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Daily array yield prediction of grid-interactive photovoltaic plant using relief attribute evaluator based Radial Basis Function Neural Network

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ABSTRACT

The progress of renewable energy is becoming an important source for meeting energy requirements of India. With the plentiful availability of solar energy, Grid-Interactive Solar Photovoltaic (GISPV) plants are becoming important in most part of the country. Due to varying climatic condition it is important to predict the daily array yield of GISPV plant. In this paper, new algorithm relief attribute evaluator is used to find most influencing variables from solar radiation (SR) and back surface module temperature (BSMT) to predict the daily array yield of 190-kWp GISPV power plant using Radial Basis Function Neural Network (RBFNN) for 26 different Indian cities. The ranks given by relief attribute evaluator are 0.00775 for SR and 0.00139 for BSMT, showing SR is relevant variables for daily array yield prediction. For analysis two Radial Basis Function Neural Network (RBFNN-1, RBFNN-2) models are developed for the prediction of daily array yield for the 190-kWp GISPV power plant. SR and BSMT are used as input parameters for the RBFNN-1model and SR is used as input for the RBFNN-2 model. The root mean square error (RMSE) for RBFNN-1 is 0.2642 kWh/kWp/day and for RBFNN-2 the RMSE is 0.2910 kWh/kWp/day. The results comparison shows that RBFNN predicts daily array yield better than the polynomial regression model. The RBFNN-2 model is used to predict daily array yield for 26 different Indian cities and it is found that total daily average daily array yield varies from 3.50 kWh/kWp/day to 7.94 kWh/kWp/day which can be used to estimate power production for solar photovoltaic power plants. The predicted total array yield by RBFNN-2 model is validated with calculated value and RMSE is found to be 2.295 kWh/kWp/day showing RBFNN-2 can be used to predict daily array yield for different sites in India.

1. Introduction

Solar energy is converted directly into electricity by a solar photovoltaic (PV) system. The PV system generates DC power which is converted to AC by an inverter and supplied to the grid or load. The reliability of a PV system can be enhanced during night time or cloudy days if sufficient storage is used in a standalone system or connected directly to the grid. The grid also acts as a back-up source of power when PV system is unable to meet the load demand. The Grid-Interactive Solar Photovoltaic (GISPV) systems are electricity generating solar PV system connected to utility grid. The GISPV systems consist of solar panels, inverters, power conditioning unit and grid connection equipment.

The GISPV daily array yield ($Y_{a,d}$) is important parameter as per IEC standard 61724. The array yield is ratio of energy output from PV array and nominal power capacity of PV. The $Y_{a,d}$ means number of hours per day that the PV array would need to operate at its rated output power to provide the same energy to the GISPV system.

$$Y_{a,d} = \frac{\sum_{daily} P_a}{P_o} \quad \text{(kWh/kWp/day)} \tag{1}$$

where P_a is PV array power and P_o is nominal power.

The solar PV plant performance is measured by performance ratio (PR) and capacity utilization factor (CUF) [1]. The PR is ratio of measured energy and the product of solar radiation, PV module area and efficiency. The PR can be calculated by Clear-cloudy sky [2]. The CUF is ratio of produced energy to installed capacity of plant. The PR value is 66% for rooftop PV system in Germany [3–5], 55–70% for eight grid interactive PV system in Europe [6], 63–76% in Netherland [7], 70% for 3 MW GISPV in Karnataka, India [8], 89% for 5 MWp GISPV at Sivagangai district in Tamil Nadu, India [9] and 76.6% for 10 MWp NTPC solar plant in Ramagundam [10].

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Nomenclature

ANN	artificial neural network
BSMT	back surface module temperature
GISPV	Grid-Interactive Solar Photovoltaic
RBFNN	Radial Basis Function Neural Network
SR	solar radiation

Symbols

I	current
V	voltage
$Y_{a,d}$	daily array yield

The India receives solar radiation of intensity 4–7 kWh/m^2/day [Fig. 1] [11] with 5×10^9GWh of incident energy per year. In India, the demand for electricity is more than the supply so PV system is a preferable solution to meet power deficit. To promote PV power generation in India, Jawaharlal Nehru National Solar Mission (JNNSM) was launched on 11th January 2010. The JNNSM has set up the target of installing 20,000 MW of Grid-Interactive Solar Photovoltaic (GISPV) systems by 2022 and target of renewable energy capacity is increased up to 175,000 MW by 2022. It aims are to reduce the cost of solar power generation and to achieve grid tariff parity by 2022. Under JNNSM the installed capacity of GISPV plant in India till 29 March 2015 is shown in Table 1. The capacity utilization factor of PV plant in India varies from 11% to 31% (data given by Ministry of New and Renewable Energy May 2013) [12]. In India, the energy yield of GISPV is shown in Table 2.

The daily array yield is affected by types of PV module, solar radiation and back surface module temperature. It is varied for different sites so it becomes an important to predict daily array yield for grid and energy management [13]. For prediction one has to select different input variables for models and run a series of experiments which is time taking. Therefore relevant input variables selection becomes an important for researchers in daily array prediction field.

In this study new algorithm relief attribute evaluator are proposed for relevant input variable selection for Radial Basis Function Neural Networks (RBFNN-1, RBFNN-2) to predict daily array yield ($Y_{a,d}$) of 190-kWp GISPV plant. The models are compared with polynomial regression model. The measured time series data of 190-kWp grid connected PV plant installed at Punjab in India are used for developing these models and $Y_{a,d}$ are predicted for 26 Indian cities first time which is novelty of this paper. The RBFNN-1 model utilizes solar radiation and back surface module temperature as inputs and $Y_{a,d}$ as output whereas the RBFNN-2 model uses only solar radiation as input. Thus RBFNN-2 model can easily be used for the prediction of $Y_{a,d}$ for sites where only solar radiation data are available and it is used for prediction of $Y_{a,d}$ for 26 cities in India.

The paper is organized as follows: In Section 2, literature review based on power prediction from GISPV system is given. In Section 3, detail methodology is given and results are presented and discussed in Section 4 followed by conclusion in Section 5.

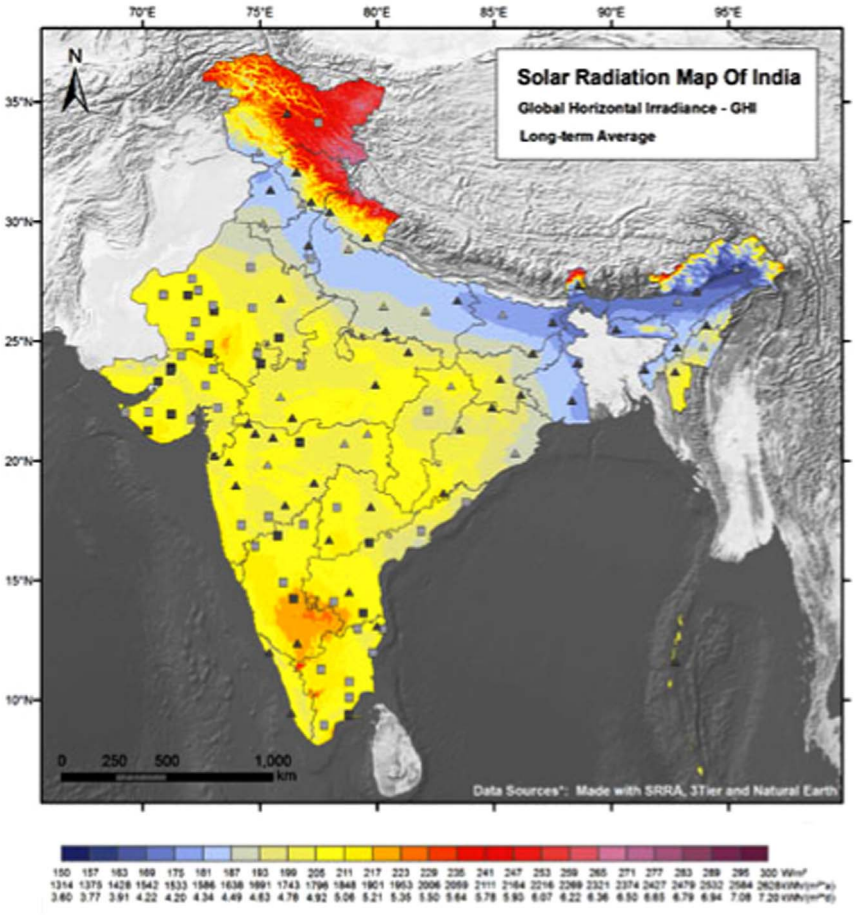

Fig. 1. Solar radiation map of India.