International Journal on Future Revolution in Computer Science & Communication Engineering
Volume: 4 Issue: 4
ISSN: 2454-4248
631 – 636

Fuzzy Logic and ANFIS based Short Term Solar Energy Forecasting

Meera Viswavandya
Deptt of Electrical Engg.
CET Bhubaneswar
India -751003
mviswavandya@rediffmail.com

Bakdevi Sarangi
Deptt of Electrical Engg
CET Bhubaneswar
India-751003
bakdevisarangi@gmail.com

Asit Mohanty
Deptt of Electrical Engg.
CET Bhubaneswar
India-751003
asitmohantycet@gmail.com

Sthitapragyan Mohanty
Deptt of Computer Sc & Engg
CET Bhubaneswar
India-751003
msthitapragyan@gmail.com

***Abstract*—** Accurate forecasting of solar energy is a key issue for a meaningful integration of the solar power plants into the grid. Solar photovoltaic technology is most preferable and vital all other sources of renewable energy. We know that the solar Energy is very irregular so the result output of solar voltaic systems (SPV) diverted by the atmospheric nature like temperatures, humidity, wind velocity, solar irradiance and other climatologically facts. It's necessary to prediction of solar energy is most important to minimise uncertainty in power harness from solar photovoltaic system. In this work fuzzy logic model and ANFIS model have been developed for manipulating solar irradiation (w/m2) data to forecasting short term solar energy. In the month of September 2017 has been monitoring for an hourly data of solar irradiance used as input and actual desired output. In the present paper sets the Normalization of input and desired output in between 0.1 to 0.9 for reducing confluence problems. Acquired results are match up to the manipulated data and get valid result. The implementation of the model is estimated on the basis of mean absolute percentage error.

Keywords- *Solar energy, solar photovoltaic system, fuzzy logic, ANFIS*

*****

I. INTRODUCTION

The solar radiation is an essential parameter for solar energy research but is not present for most of the location due to uncertentity it nature of solar radiation measuring equipment at the meteorological stations. Therefore, it is necessary to forecast solar radiation for a particular location using several climatic parameters. This parameter are sunshine duration, wet-bulb temperature, relative humidity, wind velocity/speed, daily clear sky global radiation etc like all atmospheric condition that affects solar power reaches on the earth's surface. The sunshine duration, maximum and minimum temperatures are easily available and measured at most of the location so it is generally used for modelling of solar radiation. The information about solar radiation, solar energy system models, specific site data and publications, is given in the inventory prepared by Myers for NREL. There are many Researchers have developed experimental models for solar power forecasting. The solar energy forecasting is develops to be precise with measured data. It is estimated with mean absolute percentage error (MAPE) i.e. MAPEr10% means high forecasting accuracy, 10%rMAPEr20% means good forecasting, 20%rMAPEr50% means reasonable forecasting. Now a day increasing crude the prices of crude oil highlights the exploitation of renewable energy sources applications is a best alternative. The energy from solar is among the most suitable energy technique due to its less emission of CO2 and eco-friendly Nature. In the other hand, concentration of huge amount of solar energy for the generation of electricity storage faces several difficulty levels to the power system's handlers, severely because of the variability of solar radiation fall in surface. So, the energy generated from the SPV system is changed with the solar radiation and the temperature and relative humidity, wind speed unexpected changes of the SPV system power harness may raise price of operating for the electricity storage system due to increased operation and management price based with cycling existing generation. The Optimum location selection for harness of electricity from the solar energy is determined based on the available solar irradiance data at that location. The Solar irradiance data are important for design, sizing, operation and economic assessment of solar energy. However, In India, only IMD canter gives authenticates data for quite few stations or users which is taken as the raw data for research purposes.

Forecasting is defines as the prophecy of next future trends data by analyzing historic previous year or month data. Due to renewable sources like solar power changes with time, atmospheric temperature, solar radiations, wind speed/velocity, humidity, etc., Experimenting and Forecasting output gain by solar is an essential part. It is the fact that final output solar power is irregular in behaviour .so, that to

 ISSN: 2454-4248
631 – 636

integrate this final output of generation with the grid or to utilise distribution generation (DG), proper energy management system is needed. Now days several number application can be utilised for short term solar energy prediction such as physical methods, statistical methods and artificial intelligence methods among this three group of method artificial intelligence methods are widely used. Artificial intelligence technique like artificial neural network, genetic algorithm, fuzzy logic, ANFIS, etc. Fuzzy logic is advantageous over artificial neural network because it can implement with sudden changes in temperature condition and is easy and tough in nature. ANFIS (Adaptive Neuro-fuzzy Inference System)is advantages over ANN because it is used both Neural Network and fuzzy logic techniques to gain more efficiency and for estimates solar energy get the better of the difficulty Neural Network like as a huge number of neurons and layer required for difficulty function approximation. So, in this thesis paper taking a chance has been generate to develop fuzzy logic and ANFIS model for short term solar energy forecasting so that we can easily compare the result.

This paper deals with short term solar energy forecasting and is divided into six sections. After an introduction-1, Section-2 introduces the fuzzy logic controller. Section -3 describes the brief idea about ANFIS. Section -4 describes the data collection and normalization of input and output data. Section -5 presented the fuzzy logic and ANFIS based model. Section-6 represents the result and discussion. The conclusions of the paper are summarized in Section-7.

2. Basic Fuzzy Logic

Fuzzy logic- It has been introduced in the year 1965 by Professor Lotfy A.Zadeh at the University of California. L.A.Zadeh main objective was to develop the model that could helps to read out the natural language process. Generally it replace the multi-valued logic to the binary binary 0/1 logic. Due to the Fuzzy approach is quite different from classical approaches .The fuzzy logic model used the situation where, the probabilistic or deterministic data model do not suitable for phenomenon of the realistic description in the study. In Fuzzy logic instead of subjects and verbs, fuzzy operators and fuzzy sets are used to make the meaningful the sentences it is characterize by the condition statements i.e., IF-THEN statements and it contains certain rules. Also, fuzzy logic has been used as a standard method in various applications such as modelling solar radiation at the earth surface. In fuzzy logic includes several steps for basic configuration like Fuzzification, Rule base, Decision-making logic and Defuzzification.

Table-1 shown the comparative table of forecasting at different time

Sl. No	8 A.M (Input1)	9 A.M (Input2)	10 A.M. (Input3)	11 A.M. (Input4)	12noon (Output)
1	449.69	574.47	698.84	759.56	811
2	454.36	605.01	756.24	606	631
3	387.98	573.81	715.9	763.78	737.7
4	435.19	605.01	752.14	773.9	776.8
5	419.77	544.66	623.4	735.93	757.3
6	394.99	522.81	697.2	670.96	749.8
7	394.99	544	683.26	352.87	696.5
8	378.63	476.42	691.46	710.62	698.6
9	453.89	618.2	767.34	779.81	769.8
10	473.81	650.52	771.01	770.53	762.3
11	444.54	570.5	689	694.59	723.7
12	444.08	576.46	666.04	693.75	693
13	436.13	547.31	657.84	343.59	384.1
14	100.01	120.01	115	120	248.5
15	398.73	537.37	661.12	657.46	635.9
16	450.62	551.95	683.26	723.28	705.3
17	431.45	518.82	671.78	687	677.9
18	396.39	548.63	696.38	714.84	720.6
19	424.91	559.9	673.42	682.78	658.4
20	381.9	484.3	621.76	620.34	640.2
21	368.34	528.7	612.74	634.68	586.2
22	334.68	471.12	602.9	637.21	600
23	342.16	540.31	630.78	584.06	585.3
24	318.32	450.58	572.56	573.93	561.8
25	280.45	378.37	521.72	522.46	512
26	319.72	478.66	584.04	600.09	578.1
27	311.77	436.67	605.36	624.56	616.5
28	318.32	438.05	597.98	598.4	576.3
29	254.27	494.31	142.88	405	482.6
30	273.91	388.97	425.78	612.09	565.6
31	245.86	398.25	499.58	441.46	405.3

2.1. **Fuzzification**- It helps to measure the input variables values. Fuzzification plays a major role means its function of fuzzification that helps to converts input into crisp values that means transform scale mapping the variables input range of values into respective universe of discourse.

2.2. **Rule Base**- It is also known as knowledge base or the combination of data base and linguistic control rule base, The rule base provides necessary definition that could be used as to define fuzzy data, FLC, linguistic control rules and calculation.

2.3. **Rule Decision Making Logic**- Decision making logic also refer as the Kernel of an fuzzy logic controller and it can also able to read of simulating human decision to concepts of fuzzy. It has inferring fuzzy control actions involving fuzzy implication and the rules of inference in fuzzy logic.

 ISSN: 2454-4248
631 – 636

2.4. **Defuzzification**- Defuzzification of fuzzy value means a scale mapping which converts the range of values of input variables to crisp output.

Let us take K be universal set. Consider the characteristic function μ_Z of a subset of universal set Z. Then take its values in the two element set {0, 1} . So, $\mu_Z(k) = 1$, if $k \in Z$ and zero otherwise. The range of fuzzy set Z values take as interval {0,1}. Here, μ_Z is known as membership function and $\mu_Z(k)$ is called as grade membership function of $k \in K$ in Z. The conversion between membership and non membership is gentle rather than sudden.

The intersection and union of two fuzzy subsets Y and Z, K having membership function μ_Y, μ_Z respectively then it can be expressed as

Intersection: $\mu_{Y \cap Z}(k) = \min [\mu_Y(k), \mu_Z(k)]$ (1)

Union: $\mu_{Y \cup Z}(k) = \max [\mu_Y(k), \mu_Z(k)]$ (2)

Fuzzy logic approaches, the input variables value can smoothly mapped to an output space by follows the vague concepts like as fast runner, hot weather, solar irradiation, wind speed, relative humidity etc.

3. Basic of ANFIS

ANFIS (Adaptive Neuro-Fuzzy Inference system) techniques gain more efficiency due to it is the combination of ANN and fuzzy logic. The TS structure of fuzzy model is specified using a method which allows the optimal structure on automatic manner. ANFIS is more effective than Fuzzy Inference System (FIS), but in this users have some drawbacks like only first order/zero order Sugenotype fuzzy models, OR Method : max, Aggregation Method : max, AND Method: Prod, Implication Method: Prod, Defuzzification Method: wtaver(weighted average). Also, in ANFIS users can provide to only give their own number of membership functions (num MFs) both for input and outputs of the fuzzy controller, the membership function type, the number of checking and training data sets (numPts), reduces the error measure by optimization criterion. ANFIS model was first proposed by Jang in 1993, it is based on a special FIS that means linear combination of all input variables to make the output variables and the Takagi-sugeno model. In this model the input series are changed to fuzzy input with the help of membership functions for each individual input series. The structure of membership function is mainly based on the data set. ANFIS has been approached with several forecasting domains such as weather forecasting, solar radiation prediction, internet traffic time series prediction and electricity price prediction. In this present work the all data are divided in three parts such as training data, checking data and testing data. In training process 50% data is used, for testing process 25% data used and finally for checking data process rest of 25 % used . By the help of back propagation algorithm trained for Training data.

In this present work we applied ANFIS modelling the back propagation algorithm the Takagi-sugeno fuzzy system is used for solar power forecasting estimating at Bhubaneswar with available atmospheric parameters of maximum and minimum temperature, relative humidity, wind speed, and total sunshine hour and the results are compared with the measured value calculated by using fuzzy logic. The basic structure of ANFIS models contain several layer like the fuzzification layer, the product layer, the normalized layer, the defuzzification layer, and the output layer. Now days implemented of ANFIS architecture is a popular and advanced system with a good software support. In ANFIS Each and every node has been characterized by node function with fixed or flexible parameters. By taking of first order fuzzy inference system, a fuzzy reasoning has been developed. In ANFIS model neural network work on following fuzzy IF-THEN rules of Takagi and Sugeon's type which describe as two rules.

1 If y is K1 and z is L1, then p1=a1x+b1y+c1

2 if y is K2 and z is L2, then p2=a2x+b2y+c2

Where y and z are inputs, p1 and p2 are outputs and K1, L1, K2 and L2 are fuzzy sets.

Table-2 shown the comparative forecasting value at different interval

Day	Input1 (8a.M.)	Input 2 (9a.M.)	Input 3 (10a.M.)	Input 4 11a.M.)	Output (12Noon)
1	0.848	0.786	0.812	0.858	0.898
2	0.858	0.808	0.882	0.676	0.646
3	0.716	0.785	0.845	0.863	0.796
4	0.817	0.808	0.877	0.875	0.85
5	0.784	0.741	0.72	0.83	0.823
6	0.817	0.708	0.81	0.753	0.803
7	0.731	0.74	0.793	0.376	0.732
8	0.696	0.638	0.803	0.8	0.741
9	0.857	0.852	0.887	0.882	0.841
10	0.877	0.854	0.896	0.871	0.83
11	0.837	0.78	800	0.781	0.776
12	0.836	0.789	0.772	0.78	0.733
13	0.819	0.745	0.762	0.365	0.381
14	0.1	0.1	0.1	0.1	0.1
15	0.739	0.73	0.766	0.737	0.653
16	0.85	0.752	0.793	0.815	0.75
17	0.809	0.702	0.779	0.772	0.712
18	0.734	0.747	0.809	0.805	0.772
19	0.795	0.764	0.718	0.767	0.685
20	0.703	0.65	0.718	0.693	0.559
21	0.674	0.717	0.707	0.71	0.584
22	0.602	0.63	0.695	0.713	0.603
23	0.618	0.665	0.729	0.65	0.583
24	0.567	0.599	0.658	0.638	0.549
25	0.486	0.49	0.596	0.577	0.48
26	0.57	0.581	0.672	0.669	0.572

 ISSN: 2454-4248
631 – 636

27	0.553	0.578	0.698	0.698	0.626
28	0.567	0.58	0.689	0.667	0.561
29	0.43	0.665	0.134	0.417	0.498
30	0.472	0.506	0.479	0.683	0.55
31	0.412	0.52	0.569	0.481	0.458

4. Data Collection and Normalisation

In IMD (India Meteorological Department) we collected data for short term solar energy prediction for 1hr ahead. The data sheet for solar irradiance of month September has been used. So, we can predict short term solar energy for 1hr ahead in this Thesis. The Tabular representation of September data is presented in below.

Table-1 Collected Data For 1hrs ahead

Here, we take four no. of input variables (solar irradiance in W/m2) i.e. 8 A.M., 9 A.M., 10A.M. and 11A.M., and one output i.e. 12Noon data is presented in Table-1. Again Normalized the above data both input and output values in between the range 0.1 to 0.9 to avoid any convergence problem which may occur during rule formation. Normalization of data is done according to the below expression:-

$$L_s=\frac{Y_{max}-Y_{min}}{L_{max}-L_{min}}(L-L_{min})+Y_{min}$$

Here, L represents the actual measure data, L_S refers toscaled data which is used as input to the network, Lmax represents the particular data set of maximum value, Lmin represents the particular data set of minimum value, Ymax and Ymin Upper limit (0.9) and lower limit (0.1) respectively of normalization range.

Table-2 Normalization input and output data for one hour ahead Data

5. Model Development

5.1. Fuzzy Logic Model

The short term solar energy forecasting for 1hrs ahead by fuzzy logic model is developed and presented and the developed fuzzy logic model followed by specific set of rules which are being made for qualitative descriptions. The fuzzy linguistic variables are described as high, medium and low. Here, the main concern for the development of fuzzy systems is the appropriate membership functions. Generation of membership function depends upon intuition, experience or probabilistic methods and further it have been defined such as six membership functions like L (low), L1 (Extreme low), M (Medium), M1 (Medium High), H (High) and H1 (extreme High) all values lies in between the ranges 0.1 to 0.9 .IN fuzzy model ,rules may be fired with some degree using fuzzy inference but in conventional expert systems, a rule is either fired or not fired. For the short term solar energy prediction problem, certain set of rules are described to determine the accuracy in terms of Absolute Relative Error (ARE). Such rules are expressed in the below following form.

IF premise (antecedent), THEN conclusion (consequent)

For the short term solar energy prediction purposed are followed by certain sets of multiple antecedent fuzzy rules. The input to the rule is solar energy during 8 a.m., 9 a.m., 10a.m., and 11a.m., of September, 2017 and output is 12noon.

5.2. Adaptive Neuro Fuzzy Inference System

Accordingly, the hybrid approach converges much faster since it reduces the dimension of the search space of the original back-propagation method. For this network created fixes the membership functions and adapt only the consequent part; then ANFIS can be viewed as a functional-linked network where the enhanced representation, which take advantage of human knowledge and express more insight. By fine-tuning the membership functions, we actually make this enhanced representation. The data set is available from the IMD centre .A complete data set of September month of one hour ahead global solar irradiance data (8 a.m., 9 a.m., 10 a.m., 11a.m,) are used for prediction of global solar irradiance for 12noon, output. The triangular type of membership function (trimf) is used for input and linear type function is used for output. The number of correct outputs is noted till the error is minimized.

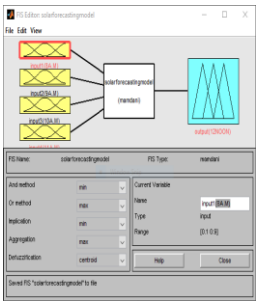
5. Fuzzy and ANFIS Rule Base for 1hrs Short Term Solar Energy Prediction:

Table -3. To develop solar Predicting model MATLAB is used to establishment the below listed rules.

6. Result and Discussion In Fuzzy and ANFIS

6.1. Fuzzy Result

In table-3 presents various set of rules for solar forecasting fuzzy rules. A general 1hrs ahead Short Term solar energy predicting base fuzzy logic model is generated by using MATLAB is shown in fig-1



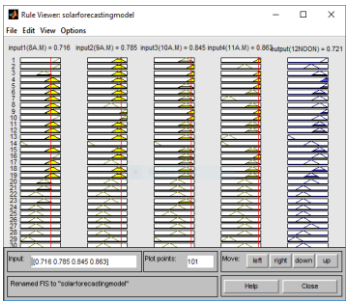


Fig-1 Solar Forecasting model by Fuzzy Generated Develop Fuzzy Model

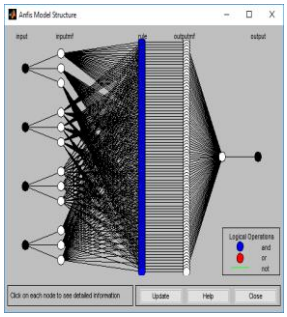
Fig-2 Results

 ISSN: 2454-4248
631 – 636

The 3rd rule results are shown in below Fig. 2. The results generated from the developed model are then defuzzified to get the predicted output in W/m2.

6.2. ANFIS Result

The short term solar energy forecasting by an ANFIS model is generated by using MATLAB 12.0 software version is shown in below fig-3. The main proposed to use an ANFIS network has adapted the training data sets to form best membership function so as to gets the desired output for testing data with less epochs.



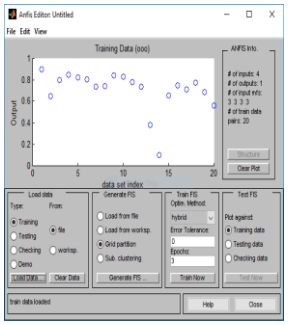
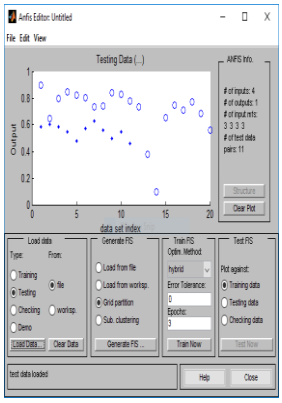


Fig-3ANFISStructure Fig-4 Training data of 31 days for propose work

The ANFIS architecture for proposed model is shown in Figure 3. Input membership function is described with Gaussian membership function. Hybrid learning algorithm is used and ANFIS model is run till the error is minimized. Error is minimized in two epochs during training. Then, testing of data is carried out. The pattern of variation of actual and predicted response is shown for training and testing dataset for proposed model Figures 4 ,5 and 6 show that actual (blue dot) and predicted (red dot) values are uniformly distributed respectively for training and testing data.



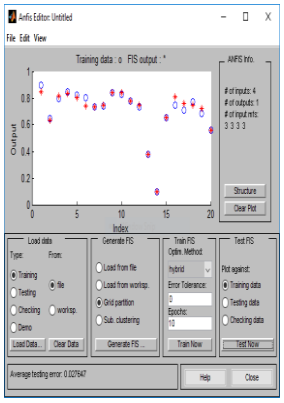


Fig-5 training and testing data for propose work Fig-6 Distribution of predicted and actual response during testing purpose work

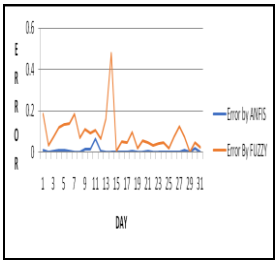


Fig-7 Rule viewer corresponding to1st rule by ANFIS
Fig.8.Error graph showing the comparison between Fuzzy and ANFIS

Table-3 shown the comparative result in between ANFIS and fuzzy logic forecasting value and also error are presented.

	Actual Measure Output	Output ANFIS-	Output Fuzzy-	ErrorANFS	Error Fuzzy
1	0.898	0.888	0.711	0.01	0.187
2	0.646	0.644	0.614	0.002	0.032
3	0.796	0.79	0.721	0.006	0.075
4	0.85	0.861	0.727	0.011	0.123
5	0.823	0.812	0.688	0.011	0.135
6	0.803	0.8	0.661	0.003	0.142
7	0.732	0.732	0.546	0	0.186
8	0.741	0.74	0.671	0.001	0.07
9	0.841	0.826	0.728	0.015	0.113
10	0.83	0.842	0.736	0.012	0.094
11	0.776	0.709	0.668	0.067	0.108
12	0.733	0.727	0.668	0.006	0.065
13	0.381	0.381	0.545	0	0.164
14	0.1	0.1	0.58	0	0.48
15	0.653	0.652	0.659	0.001	0.006
16	0.75	0.752	0.696	0.002	0.054
17	0.712	0.714	0.664	0.002	0.048
18	0.772	0.778	0.674	0.006	0.098
19	0.685	0.685	0.663	0	0.022
20	0.559	0.558	0.616	0.001	0.057
21	0.584	0.581	0.631	0.003	0.047
22	0.603	0.603	0.569	0	0.034
23	0.583	0.581	0.54	0.002	0.043
24	0.549	0.549	0.5	0	0.049
25	0.48	0.48	0.5	0	0.02
26	0.572	0.571	0.498	0	0.047
27	0.626	0.624	0.5	0	0.002
28	0.561	0.551	0.487	0.01	0.074
29	0.498	0.498	0.5	0	0.002
30	0.55	0.53	0.5	0.02	0.05
31	0.458	0.458	0.485	0	0.027

7. Conclusion

In solar power applications of solar energy forecasting plays a vital issue because solar power is fluctuating in nature and it depends on several meteorological parameters. So, considering the above fact and

 ISSN: 2454-4248
631 – 636

Keeping in view the aforesaid, general fuzzy based model and ANFIS model are generated for short term solar energy predicted. The proposed ANFIS has effectively forecasted the global solar radiation and then becomes utilise preferably for any design of conversion solar energy application. The ANFIS model shows better results in comparison with other models. The evaluation results of solar radiation shows a significant improvement in statistical parameters and depicts better accuracy than other models. The comparative results deduce the forecasting ability of Adaptive-Neuro fuzzy inference system model and its compatibility for any location with different atmospheric conditions.

Reference-

[1] Ramedani, Z., Omid, M. and Keyhani, A., 2013. Modeling solar energy potential in a Tehran Province using artificial neural networks. *International Journal of Green Energy*, *10*(4), pp.427-441.

[2] Rahoma, W.A., Rahoma, U.A. and Hassan, A.H., 2011. Application of neuro-fuzzy techniques for solar radiation.

[3] Iqdour, R. and Zeroual, A., 2006. A rule based fuzzy model for the prediction of solar radiation. *Revue des energies renouvelables*, *9*(2), pp.113-120.

[4] Sumithira, T.R., Kumar, A.N. and Kumar, R.R., 2012. An adaptive neuro-fuzzy inference system (*ANFIS*) based Prediction of Solar Radiation: A Case study. *Journal of Applied Sciences Research*, *8*(1), pp.346-351.

[5] Yadav, A.K. and Chandel, S.S., 2015. Solar energy potential assessment of western Himalayan Indian state of Himachal Pradesh using J48 algorithm of WEKA in *ANN* based prediction model. *Renewable Energy*, *75*, pp.675-693.

[6] Mellit, A., Kalogirou, S.A., Shaari, S., Salhi, H. and Arab, A.H., 2008. Methodology for predicting sequences of mean monthly clearness index and daily solar radiation data in remote areas: Application for sizing a stand-alone PV system. *Renewable Energy*, *33*(7), pp.1570-1590.

[7] Bhardwaj, S., Sharma, V., Srivastava, S., Sastry, O.S., Bandyopadhyay, B., Chandel, S.S. and Gupta, J.R.P., 2013. Estimation of solar radiation using a combination of Hidden Markov Model and generalized Fuzzy model. *Solar Energy*, *93*, pp.43-54.

[8] Mohammadi, K., Shamshirband, S., Petković, D. and Khorasanizadeh, H., 2016. Determining the most important variables for diffuse solar radiation prediction using adaptive neuro-fuzzy methodology; case study: City of Kerman, Iran. *Renewable and Sustainable Energy Reviews*, *53*, pp.1570-1579.

[9] Mohanty, S., Patra, P.K. and Sahoo, S.S., 2015. Comparison and prediction of monthly average solar radiation data using soft computing approach for Eastern India. In *Computational Intelligence in Data Mining-Volume 3* (pp. 317-326). Springer, New Delhi.

[10] Jafarkazemi, F., Moadel, M., Khademi, M. and Razeghi, A., 2013. Performance prediction of flat-plate solar collectors using MLP and *ANFIS* . *Journal of Basic and Applied Scientific Research*, *3*(2), pp.196-200.

[11] Hawlader, M.N.A., Chou, S.K. and Ullah, M.Z., 2001. The performance of a solar assisted heat pump water heating system. *Applied Thermal Engineering*, *21*(10), pp.1049-1065.

[12] Mohanty, S., Patra, P.K., Sahoo, S.S. and Mohanty, A., 2017. Forecasting of solar energy with application for a growing economy like India: Survey and implication. *Renewable and Sustainable Energy Reviews*, *78*, pp.539-553.

[13] Mellit, A., Arab, A.H. and Shaari, S., 2007. An *ANFIS* -based prediction for monthly clearness index and daily solar radiation: application for sizing of a stand-alone Photovoltaic system. *Journal of Physical Science*, *18*(2), pp.15-35.

[14] Mohanty, S., 2014. ANFIS based prediction of monthly average global solar radiation over Bhubaneswar (State of Odisha). *Int J Ethics Eng Manage Educ ISSN*, *1*(5), pp.2348-4748.

[15] Yadav, A.K. and Chandel, S.S., 2014. Solar radiation prediction using Artificial Neural Network techniques: A review. *Renewable and Sustainable Energy Reviews*, *33*, pp.772-781.

[16] Mohanty, S., Patra, P.K. and Sahoo, S.S., 2015, December. Prediction of global solar radiation using nonlinear auto regressive network with exogenous inputs (narx). In *Systems Conference (NSC), 2015 39th National* (pp. 1-6). IEEE.

[17] Varzandeh, M.H.M., Rahbari, O., Vafaeipour, M., Raahemifar, K. and Heidarzade, F., 2014. Performance of Wavelet Neural Network and *ANFIS* Algorithms for Short-Term Prediction of Solar Radiation and Wind Velocities. In *The 4th World Sustainability Forum*.