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Prediction of Solar Radiation using Multilayer ANN

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Abstract- **In present work single layer and multi-layer Artificial Neural Networks (ANNs) were developed using MATLAB Version 8.3.0 (R2014a), to estimate solar global radiation for Hubballi by considering geographical parameters (standard longitude, elevation, declination angle), climatographical parameters like relative sunshine hours and wind velocity and day of the year in different combination as input parameters, average global solar radiation (2002-2011) collected form Typical Metrological Year (TMY) as target data for the network. The target value was trained in the ratio of 70:15:15, using Levenberg Marquardt back propagation algorithm. The results of the model were analyzed using statistical parameters like Root Mean Square Error (RMSE), percentage Root Mean Square Error (% RMSE), Mean Biased Error (MBE) and hypothesis test.The results showed that ANN model with 3 layer 10 neurons exhibited least value of RMSE (less than 5 percent), MBE and SSE. In t- stat test the h index of both the models have 0 for more than 80 percent of days of the year.**

Index Terms- **Solar radiation, ANN, Statistical method.**

I. Introduction

Today solar energy sector has emerged as one of the prominent energy contributors in developing country like India in the field of both thermal and electric power sector. The key success of solar projects depends on optimum design, energy conversion efficiency and long-term performance of project. The optimum design of solar system demands accurate knowledge of important climatological parameters like solar radiation, temperature and wind velocity distribution at a particular geographical location. Unfortunately in developing country like India solar radiation distribution data is not available for most of the locations due to shortage of metrological stations and measurement equipments. Hence it is important to develop prediction model to estimate solar radiation based on readily available meteorological parameters.

Solar radiation prediction model can be developed based on statistical regression techniques (empirical models), based on training (simulated models), and based on optimization algorithms (optimized models) [1]. But in recent decades the simulated model developed based on Artificial Neural Network (ANN) technique has become more popular due to simple construction, accuracy, speed and ease of operation for the solution of both linear and nonlinear problems. The ANN model is information processing system that is non-algorithmic, non-digital and intensely parallel [2].The function of ANN model resembles a biological neural system, composed of layers of parallel elemental units called neurons. The neurons are connected by a large number of weighted links, over which signals or information are communicated.

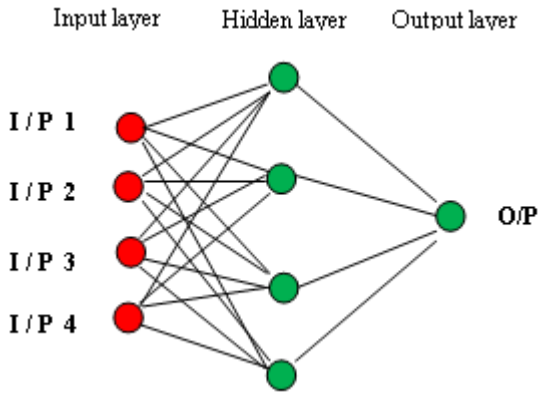

Fig 1. Typical structure of ANN model

The fig. 1 depicts typical structure of ANN model that consists of three components that include one input layer, one or more hidden layers and one output layer. The model has all three layers that are successively interconnected and referred as single layer perceptron model and multilayer perceptron model respectively based on number of hidden layers to be one and multiple numbers. The Training phase has training data fed to input layer with the hidden layer(s) receiving input data from all nodes of the input layer and multiply the data with appropriate weight value and then summed, to result into non-linear transformation. The output layer receives data from all hidden nodes of hidden layer (s) for comparison with target values. The resulting difference termed as error was propagated back to hidden layer through the process called as Back propagation (BP). The BP algorithm utilizes mean square error and steepest descent method to realize the modification to the connection weight of network. It would help to regulate weight value and threshold value of network to achieve minimum error sum of square and also store mapping relations of input-output model without disclosing mathematical equations of mapping relations [3]. The error was later used to update connection strengths between nodes, i.e. weight matrices between input-hidden layers and hidden-output layers are updated. During test-phase the test data/ test vector were fed into input layer without weight matrices being subjected to changes (Non-learning phase) [4].

The present work intends to optimize MLP neural network model for prediction of solar global radiation at Hubballi location. Some of the related recent research has been discussed in this section. Development of short term solar irradiation forecasting (STSIF) model based on ANN using statistical feature parameters (ANN-SFP), showed greater significance in optimization and power prediction of grid connected photovoltaic plants.

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However, ANN-SFP model was random and nonlinear characteristics of solar irradiance under changeable weather conditions, hence it was complex to handle [5, 6].Feed forward multilayer perception ANN models are used to estimate global solar radiation using latitude, longitude, day number and sunshine ratio and clearness index as output data for the long term data of 28 sites in Malaysia. The solar global radiation has been estimated by predicted clearness index [7].

A new methodology called ANN ensemble model has showed less biased errors compared to ANN model when optimized using genetic algorithm technique for Andalusia where data collected from 65 stations used to train the model out of 83 metrological stations and data from rest 18 stations used to test the model [8].

The solar global radiation prediction for locations with different climate was developed based on feed forward multilayer perception with seven inputs parameters such as wind speed, rainfall, sunshine hour, temperature, vapour-pressure, humidity and rainy day and one output layer. The statistical results showed least variations and predicted data were in agreement with the measured data. The MLPANN models was an effective tool to estimate the solar global irradiations when compared to other models [9].

2. Methodology

The model was developed using neural network tool box (nntool) of MATLAB Version 8.3.0 (R2014a) with 32-bit (win 32) was to map numeric input data set (ten inputs) and numeric targets data set. In the present work MLP based ANN model was developed to estimate global solar radiation for Hubballi using ten input parameters viz: day of the year, latitude and longitude of location, standard time longitude, elevation from the mean sea level, day length, ratio of bright sunshine hour to day length and wind velocity, declination angle and hour angle. Ten years average of daily solar global radiation collected from TMY data for Hubballi location were identified as the target parameters for validation of ANN output. .

The execution of ANN algorithm as explained in Fig 1 was executed for 10 input parameters for various configurations of hidden layer in terms of Number of layers, number of neurons and type of transfer functions to fix the weights for input parameters. In the reported work hidden layers were selected between 2 to 5 in steps of 1 on account of minimization of computation time and memory requirements. The number of hidden layers was varied from 8, 10, 12 and 15 for each hidden layer selected to capture the contribution of each input variable in form of weight generated through the neurons selected.

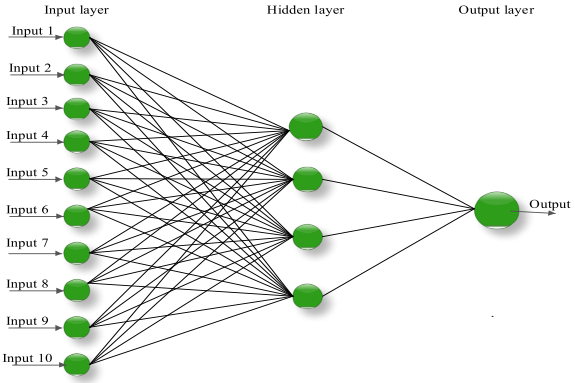

Fig 2: Nodes of developed ANN

Three transfer functions namely TANSIG, LOGSIG and PURLIN were used to for the training Algorithm for generate appropriate weights that were iteratively revised and updated to establish convergence of results. The results obtained through the selected combinations of Hidden layer number, number of neurons and type of transfer function indicated that2 layer hidden segment- 8 neuron-TANSIG algorithm for Transfer function generation was the best solution mix that resulted in lowest value of error(MSE) and minimum computational time.

3. Results and Discussion

The MLP model developed was trained and tested with for 2 to 5 layers with the combination of 8, 10, 12, 15 neurons in hidden layer. The performance of the model was evaluated in-terms accuracy (mse), root mean square value, t-stat test and computation time. The results obtained were presented below.

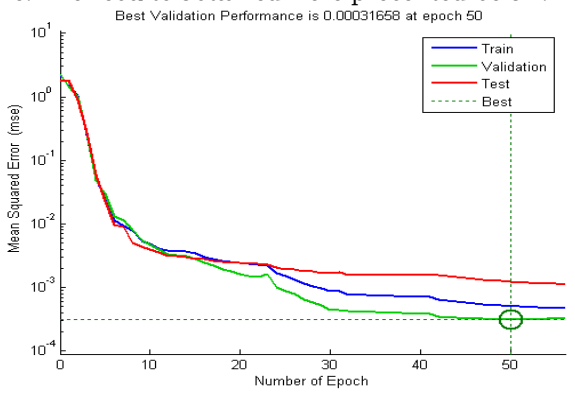

Fig 3. Convergence plot of ANN (optimized) model

Fig.3 indicates the convergence plot of ANN model developed with 2 layers with 8 neurons in hidden layer. The ANN models were tested for different configuration as mentioned above in methodology. The optimum results were obtained for the configuration of 2 layers, 8 neuron at hidden and with the TRANSIG transfer function converge with mse of 0.00031658 at the epoch of 50 indicating better results as compared to other models.

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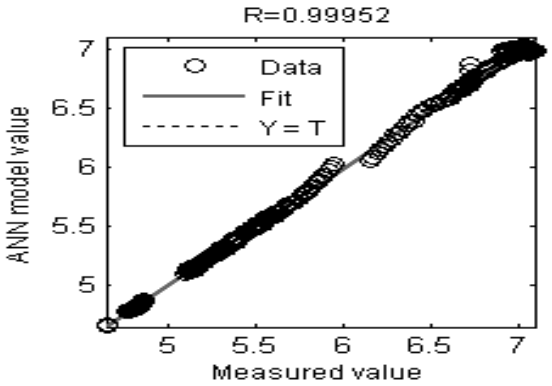

Fig 4 Variation of measured and optimum ANN model value

Fig. 4 indicates variation of measured value daily average solar radiation with that of ANN model. The figure5 depicts the results of optimized model. It indicates results of optimized ANN model are good agreement with measured value with co-efficient of variance of 99.952%.

Table 1. ANN parameters for Hidden and Output layer

Model No.	Hidden layers	Output layer
1	10	1
2	15	1
3	12	1
4	10	1
5	10	5
6	15	2
7	8	2

Table 1 indicates combination of hidden and output layers for seven different Models in ANN for TRANSIG transfer function with 10 input layers.
Fig 5 depicts the Performance of different ANN models in-terms of % RMSE. The results shows that model 6 exhibits better performance with % RMSE accepted range of less than 5 percent for all months of year. Hence it is recommended for long term estimation of solar radiation.

Fig 6 shows performance of different ANN models 1-7 in terms of % MBE. The results shows that model 5 exhibits better performance with % MBE accepted range of less than 5 percent for all months of year. Hence it is recommended for short term estimation of solar radiation.

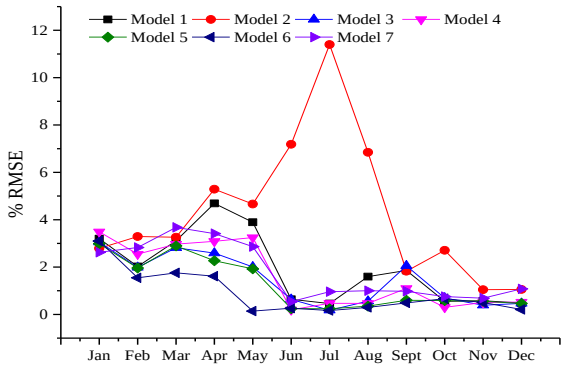

Fig 5: Variation of % RMSE for different ANN models

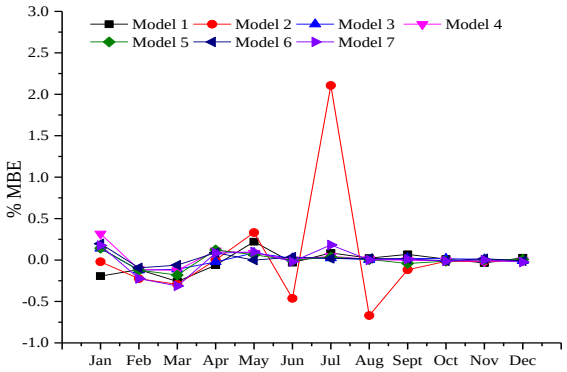

Fig 6 Variation of % MBE for different ANN models

Table 2 shows the performance of six types of ANN models in- terms of hypothesis test. It indicates the results obtained from all the model accepted (i.e h=0) for all months expect the month of July. More than 90 percent of results of the all the models are in acceptable limit.

Table 2 Hypothesis test of ANN

Model No / Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Jan	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0
May	0	1	0	0	0	0	0
Jun	0	0	0	0	0	0	0
Jul	1	1	1	1	1	1	1
Aug	0	1	0	0	0	0	0
Sept	0	0	0	0	0	0	0
Oct	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0

CONCLUSIONS

The ANN models to estimate daily average solar global radiation have been statistically analyzed in-terms of mean square errors, root mean square, co-efficient of variance. The results indicated that best of the neural network models for estimation of solar radiation achieved more than 97 % prediction accuracy in-terms of RMSE and MBE, when 8 neurons were set up at two hidden layer with 10 inputs. Result of this ANN model showed good agreement with the measured values of monthly average global solar irradiation.

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