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Online Tracking of Maximum Panel Power Output in Photovoltaic Stand Alone System with Different Insolation

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ABSTRACT: In solar photovoltaic stand - alone system the basic device is the PV module which is used to charge the storage device during daytime and supplies power to the load during dusk to dawn. This paper presents knowledge based system for evaluating power generation system in PV model. The performance of a PV system depends on the environmental factors such as irradiation and cell temperature. It is a non-linear characteristic and this characteristic is varied in different PV technologies. To solve this problem, an intelligent technique called the Artificial Neural Network (ANN) can be talented solution for obtaining the maximum output power in real-time operation. Initially this work focuses on the simulation of characteristics of the panel power output of PV module at different level of radiation. Thus panel power output is evaluated different level of radiation and the simulated characteristics are figure with the 3D nomogram analysis. The database device using microcontroller is designed as per the simulation studies and it is attached in the solar panel to monitor the real time value of PV standalone system. The above mentioned simulated comparison is validated with results of local climatic data and its accuracy of the proposed methods has been measured with the error estimation method. Thus the proposed method will be very useful for determining the real-time optimum operating condition of PV system with estimated maximum power generation.

KEYWORDS: PV Standalone System, PV Module, Panel Power Output, Knowledge Based System, Artificial Neural Network.

1 INTRODUCTION

Photovoltaic is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight [1]. Major components of solar photovoltaic system are solar photovoltaic Panel, battery to store energy, controller to prevent battery from over charging and discharging and a cable that connects the panel to battery and with each other to complete the system [2]. Output voltage from a solar panel will vary depending upon the solar panel design, the attached load, and the amount of light striking on its surface. Most panels are rated in watts of power that can theoretically be produced on a high intensity day. For an example, a 40W panel with a 16V output will generate 40W / 16V = 2.5A peak current. In reality, these peak currents are normally not achieved, and true outputs are about 80 to 90% of the ratings [3].It is the nature of a solar panel, that energy will only be available for a limited time frame during the day and also during winter. Further, conditions with heavy overcast skies or panels coated with snow will also limit energy production. To maintain continuous operation of a load, it is therefore necessary to have a storage battery that can be discharged and recharged upon demand [4]. In order to prevent an overcharge of the battery, it is necessary to use a controller between the panel and the battery .Currently, lead-acid battery is used as storage device for photovoltaic applications on account of low cost and high storage capability. Overcharging of a lead-acid battery will result in hydrogen gas generation, and shorten its life. Regulation of the solar panel output is performed by monitoring the lead acid battery voltage level and applying a shunt load across the panel when the battery is fully charged [5].In order to determine the characteristics of the PV module, the Power vs. Voltage (PV) and Current vs. Voltage (IV) curves must be constructed. The current and power outputs of photovoltaic modules are approximately proportional to sunlight intensity. At a given intensity, a module's output current and operating voltage is determined by the

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characteristics of the load and it is necessary to operate the PV at its Maximum Power Point [6].Manufacturers of photovoltaic modules, provide only a few experimental data about electrical and thermal characteristics of the panel. Some of the parameters required for adjusting photovoltaic module models such as the light-generated or photovoltaic current, the series and shunt resistances, cannot be found in the manufacturer's data sheets. All photovoltaic array datasheets basically has the following information: the nominal open-circuit voltage V_{oc}, the nominal short-circuit current I_{sc}, the voltage at the maximum power point V_{mp}, the current at the maximum power point I_{mp}, the open-circuit voltage/temperature coefficient K_V, the short-circuit current/temperature coefficient K_I, and the maximum experimental peak output power P_{max}. In this paper three remarkable parameters namely open circuit voltage (V_{oc}), short circuit current (I_{sc}) and maximum power point tracking (V_{mp}, I_{mp}) given by the manufacturer of the PV module is used for the prediction of PV characteristics of solar panel and panel power output for different level of radiation ranges from 100 to 1000W/m^2 . For the simulation of PV module an equivalent circuit model is proposed and in that, solar cell is modeled as a current source, I_{ph} which is proportional to ambient irradiance level and to the temperature of the panel [7]. For losses estimation, a series resistance R_s and a parallel resistance R_p are included in the circuit. The curve fitting factor was considered as an adjusting parameter so that at rated input values of temperature and irradiance, the data sheet values of the output were obtained as model outputs. The same approach was taken to obtain the temperature and irradiation correction coefficients. In another model active compensation is done at every moment is affected through a function for R_s, V_c and I_{ph} as a function of temperature and irradiance [8]. In the present model the equivalent circuit methodology has been attempted with Shunt resistance in parallel using circuit simulator in MATLAB/SIMULINK.The validity of the model with the new equation has been tested through prediction using ANN. For this purpose, irradiation and temperature are utilized as the input information of ANN Network and in the output layer it predicts maximum performance of PV system power generation it is compared with local climatic data. The details are described in this communication.

2 Method

2.1 Artificial Neural network

ANN method using back propagation algorithm is utilized to estimate the maximum power generation of PV modules. This approach can be done because the open circuit voltage depends on the variations in insolation and cell temperature, while the cell temperature may be changed due the ambient temperature. From the practical point of view, the open-circuit voltage of PV module can be easily measured by interrupting the normal operation of the system temporarily and storing the measured value [9].On the other hand, the cell temperature can be simply measured at the backside of PV modules.

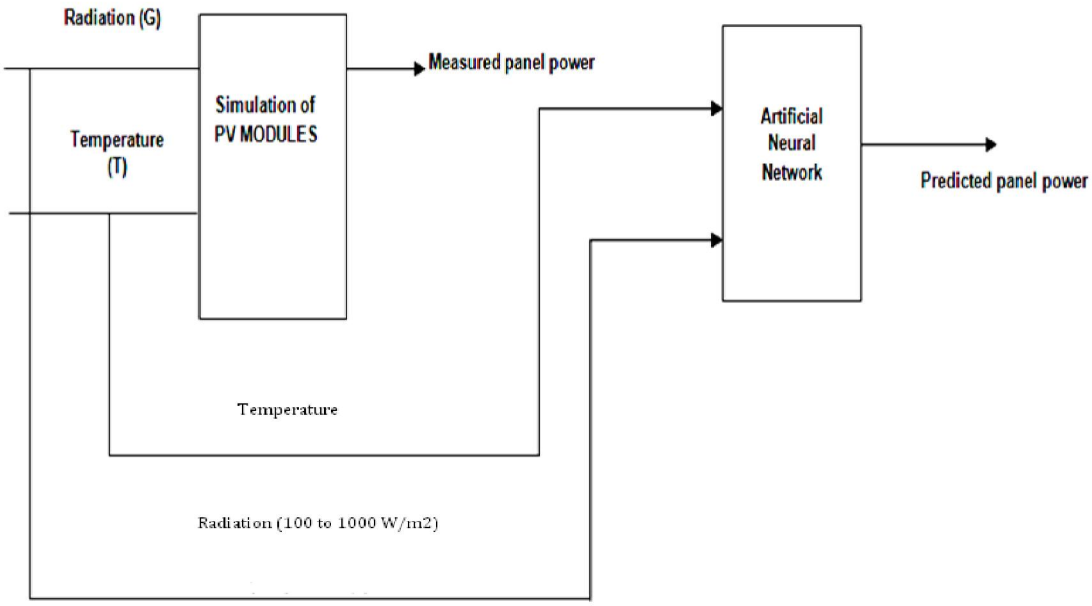

Fig. 1. General block diagram of the proposed system

The proposed system consists of two main blocks simulation of PV modules block and ANN blocks. The main objective of simulation of PV module block is to find the parameters of the nonlinear IV equation by adjusting the curve at three points: open circuit voltage, maximum power, and short circuit current, these three points are provided by all commercial array datasheets, with the parameters of the adjusted IV equation one can build a photovoltaic circuit model with any circuit simulator by using basic math blocks. Computer simulation program of PV module was developed for calculating the IV and PV characteristics at different level of radiation. The Simulation part of PV Module consists of three parts namely User friendly part, input part and internal model part. User Friendly block is designed in such a way that it holds only basic information about the simulation of the particular PV module such as type of model, manufacturer, nominal power and technology of the panel etc. The input block provides the basic information required in the nonlinear IV equation of the equivalent circuit in general form. These parameters are obtainable in manufacturer data sheets. The parameters include are: the reference irradiation (G_{Rref}) and module temperature conditions (T_{Ref}) during measurements, short circuit current (I_{sc}) and open circuit voltage (V_{oc}) at the given conditions. I_{mp} and V_{mp} are the operating point in the region of the maximum power point and current temperature coefficient, by default it can be taken as about 0.05%/°C. After defining the basic parameters, the program still needs some additional parameters to design the internal model parameters of the PV panel, such as shunt resistance and series resistance. In the real-time operation of the PV module some losses exist, they have been added to the model as a resistance in series (R_S) and another in parallel (R_{Sh}) to get a more real behavior [10]. For an ideal cell, R_{Sh} would be infinite and would not provide an alternate path for current to flow, while R_S would be zero. The R_{Sh} value can be obtained on the basis of measured IV characteristics of the module. R_{Sh} is the inverse of the slope around when voltage is zero. It is possible to approximate the series and shunt resistances, R_S and R_{Sh}, from the slopes of the I-V curve at V_{OC} and I_{SC}, respectively, therefore, series resistance and shunt resistance at different level of radiation are predicted. The main aim of internal model block is to develop simple and more realistic models for the photovoltaic peak power and at the same time to use the maximum of information provided by the manufacturer's data sheet. This block design the model of PV model with the information given in the input block and shows the results for any specified operating conditions .This model is very useful for real-time applications where the power needs to be monitored and it is referred to obtain the maximum power at different level of radiation. Thus the simulation block is designed using MATLAB/SIMULINK. Second block is ANN block, in that artificial neural network with specifically feed-forward back propagation algorithm is developed. ANN overcomes the limitations of the conventional approaches by extracting the desired information directly from the experimental data. The fundamental processing elements are neurons. Network is a parallel distributed information processing technique [11]. In this Configuration, networks are arranged in layers, with the first layer taking in inputs and the last layer producing outputs. The middle layers have no connection with the external world, and hence it is called hidden layers. Each layer is connected with Neurons in between them. The sizes of middle (hidden) layers are determined by trial and error methods. A typical ANN operation starts with the training stage, which modifies the connection weights in some orderly fashion using a suitable learning method [12]. To train this network, back propagation algorithm based on experimental result is used. The space of input X of dimension n (Level of the input) is connected to the space of the output Y of dimension m (Level of the output) by the intermediary of a hidden level. This level has a fixed number of neurons, but which varies from a study to another according to the complexity of the problem. In the present study, architecture is considered; multi-layer perception networks with back propagation of the gradient. They are probably one architectures most current and simplest non-linear network. The capacities of modeling of these networks are analyzed. The multi-layer networks are composed of a input layer whose neurons code the information presented at the network, of a variable number of internal layers called "hidden" and of a input layer containing as many neurons as of desired responses. The neurons of the same layer are not connected between them. The training of these networks is supervised. The algorithm used during this training is known under the name of method of Back propagation learning BPL. This method of training is divided into two phases: A phase of propagation, which consists in presenting a configuration of input at the network then to propagate this input gradually layer of input to the output layer while passing by the hidden layers. A phase of back propagation, which consists, after the process of propagation, to minimize the error made on the whole of the examples presented, error considered as a function of the synaptic weights. This error represents the sum of differences squared between the calculated responses and those desired for all the examples contained as a whole of training generally, the stages of construction and validation of the neural networks are divided into phases: the input of the networks, the output of the networks and the tests of the networks with real time data. In our applications, the MATLAB software, "neural networks Toolbox" is used in order to carry out these stages. For our application, irradiation and temperature are utilized as the input information of ANN Network and in the output layer it predicts maximum performance of PV system power generation and the simulated characteristics are explained using 3D nomogarm. Irradiation and temperature are some of the factors which affect panel power output .They are Output rating of the solar panel, intensity of solar radiation and hours of available light. The average current I_{avg} generated by the solar panel is proportional to the ratio of the actual solar radiation to 1000 W/m^2 multiplied by I_{sc} (short circuit current). Therefore, the average current would be

$$I_{avg} = (G / 1000)\ W/m^2 * I_{sc} \quad (1)$$

G = Level of radiation (100 to 1000 W/m^2)

In this proposed model, the radiance level is considered to vary from 100 to 1000 W/m^2.To show the effect of irradiance on the performance of a module the temperature is kept fixed at 25º C and the values of irradiance are changed to different values. It is quite clear that irradiance has a major effect on the short circuit current and indeed the relationship between irradiance and the short circuit current is a linear one [13]. Power was also calculated at different levels of irradiation. It are seen from the current and power characteristics, the nonlinear nature of the PV array is apparent. The proposed model can be applied to any brand of PV modules by setting the parameters properly. Thus the power produced by the cell in Watts can be easily calculated along the I-V sweep by the equation. [14]

3 Results and Discussions

3.1 Representation of Panel power output in 3D Nomogram

Using this proposed model, we can create a database of the panel power output for various rated panels. This type of data analysis is more suitable in making initial determination of panel power output of the particular rated panel. The database is represented in a 3D nomogram. These types of nomogram are very useful to the quality control engineer for analyzing the power output of group of panels. The 3D Nomogram of PV Module with the Panel Power output of 40, 80 120 and 160 watts are simulated by considering its short circuit current at different level of radiation. The simulated panel power output is compared with the field data.

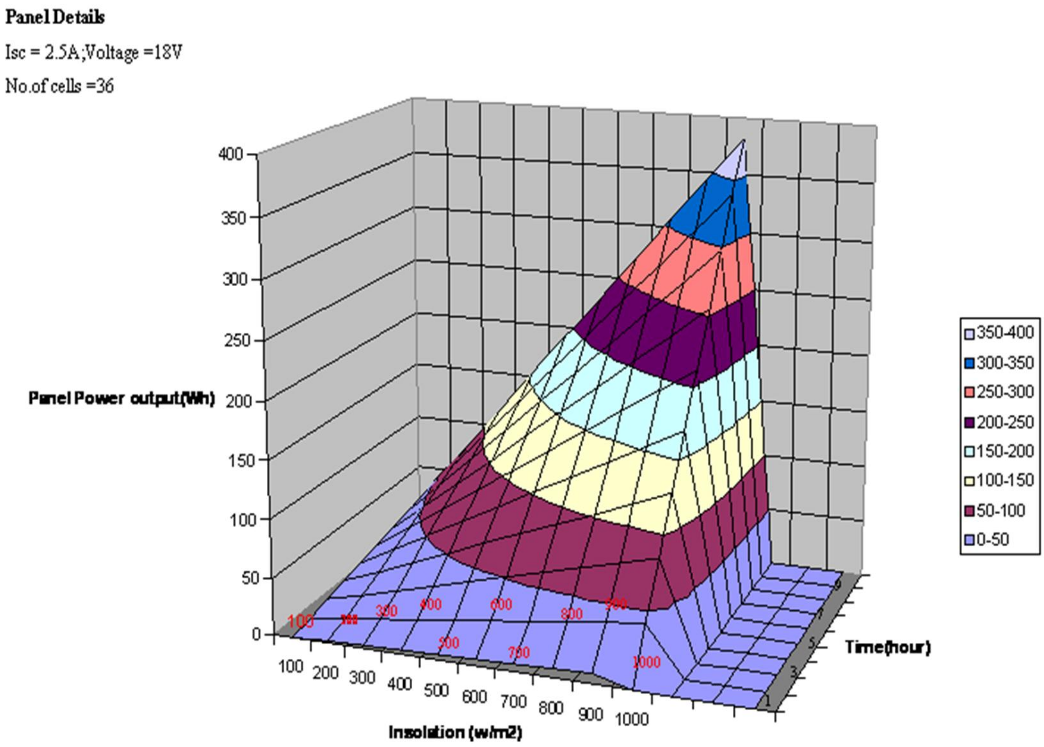

Fig. 2. 3D Nomogram of PV Module with the Standard Panel Power output of 40

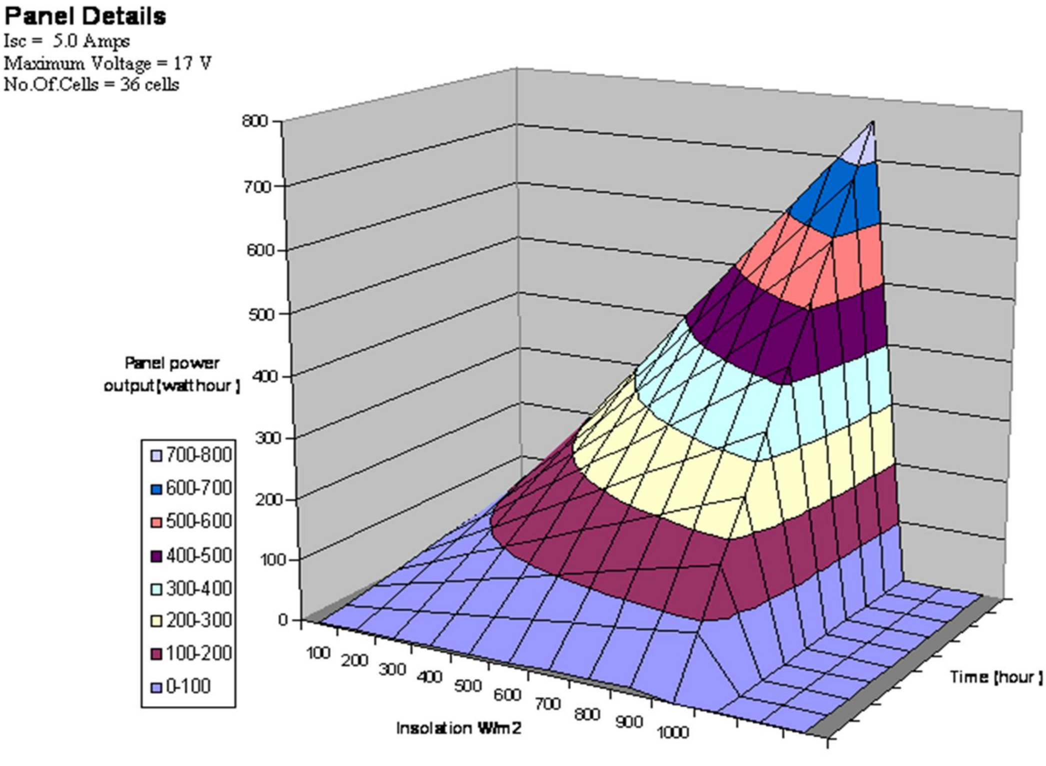

Fig. 3. 3D Nomogram of PV Module with the Standard Panel Power output of 80

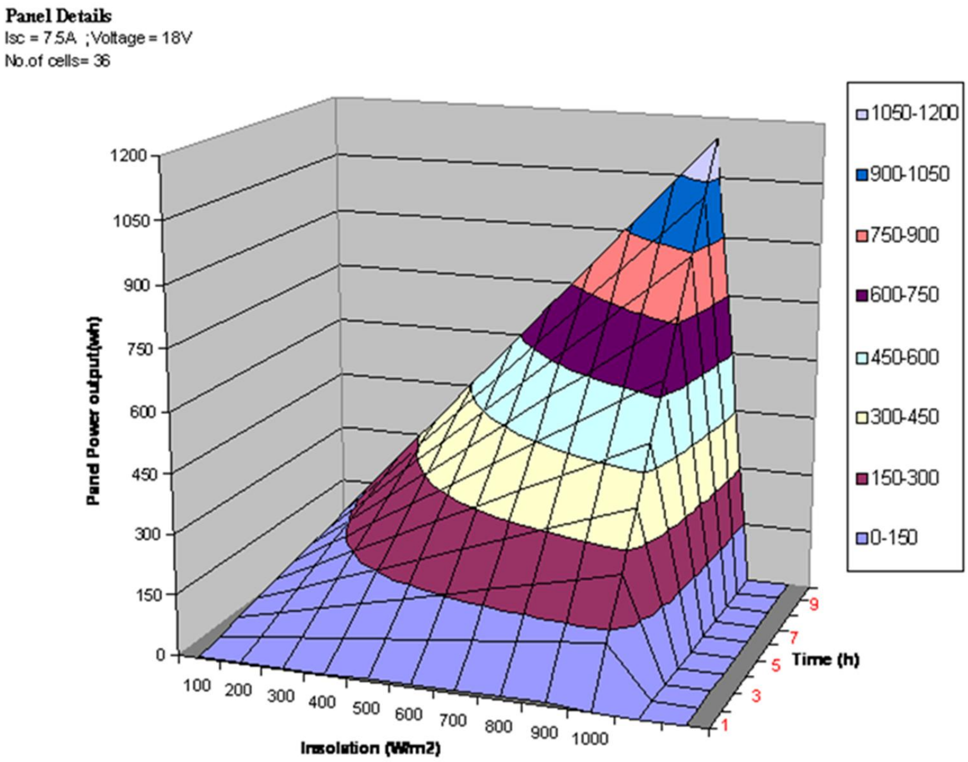

Fig. 4. 3D Nomogram of PV Module with the Standard Panel Power output of 120

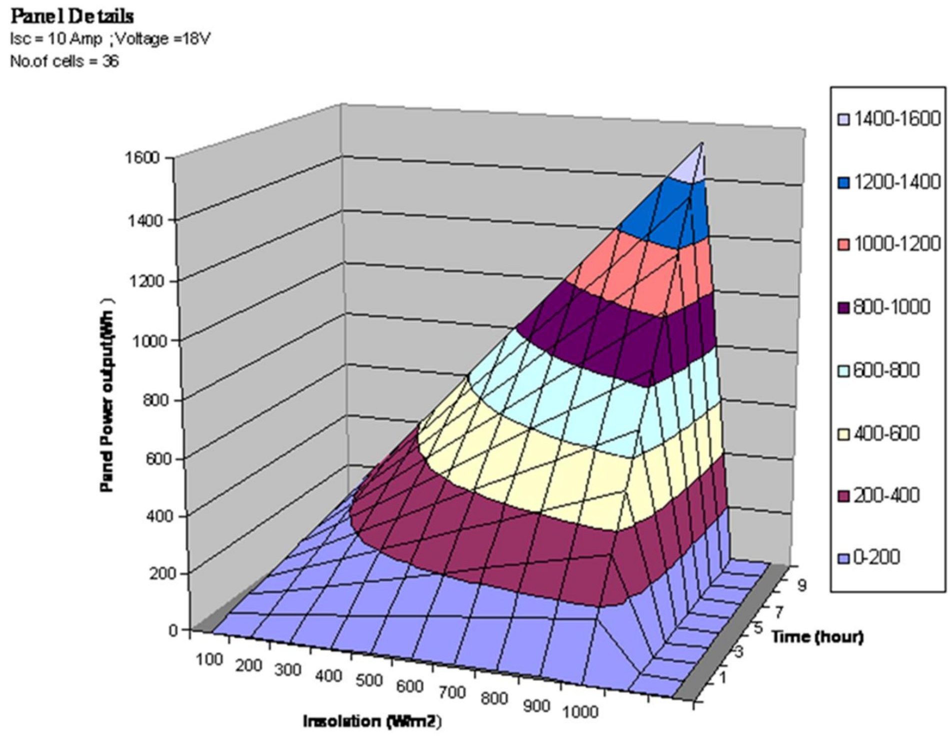

Fig. 5. 3D Nomogram of PV Module with the Standard Panel Power output of 160

3.2 Design of Real-Time Simulator for Power Generation of PV Module

Based on the simulation study using MATLAB; a database device for PV model is being designed to monitor parameters of PV standalone system and to calculate the power generated by the total solar radiation falling on a panel during insolation per day. This database device is designed using microcontroller

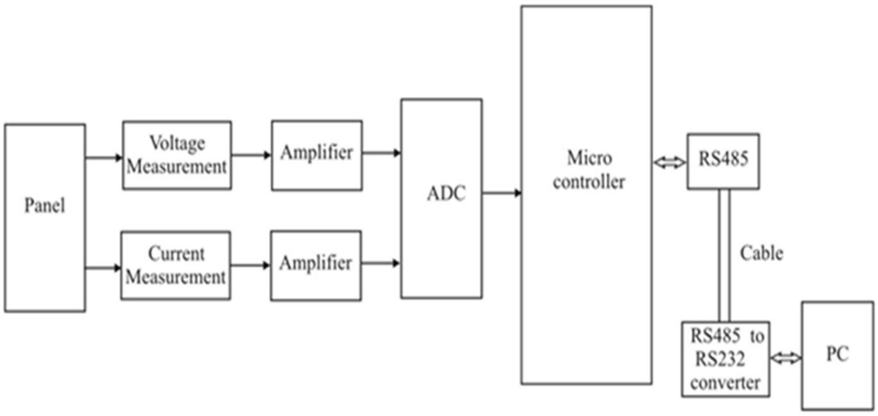

Fig. 6. Block diagram of database device

The data base device consist of sensor for voltage and current measurement, ADC device, Control system using microcontroller and a Monitoring PC connected via RS 232. It contains two LEDs: RED and GREEN to display the status of the watt hour generated per day. Every solar panel is rated by their peak power or Watt-hour. So, for calculating the peak power of the panel, the watt - hour value for the whole day will be compared with the Wh generated per day,

1. Once if it is lower than the required Wh, RED LED will glow otherwise GREEN LED will glow.
2. On the next consequent days, when the Wh lost is achieved in addition to the present day Wh, and then GREEN LED will glow.

In our study we have used two sub-panels each consists of 36 silicon cells. Voltage at maximum power is 17V, short circuit current (I_{sc}) is 2.5A, maximum power is 40+10%, 11 Watt CFL is used as the load which has operating voltage of 12V ,with current consumption of 1.13 A ,dusk to dawn is 12 h/day and discharge output = 1.13 *12 = 13.56 Ah /day. Provision is made to collect battery temperature (both ambient and cabinet), current, voltage, energy input and intensity of solar radiation using data logging system. Average current over particular insolation hours is calculated using the formula (1) and panel power output is calculated for different levels of radiation by knowing the average current and voltage as per designed model. The radiation in terms of lux*1000 is in turn converted to W/m^2. Likewise the Panel Power output is calculated for all sunless days and sunny days. Error estimation method is carried out using sigma plot so as to get relationship between measured and predicted data. For a typical field data collected on cloudy (sun less) days, the maximum lux is 30,000/mm^2 and sunny days the maximum lux is 90,000/mm. From the result it is seen that our model predicts to a larger extent the output of solar panel within experimental limitations.

Table 1. The results of panel power output and data analysis of PV standalone lighting model for various sunny and sunless days

No. Of Days	Panel voltage (V)		Panel Current (I)		Watt hour Wh	Ampere Hour Ah	Temperature (T)	Battery Voltage (V)
	MAX	MIN	MAX	MIN				
1	14.27	13.03	4.3	0.01	272.23	20.25	35.93	12.92
2	14.1	12.56	4.1	0.01	260.2	20.16	36.13	13.08
3	14.07	12.99	3.72	0.01	251	18.33	37.787	13
4	14.15	12.55	3.89	0.01	311	22.91	35.88	13.09
5	14.21	13.11	3.76	0.01	272.9	19.75	36.09	13.11
6	14.19	12.65	3.754	0.01	253.21	18.47	37.67	13
7	14.18	12.62	3.78	0.01	255.11	18.49	37.71	13.12
8	14.22	12.61	3.7	0.01	259.11	18.52	37.11	13.12
9	14.21	12.69	3.72	0.01	267.78	18.88	38.15	13.12
10	15.3	13.4	3.84	0.01	243.38	17.087	36.62	13.06
11	15.29	13.32	3.97	0.01	254.59	17.99	36.96	13.06
12	14.68	13.15	2.9	0.01	112.7	8.05	37.7	13.06
13	15.35	13.4	3.6	0.01	246.71	18	37.35	13.1
14	15.21	13.28	3.55	0.01	245.52	17.91	37.81	13.08
15	15.05	13.11	3.41	0.01	231.11	17.8	37.88	13.09
16	15.31	13.37	3.55	0.01	229.08	15.94	36.33	13.05
17	15.28	13.28	3.48	0.01	221.11	15.85	36.11	13.09
18	15.31	13.17	3.5	0.01	220	15.81	35.58	13.08
19	14.51	13.37	3.75	0.01	162.25	11.51	36.19	13.05
20	15.32	13.46	3.86	0.01	244.1	17.07	36.62	13.09
21	16.18	13.52	3.11	0.01	173.41	11.86	36.22	13.04
22	13.93	13.66	3.12	0.01	33.66	2.41	34	13.02
23	15.88	13.33	3.15	0.01	168.21	11.21	37.11	13.03
24	14.08	13.36	3.29	0.01	31.09	2.38	34.49	13.03
25	15.49	13.32	3.97	0.01	254.59	17.36	36.96	13.06
26	16	13.51	3.59	0.01	180.2	12.23	35.31	13.04
27	15.3	13.11	3.55	0.01	240.88	17.89	38.72	13.07
28	14.18	12.44	3.65	0.01	258.71	20.01	38.72	13.02
29	14.22	12.34	3.49	0.01	222.11	14.98	36.77	13
30	14.29	12.29	3.29	0.01	223.14	15.09	37.11	13

4 CONCLUSION

In this study, panel current generated at any time are simulated and the behavior of a PV module at different level of radiance is designed. This physical modeling technique does not require the knowledge of internal system parameters, involve less computational effort and offer a compact solution for multivariable problems. The proposed model has the advantage of using the information provided by manufacturer data sheets. Learning from the results of PV module characteristic, a database device is designed and implemented in our solar local climatic data. This type of simulation can save a large amount of time and money. We can often explore a large number of scenarios very quickly. The result will help system engineers to choose the right control strategies for panel and batteries.

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