Energy Reports 4 (2018) 252–259

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Research paper

Soft computing based approach to evaluate the performance of solar PV module considering wind effect in laboratory condition

Subhash Chandra [a,*], Sanjay Agrawal [b], D.S. Chauhan [a]

[a] Department of Electrical Engineering, GLA University, Mathura U.P. 281406, India
[b] School of Engineering and Technology, IGNOU, New Delhi 110068, India

ARTICLE INFO

Article history:
Received 22 August 2017
Received in revised form 28 October 2017
Accepted 15 November 2017

Keywords:
Photovoltaic
Energy
Wind
Performance ratio
Back propagation

ABSTRACT

Energy is the key factor for the growth of any country. Per capita energy consumption is the significance of the progress of any nation. With the increasing environmental impacts, word community is searching the way to shift towards sustainable energy sources. Recently the penetration of photovoltaic systems has increased to generate the electricity at grid or local level. Although this technology has improved a lot however the performance of these systems is site dependent. The experiment is conducted in laboratory of GLA University, Mathura, UP, India (hot and dry climate zone of India). Two PV modules of same electrical and mechanical specifications are taken for experiment. To analyze actual performance; different months of a year from various seasons are chosen including artificial wind. It has been observed that increased module temperature reduces performance but the cooling mechanism provided, bring down the module temperature due to which a net energy gain is 5.07% in considered time. Performance measure indices i.e. PR is improved by 3.4%. Experimental and Simulated energy is 431.28wh and 434.98wh for cooled module while for not cooled module experimental and simulated energy is 410.44wh and 439.7wh. Simulated values of energy are closer to experimental values for cooled module hence ANN avoids the underestimation of performance and overestimation of size, average simulated PR is also same as that of experimental PR i.e. 98.6%.

1. Introduction

In the current scenario of growing photovoltaic industry, it is essential to estimate high quality energy yield. In India the backbone of power sector is coal because it contributes maximum in power generation. India is aiming high to achieve the target of 175 GW installed renewable energy capacity by 2022 (Birol, 2015). Since abundant amount of solar energy is available in India hence to supplement the target, government made a plan to generate 100 GW from solar photovoltaic systems, out of which 40 GW must be generated from roof top solar photovoltaic systems. State wise target of solar power is shown in Fig. 1 (Anon, 2017).

In order to generate electricity from non polluting energy sources, many efforts are being made to integrate different renewable energy sources However PV systems are expected to play a key role for the sustainability of the future (Yang and Yin, 2011). Harnessing of electrical energy from solar energy depends upon geographical location, site conditions, characteristics of solar cell etc. i.e. the performance of PV system is highly climate dependent. Many researchers have already contributed a lot to improve the efficiency, actual performance and sizing of PV system (Bizzarri et al., 2013; Gong and Kulkarni, 2005). Two well known parameters i.e. radiation and temperature affect the performance of PV system directly. Maximum electricity can be harnessed by maximizing radiation and minimizing temperature. Radiation is module orientation dependent and temperature depends on the semiconductor material used for manufacturing the solar cell. Although tracking methods can be used to get maximum radiation but due to limitations, they are not always beneficial. Since India is in northern hemisphere so generally the PV modules are placed facing due south (i.e. equator facing), as a thumb rule the tilt angle is fixed equal to the latitude of the location to maximize the solar radiation on a tilted surface. Seasonal variation in tilt angle is beneficial for better performance of PV system but in fixed roof top PV system the optimal tilt angle is equal to latitude (Gong and Kulkarni, 2005; Khatib et al., 2012; Dolara et al., 2012; Beringer et al., 2011; Kaldellis et al., 2012).

Solar cells are very sensitive to temperature; their power is significantly affected by temperature. For crystalline silicon the voltage temperature coefficient is about −0.45%/K and current temperature coefficient ranges between 0.04 to 0.09% K (Beringer et al., 2011). Manufacturers indicate the PV module efficiency under standard test conditions (STC), temperature of module 25 °C,

* Corresponding author.
E-mail address: 2003subhash@gmail.com (S. Chandra).

https://doi.org/10.1016/j.egyr.2017.11.001

Nomenclature

STC	Standard Test Conditions
AM	Air Mass Ratio
PV	PhotoVoltaic
I	Irradiation, W/m^2
T_a	Ambient temperature, °C
W_s	wind speed, m/s
I_{sc}	Short circuit current of module, Amp.
$\tau \cdot \alpha$	Transmittivity and absorptivity product
PR	Performance Ratio
d_j	Target value of output
V_m	Maximum voltage of module, V
I_m	Maximum current of module, Amp.
P_m	Maximum power of module, Watt
βstc	Temperature coefficient of power, /°C
NOCT	Nominal operating cell temperature, °C
T_{mb}	Module back side temperature, °C
V_{oc}	Open circuit voltage of module, V
Hw	wind convection coefficient
CUF	Capacity utilization factor
e_j	error between actual and desired value
Y_j	Actual value of output

solar radiation of 1000 W/m^2 and air mass ratio AM = 1.5 (Deutsche Gesellschaft für Sonnenenergie, 2010). Large variations can be seen under outdoor conditions, therefore an important impact on efficiency and energy yield is observed. Module efficiency is temperature dependent (Skoplaki and Palyvos, 2009; Mattei et al., 2006; Evans, 1981). Although a lot of literature is available on PV cell temperature, which can be assumed to be same as that of PV module temperature but recently it is reported that wind speed provides natural cooling for PV module, which decreases the Module temperature hence improves the efficiency. Yet the effect of cooling by wind is not broadly applied that can be an important factor for estimating the true potential for large PV system (Gökmen et al., 2016; Bhattacharya et al., 2014; Schwingshackl et al., 2013). In order to collect the hot air, a channel can be made having inlet and outlet port and hot air from outlet port can be used for space heating i.e. utilization of both types of energy improves the efficiency of the system (Agrawal and Tiwari, 2011). In general the performance is assessed by measuring the actual output and comparing it with expected output. The ratio is called performance ratio (PR) usually employed to optimize the performance and for proper maintenance, a healthy system must have a certain PR value depending on the site, where the system is located (Padmavathi and Arun Daniel, 2015). Although CUF is an important metrics for performance measurement but it actually does not include various solar PV system parameters, hence less suitable in comparison to PR (Kumar and Sudhakar, 2017). Different Solar PV systems have PR value in the range of 0.6–0.9, depending upon site conditions. The inherent losses present in the system reduces the PR value, detailed losses are weak irradiation losses, temperature losses, DC cable losses, shading losses, dust and snow losses, inverter looses, and others if applicable. Although losses cannot be reduced to zero, however they can be minimized. In India very little literature is available on energy performance indicators hence a lot of documentation is required (Kumar and Sudhakar, 2017; Ayompe et al., 2011; Sharma and Chandel, 2013; Rawat et al., 2016). It is important to evaluate and forecast the site dependent performance of PV system before the installation, several soft computing based approaches like artificial neural network (ANN), genetic algorithm, fuzzy logic are playing key role in this. ANN's have many applications due to their reliability in forecasting; some tasks are intelligently performed by them. They can be trained from examples which develop the ability to deal with non linear problems. Although ANN's are less efficient with high accuracy and precision as in arithmetic and logical operations but they are widely used in engineering, economics, adaptive control, robotics etc. (Ceylan et al., 2014; Kalogirousa et al., 2014; Kalogirousa, 1999).

This paper is intended to help investors and project planners to estimate the true potential of PV system by considering less module temperature due to wind cooling effect. The energy and instantaneous performance ratio are evaluated experimentally and ANN methods by considering wind effect, which is different from the literature available. Artificial wind is provided for cooling behind the PV module which also reduces the risk of PV cell damage by decreasing the temperature. An experiment is conducted in laboratory to analyze the comparative performance of two modules of similar characteristics, a fan is connected behind one module (cooled module), which is powered by module itself. Analysis is done for gain in energy by cooling mechanism during different months of various seasons of the year. Moreover this mechanism is beneficial in actual size estimation in large power plants and in BIPV applications. Fig. 2 is showing the mechanism for cooled module.

2. Experimental setup

An experiment is conducted in the solar energy laboratory in GLA University, Mathura, UP, India (27.4924° N, 77.6737° E). The Experimental setup is consisting two polycrystalline type PV modules of 0.353 m^2 areas as shown in Fig. 3. One of the PV modules is cooled by connecting a DC fan below it and powered by itself while another is not cooled. Two modules can be connected in series or parallel for different experiment. Keeping in mind the continuous consumption of energy by fan, a mechanism of adaptive cooling is chosen, this mechanism consist a temperature sensor and microcontroller. Temperature sensor is kept in touch with the back side of module, during programming of microcontroller reference temperature is set which decides the Turn ON and Turn OFF of the fan. Halogen lights are used to get the variable artificial radiation, to ensure uniform irradiance all the lights are connected in matrix form. Irradiance is measured by solar power meter TM 207. It indicates the range in W/m^2 and in BTU. It is high precision equipment and its operating temperature ranges between 5 °C to 40 °C. The instrument operates with a 9 V battery and below 2000 m altitude. Its dimensions and weight are 143 (l) × 74 (w) × 34 (h) mm, and 250 g respectively. A prototype of mini solar power plant kit has been used to measure the temperature, output voltage and current. This kit has two PV modules of same power rating which can be adjusted at desired latitude. The output of two modules can be measured individually or in series/parallel. AC/DC loads are available to conduct an experiment. Controlled switch are used for regulated irradiation; a digital anemometer AVM 06 is used to measure the speed of the wind. It has large screen LCD, backlight, auto power off and standard accessories. For checking the latitude an angle finder having magnetic base is used which can measure the angle 0–90° in any quadrant. Its accuracy is between $\frac{1}{2}$ to 1°. Data obtained from the experiment is processed with the *MATLAB neural network tool* to form the ANN for simulation work.

3. Methodology

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.