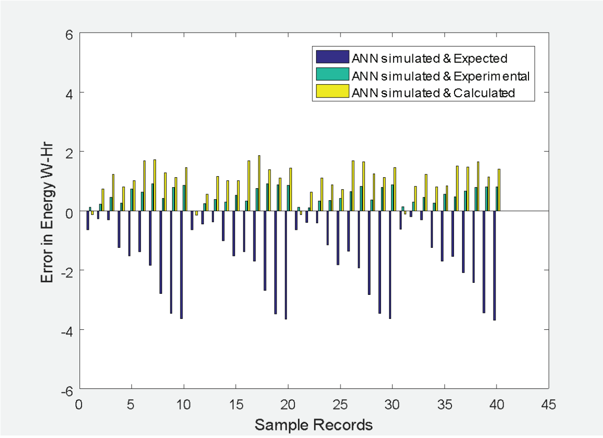

Fig.11: Error in the value of energy with wind cooling effect

5. Conclusions

Environmental impacts like ambient temperature, wind speed and solar irradiance plays a very important and unpredicted role as the natural parameter for the efficiency of the solar PV modules because of the thermodynamic losses. Solar PV module technology with high electrical efficiency is getting status of better options of electric power source for the regions where the average temperature is higher but good windy speed is available in specific locations as comparison with lower efficiency module technology that causes issues of lower power temperature coefficient. Experimental analysis observed in this work shows that the artificial wind based cooling process is very helpful in achieving higher gain of the electrical energy.

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