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A Soft Computing-Based Method to Assess Solar PV Module Performance in A Lab Setting While Accounting for Wind Effect

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Abstract: Energy sources are very important for the development of a country. Energy consumption by the people in a country in per capita plays very important role for the national growth of economy. The experimental set up consist of two solar cell array PV modules of 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 wind cooled module experimental and simulated energy.

Keywords: ANN, Wind, PV Module, PV array

1. Introduction:

Energy and environmental issues are common concerns in the world today [1,2]. The development and utilization of renewable energy have become important to ensure energy security, strengthen environmental protection and cope with climate change [3]. Among them, solar photovoltaic (PV) power generation is considered as one of the most attractive and promising renewable energy technology [4–7]. According to the well-known Shockley and Queisser (SQ) efficiency limit, the maximum efficiency of the solar cell is claimed to be 30% for the optimum bandgap of 1.1 eV [8]. Among the assumptions is that, all incident photons with energy above the bandgap are absorbed and each absorbed photon could generate exactly one electron-hole pair. Also, radiative recombination is assumed as the only recombination mechanism in the solar cell and the charged particles could be transported to the external circuit without any losses [9]. For a real solar cell, however, the conversion efficiency is much lower than that and losses occur in the whole physical process, including the carriers' generation, transportation and recombination [10,11]. Furthermore, for a solar PV module, there are other loss factors from cell to module (CTM), such as reflection and resistance losses in interconnection [12]. Thus, a comprehensive analysis and quantification of energy distribution in PV modules are essential to optimize the module structure and improve photovoltaic conversion efficiency [13,14]. In the literature, different methods to quantify energy distribution and mitigate losses in PV modules have been put forward [15–16]. Some of them analyzed optical losses of PV modules and evaluated the impacts of different approaches to reduce these losses, while other losses, especially heat source, are not mentioned in these studies [14,15]. Rodolphe et al. [4] and Dupre et al. [5] proposed some strategies to minimize thermal losses in solar photovoltaics, whereas heat generation was not considered. Louise et al. [2] quantified five intrinsic loss processes of the solar cell and introduced advanced devices to avoid these losses. Nelson et al. [2,3] focused on sub-bandgap and thermalization (hot carrier) losses, the necessity of hot carrier scattering and the challenge of photon flux. There is no doubt that intrinsic losses are dominant, but in real solar cells there are more loss mechanisms that influence the final conversion efficiency. Johannes et al. [2,4] presented a method to analyze the optical, thermodynamic and electrical losses, as well as the electrical output. The focus of this research is the free energy or chemical potential, rather than incident power. Hanifi et al. [2,5] introduced an optical and electrical model to estimate the power loss and heat source with pseudo and ideal fill factor, which are not directly available. Shang et al. [26] studied the electromagnetic absorption, non-isothermal carrier transport and heat flow in solar cells by finite element method (FEM) on the COMSOL multi-physical platform. Besides intrinsic losses, more factors were introduced and the simulation results were closer to the actual cells, while the limitation of this type of research is hard to verify through experiments. Wang et al. [2,7] probed into both the intrinsic and extrinsic losses in solar cells, without considering the loss from cell to module.

2. Related Work:

A few improvement of execution examination of PV modules. Likewise there are a few usage of Fault Detection of PV modules utilizing the IoT Wireless/wired Networks. Likewise there are novel executions of Solar PV modules checking sun oriented PV power molding unit Fault Detection, Home Appliances, Maintenance. Work done in such manner by scarcely any analysts is talked about here.

The brilliant sun based photovoltaic distant observing and control unit utilizing the Internet of Things Technology is actualized [1]. With progression of innovations the expense of sustainable power source hardware's is going down all around the world empowering enormous scope sun based photovoltaic establishments. This monstrous size of sun based photovoltaic arrangement requires modern frameworks for robotization of the plant checking distantly utilizing online interfaces as greater part of them are introduced in blocked off areas and hence unfit to be observed from a committed area. The conversation in this paper depends on usage of new savvy strategy dependent on IoT to screen a sun powered photovoltaic plant for execution assessment. This will encourage preventive upkeep, deficiency identification, recorded investigation of the plant notwithstanding constant checking.

For Monitoring Solar PV Power Conditioning Unit dependent on IOT System is planned [2].An viable usage of a shrewd distant checking framework for Photovoltaic (PV) Power Conditioning Unit which is utilized in a nursery situation. The proposed framework configuration can be introduced in sun powered PCU so as to tackle the board issues, upkeep and abbreviates the interim to fix. They have planned a shrewd far off observing framework dependent on web of thing for checking Solar PCU. This framework had joined far off observing for sun powered PCU through web utilizing host, network Global Positioning Radio Service, inserted framework entryway and different parts. The aftereffect of our exhibit shows the framework can screen store and control information from sun oriented PCU. Subsequently, the far off checking capacities are acknowledged in genuine framework.

Computerized Controlling Software System and Intelligent Monitoring framework for sunlight based vitality is actualized [3]. The investigation of the sun based boards on an occasional premise is essential to improve execution of the sunlight based force framework. To get the more sun oriented vitality of the photovoltaic (PV) framework is conceivable through a clever checking framework. The checking framework has quickly expanded its prominence due to its easy to use graphical interface for information securing, observing, controlling and estimations. So as to screen the presentation of the framework particularly for sustainable power source application, for example, photovoltaic, information securing frameworks had been utilized to gather all the information with respect to the introduced framework. The improvement of a brilliant mechanized observing and controlling framework for the sunlight based board is portrayed, the center thought depends on IoT (the Internet of Things). The benefits of the framework are the presentation of the PV board framework which can be observed and investigated.

Programmed identification checking of Solar Panels Using Internet of Things is created [4]. Look at and checking issues on a lot of Solar boards, utilizing Internet of Things. A compelling execution of distant watching framework for sunlight based Photovoltaic cell (PV) and Power Conditioning Unit. Today, with the development in sensor innovation it is a presumable choice to associate the PV vitality frameworks to the cloud (web) with the assistance of Internet of Things, the investigation of the presentation, profitability and productivity can be determined effectively when framework is associated with cloud. With the product innovation checking of immense PV boards are made simple and precise. In yield of framework the information are observed physically and noted down in journals and dominate record. The sensors, for example, temperature sensors are fixed on the PV boards and the current voltage created are been sent through remote correspondence and screen in base station (framework).

In view of IoT the Smart Monitoring and Controlling of PV System is executed [5]. So as to investigations the presentation of photovoltaic frameworks, they have built up an ongoing master framework focal microcomputer utilized as a miniature worker and can be effectively counseled from various programmed stations. The created framework can guarantee the observing, management, and control of PV frameworks introduced over a wide region, on one hand, an a general PV frameworks information base, on the other. This framework presents a plan of a widespread information securing framework with accessible segments and which is effectively available through a worker. This framework presents a novel method for shortcoming diagno in PV frameworks with Internet of Things (IoT).This work depicts the improvement of a framework intended for power age incorporation.

3. Methodology:

There are 4sub units in the system which can be classified as power generating unit with artificial radiation source, main measurement unit, logger-plotter unit and inverter and controller unit. Power generating unit consists of two modules which are fixed on a small structure. This structure allows the user to change tilt angle (of modules) with the help of gear box. There are two halogen light fixtures attached with this structure which provides the artificial radiation for PV modules. Radiation level of this unit can be changed with the help of regulator and on-off action also can be done with the help of switch box (2 switches). Main measurement unit and inverter-controller box are connected to each other through connectors at the back. In this way, ports of charge controller and inverter will become active for different circuit connections. Modules output will be connected with main controller unit through back connectors and will enable the module 1 and 2 ports on the front panel of measuring unit for different connections of modules. Data logger plotter unit will be connected by module ports and log the data in PC for storage and plotting. After making these connections and settings, different experiments can be performed by making various connections of different components according to experiment.

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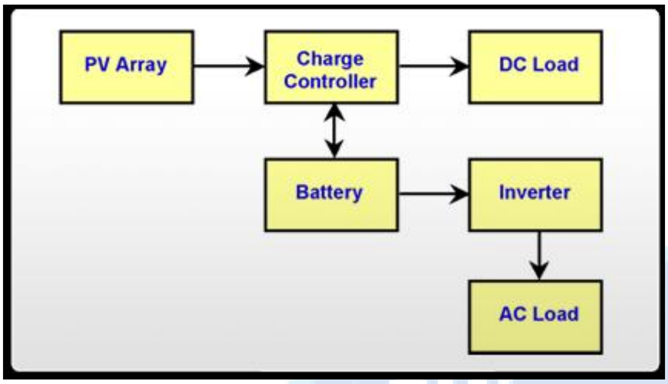

Fig 1: Flowchart of PV module system [8]

Fig 2: Experimental Set-up of PV module[10]

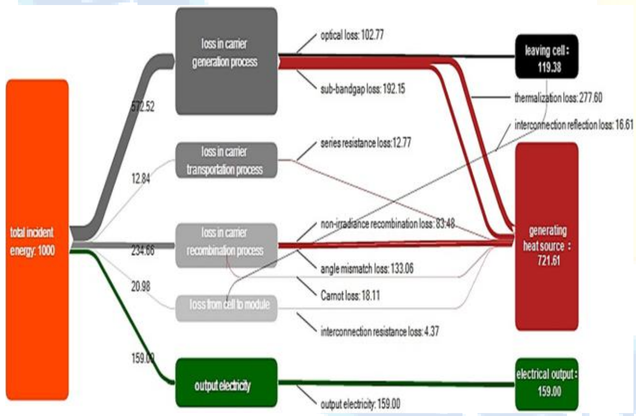

Fig 3: The distribution of incident solar radiation in a typical PV module (unit: W/m²).[11]

The experiment is performed for four and half hours weekly with artificial irradiation in the month of March, May, September and December by keeping one module cooled while another not cooled. Weekly average values are taken to analyze the energy. In experiment, radiation and wind speed are two artificial parameters and controllable while ambient temperature is natural parameter

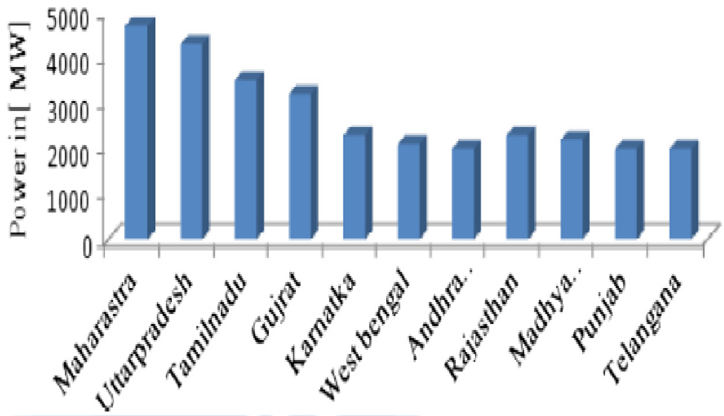

Fig. 4: State wise target of solar power.[11]

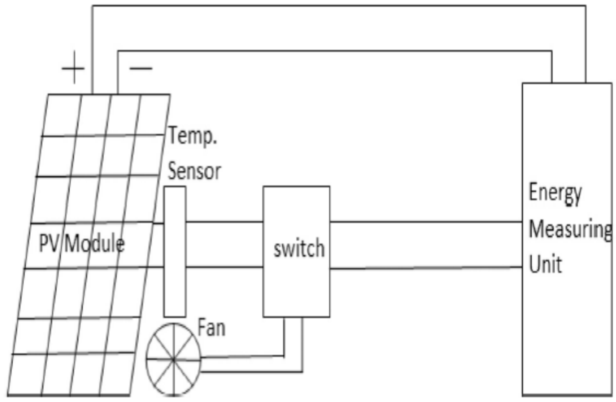

Fig. 5: Block diagram representation of cooled module.[13]

First of all equal amount of irradiation (G) falls on both modules, which is varied from 50 W/m2 to 500 W/m² in step of 50, at the same instant Ta, Tmb, Voc and Isc of individual PV modules are measured by mini solar power plant kit. After some time, the radiation is increased and measuring steps are repeated, this time Tmb of not cooled module is obtained higher than the Tmb of cooled module. The concept behind cooling is that when Tmb is more than Ta, it is sensed by temperature sensor and signal goes to microcontroller which makes switch ON and fan starts cooling in order to bring down the Tmb. As soon as the Tmb becomes closer to or equal to

Ta, microcontroller turns OFF the switch. Fan speed is also measured to observe its effect on solar cell temperature and thermal energy if collected. For not cooled PV module Tmb is theoretically calculated based on approaches given by various researchers and compared with the measured values, while for cooled module Tmb is theoretically calculated including wind effect and compared with measured values by temperature sensing device. To observe the effect of wind speed, module temperature is calculated by different approaches and measured also. Mathematical expressions for these approaches are:

$$T_{mb} = T_a + (TNOCT - TaNOCT) * \frac{I}{INOCT} \quad (5)$$

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Although this expression accurately determines the module temperature but it neglects the wind effect. In addition to the irradiance, temperature the wind effect is integrated thus considering wind effect Tmb is calculated as:

$$T_{mb} = Ta + \frac{I}{INOCT}(TNOCT - TaNOCT)\frac{HwNOCT}{Hw} * [1 - \frac{ήstc}{\tau.a}(1 - \beta stc.\ Tstc)] \quad (6)$$

Above two equations are used to calculate theoretical Tmb of not cooled module and cooled module. Hence temperature dependent electrical efficiency of both modules can be calculated by

$$\eta_{el} = \eta stc\ [1 - \beta stc(Tmb - Ta)] \quad (7)$$

Now the measured value of Tmb is used to calculate the actual electrical efficiency by Eq. (3).

Electrical energy of both modules is calculated by following equation.

$$E = \sum_{j=1}^{n} \eta e I j t j A \quad (8)$$

$$\Delta E = E_{\text{cooled module}} - E_{\text{not cooled module}} \quad (9)$$

$$PR = \frac{Actual\ KWh}{Expected\ KWh} \quad (10)$$

4. Result and Discussion:

In order to consider the seasonal effect of temperature the experiment is conducted once in a week periodically from 11:30 am to 4:00 pm in the month of February, March , August and September in year 2020. The mean value of temperature in each month is plotted here. Artificial irradiance is varying from 50 Watt/m^2 to 500Watt/m^2 while wind speed is constant during the experiment in each month. Forty samples are taken, first ten samples in February month, next ten in the March and similarly in the month of August and September as shown in Figure.

Table 1: Experimental Data record for PV module

Month	Irradiation (Watt/m^2)	Time	Ambient Temperature (°C)	Wind Speed (m/sec)	Energy (W-hr) Without cooling	Energy (W-hr) With cooling
February	50	11:30	20	2.5	1.5	2.2
	100	12:00	22	2.5	4	5.8
	150	12:30	25	2.5	6	7.9
	200	01:00	26	2.5	7.5	9.7
	250	01:30	24	2.5	9	12
	300	02:00	23	2.5	11.5	14
	350	02:30	21	2.5	13	17
	400	03:00	20	2.5	14.8	19
	450	03:30	19	2.5	16	20
	500	04:00	19	2.5	18	22
March	50	11:30	15	2.5	1.6	2
	100	12:00	17	2.5	3.8	4.6
	150	12:30	19	2.5	6	7.8
	200	01:00	20	2.5	7.7	10
	250	01:30	24	2.5	9.2	12
	300	02:00	23	2.5	11.8	14
	350	02:30	23	2.5	13.3	17
	400	03:00	22	2.5	14.4	18
	450	03:30	22	2.5	15.9	19
	500	04:00	22	2.5	18	22
August	50	11:30	18	2.5	1.5	2
	100	12:00	19	2.5	4	5.8
	150	12:30	20	2.5	6	7.6
	200	01:00	22	2.5	7.5	9.6
	250	01:30	22	2.5	9	11
	300	02:00	21	2.5	11.5	15
	350	02:30	20	2.5	13	16
	400	03:00	19	2.5	14.8	19
	450	03:30	19	2.5	16	20
	500	04:00	18	2.5	18	22
September	50	11:30	24	2.5	1.5	2.3
	100	12:00	24	2.5	4	4.9
	150	12:30	25	2.5	6	7.5

	200	01:00	26	2.5	7.5	10
	250	01:30	28	2.5	9	11
	300	02:00	29	2.5	11.5	15
	350	02:30	30	2.5	13	16
	400	03:00	30	2.5	14.8	19
	450	03:30	29	2.5	16	19
	500	04:00	28	2.5	18	22
						2.2

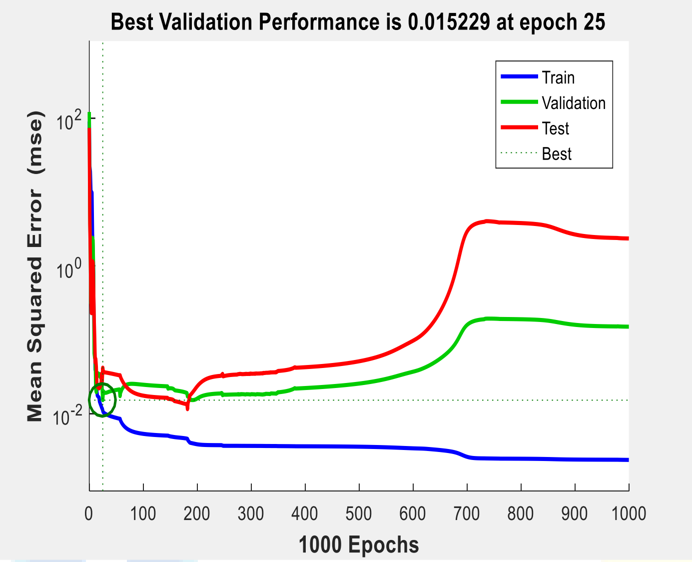

Fig 6: Mean Square value during development of ANN model

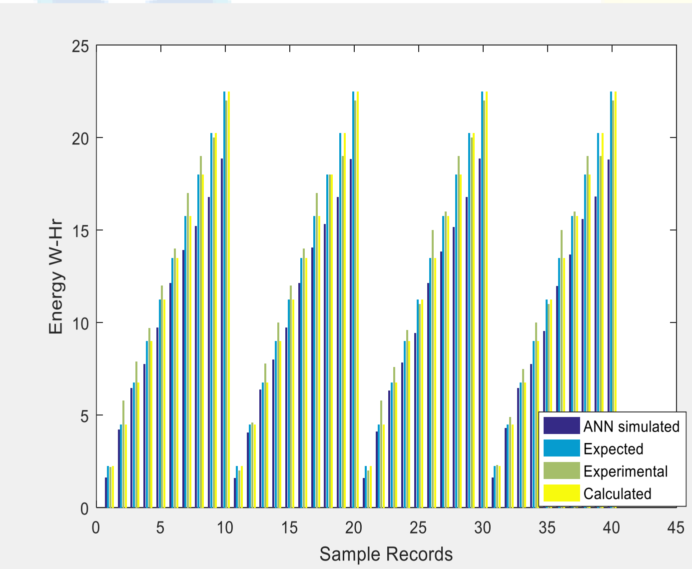

Fig. 7: Variation in the value of energy output in different months with considering the wind cooling effect.

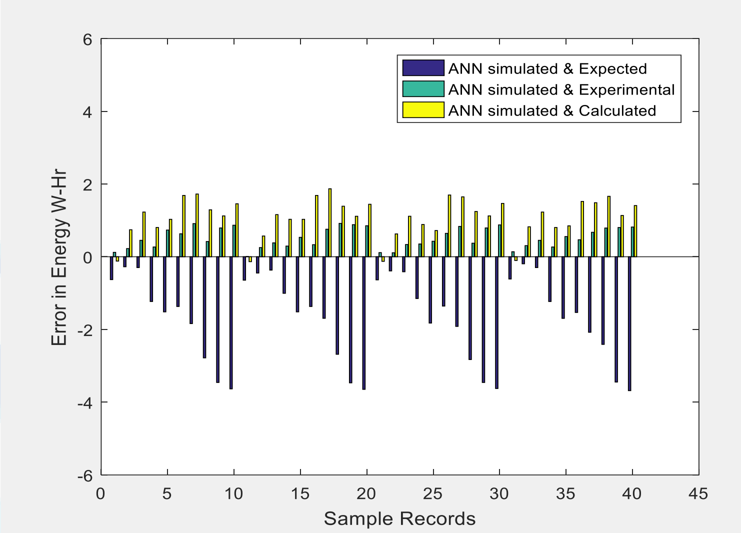

Fig 8: Error in the value of energy obtained at different time in different months with wind cooling effect.

5. Conclusion:

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. This work describes that the cold regions in our country are better for solar PV module systems because of lower electrical load demand like domestic applications. This work justifies that in future scope if the solar PV system with controlled cooling mechanism by forced wind power is managed than utilization of more energy is expected. This additional energy is helpful in heating, swimming pool, bathroom hand drawer etc in the cold regions.

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