International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-7, Issue-6, March 2019

Computation of Daily Global Solar Radiation by Using Decision Tree Algorithm

R. Saranya, N. Selvam

Abstract: ***Consumption of electricity is increasing day by day, for the of electricity both the renewable and non renewable energy resources is utilized. The renewable energy of production wind, solar and tidal energy is preferred. Among these energy resources solar energy is most commonly used for production of electricity. In solar energy system the prime important parameter is Global Solar Radiation (GSR).While the global solar radiation data's and its records are not available in many places due to the high cost and maintenance of the corresponding instrument is also quite difficult.The main aim of this work is the Prediction of Solar Radiation by using machine learning algorithm of Decision Tree. Both Classification and prediction of attributes is possible by decision tree. The benefit of this algorithm is, it provides predictive model for the corresponding data with the tree structure. MATLAB is used for analysis and prediction of solar radiation using 365 data samples. The data is collected from the website of open Government of India and Government of India. The data set is divided into the ratio of 10:90. The ten percent of data is used for testing the data and the remaining ninety percent is used as training data. The different type of error is estimated for the data set.***

Keywords: solar radiation, decision tree, standard deviation, standard deviation reduction, predictor importance, training data, testing data

I. INTRODUCTION

Solar power is one of the commonly used power in Indian industries. In June 2017 country's solar power rating is raised to 23GW. The rating reached in 2017 is 8 times higher than the rating attained in the year 2014. The target rating of solar power in 2014 is 2,650 MW to achieve 20 GW in the year 2020 but the country achieved rating of 23 GW in the year 2017 itself. In year 2015-2016 the country added 3GW, in the year 2016-2017 5 GW is added similarly 10 GW is added in the year 10GW. The figure shows the energy produced by solar energy.

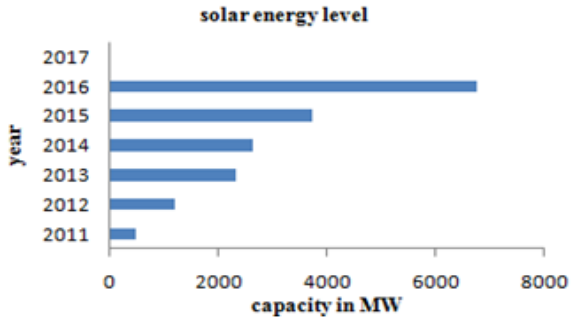

Figure 1Energy Sroduction in Mw

Solar power is used for various application such as the solar water heating, solar pumping, solar drying for agricultural drying for agricultural and animal products etc.

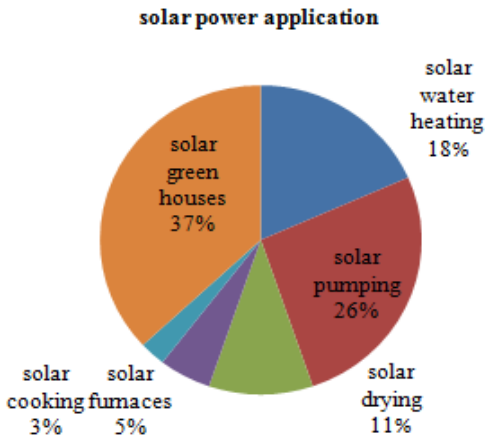

Figure 2 Various Solar Power Application

The figure shows the various application of solar power

Solar radiation is one of the important parameter in solar power. The radiation given by the sun involves the process of nuclear fusion for creating electromagnetic energy and the energy emitted is turn converted into as electricity. Solar radiation reaching the surface is split up into three regions 50% energy in visible short wave part, while remaining half in infrared region and with some in ultra violet region. The solar radiation spectrum is about 5800k. The total production of solar power in year 2017 is 1,575–49,837 exajoules (EJ).

The solar radiation data and records are not available due to high cost and the maintenance of corresponding equipment is quite difficult. So for the prediction of solar radiation various technique such as artificial neural network and learning algorithms is preferred.

Revised Manuscript Received on 30 March 2019.
***** Correspondence Author
R.Saranya, Electrical and Electronics Engineering, M.Kumarasamy College of Engineering, Karur, India.
N.Selvam, Electrical and Electronics Engineering, M.Kumarasamy College of Engineering, Karur, India

The mathematical derivation and equation form the tree model it compare solar radiation with input attributes such as average temperature,humidity,wind speed, atmospheric pressure and sunshine hours and produce prediction of solar radiation. Decision tree enables easy implementation and understandable than traditional algorithm. The artificial neural technique is also developed but the prediction accuracy is less and it requires more process for prediction.

Decision tree has able to handle both binary and continuous variable. Decision tree is used in various application such as agriculture, medicine and science in which it generate prediction with tree structure.

The process of decision tree is simple to develop and easy to handle than other algorithms. In this paper decision tree technique is implemented for the efficient prediction of solar radiation..

II. DECISION TREE

A overview

Decision tree is one of the most commonly used algorithms in machine learning. It is used mainly for classification problems and is of course supervised algorithm having pre-defined target variable. In this algorithm, the sample is split into two or more sub-parts based on most significant differentiator in input variables, which is done by various techniques like Gini, Chi-square, entropy etc. Internal node, root node, branch and leaf node are the nodes present in decision tree which gives the tree like structure. The test on an input is denoted by internal node the outcome of the data is represented as branch node and the class label is represented as leaf node. In this paper sample of 365 data's is taken to create the model with the input attributes of average temperature, humidity, atmospheric pressure, wind speed and sunshine hours. Figure shows the schematic diagram of decision tree.

B Implementation of Decision Tree

Two steps are involved in development of decision tree one is learning and the other is classification or regression depends on the target class.

In the first step the data is separated into test and training data. The most significant part in decision tree is the separation of test and training data. In this work 10% of data is used for testing and 90% of data is used for training. The training data is given as input to the decision tree and it executes tree as output. The Iterative dichotomizer 3 technique is used for development of decision tree.The tree is executed by using this technique and then 10% testdata is fed to the developed model to predict the global solar radiation. By comparing the predicted value and actual value of the solar radiation the accuracy of the model can be determined. The model can be used to predict the solar radiation if the accuracy is within the acceptable range.In case of low level of accuracy the corresponding issue should be determined.

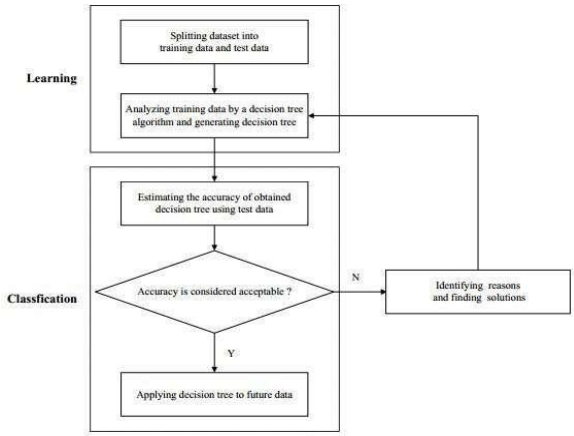

Figure3 Flow Diagram of Decision Tree Model

C Attribute Selection

The data used in this work is continuous so the regression type decision tree (Iterative Dichotomizer 3) algorithm is used. The calculation of entropy and information gain is avoided in this work.The model is build by determining the standard deviation and standard deviation reduction. At first for the target variable, the standard deviation is determined by using the equation (1)

$$s(T)=\sqrt{\frac{\sum(x-\mu)^2}{n}}$$

x is the target variable
μ is the mean of target variable
n is the number of data's in target class.
The value of standard deviation for the target label is estimated. secondly the standard deviation is evaluated for the two predictor attribute by using the mathematical formula(2)

$$s(T,x)=\sum_{cEx} p(c)s(c)$$

P(c) is the probability of the corresponding attribute
S(c) is the standard deviation of the corresponding attribute

The two attributes ,atmospheric pressure and target label is taken, standard deviation is calculated and the value obtained is 0.133.The standard deviation is determined for all the other attributes such as average temperature,humidity,wind speed and sunshine hours and the derived value is 0.147 and 0.159 respectively.

Table1 Calculation of SD value

S.NO	ATTRIBUTE	SD VALUE
1	Average temperature	0.147
2	Humidity	0.159
3	Wind speed	0.175
4	Atmospheric pressure	0.133
5	Sunshine hours	0.182

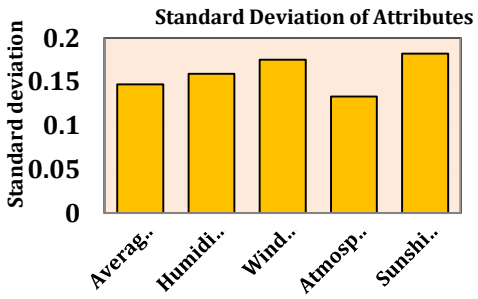

Figure 4 Standard Deviation Estimation

The figure gives the clear description about the standard deviation of all the data's. Now for all the data label, the standard deviation reduction is estimated by using the expression (3)

$$SDR(T,x) = S(T) - S(T,x)$$

Standard deviation reduction (SDR) is determined for all the data sample by substituting the values of standard deviation and it is represented in table.

Table 2 calculation of SDR value

S.NO	ATTRIBUTE	SDR VALUE
1	Average temperature	0.0519
2	Humidity	0.0399
3	Wind speed	0.0239
4	Atmospheric pressure	0.0659
5	Sunshine hours	0.0169

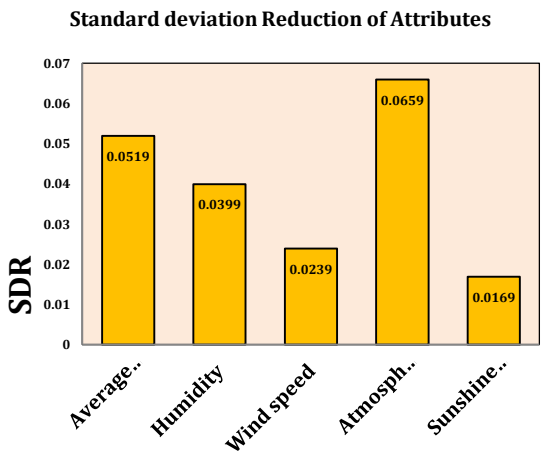

Figure 5 Standard Deviation Reduction Estimation

III Result of the model

A Data collection

Prediction of solar radiation is important since in India most of the electricity application takes place by solar energy. Data samples for the implementation of model are taken from the website open government of India and government of India. All the sample data is given to develop the model.

B Solar Radiation Prediction

Decision tree is created by interpretation of collected data samples. The average temperature, humidity, wind speed, atmospheric pressure and sunshine hours are given as input to the model. Decision tree is created based on the values of the input attributes. The input parameters undergo the process according to the decision tree algorithm and the value of solar radiation is predicted. The ratio of the data sample is 10:90. For learning the model ten percentages of data is given and the remaining ninety percentage data is used for the prediction.

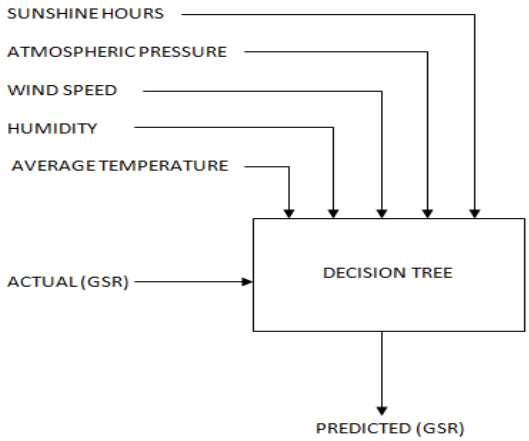

Figure 6 Block Diagram

Some of the data which is not involved in the learning of the model is used to develop the tree for the prediction process. The model designed for the prediction of solar radiation is shown in figure 7.

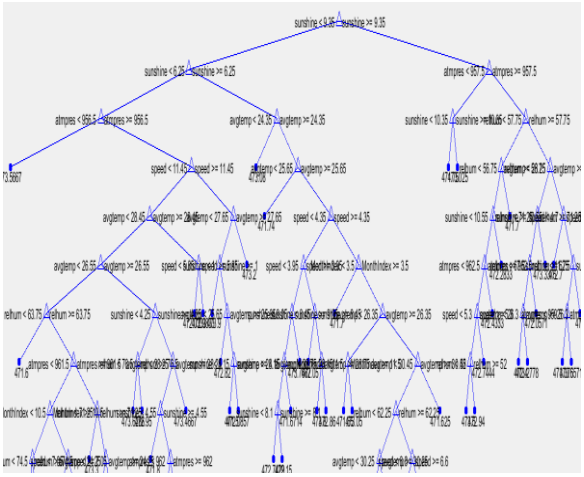

Figure 7 Decision Tree of GSR

The most important attribute which is used for the prediction process is determined by the parameter variable importance. The figure gives the description of the variable importance of input samples. The attribute with higher value indicates the variable importance.

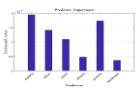

Figure 8 Predictor Importance

The accuracy of the predicted model is illustrated in figure. From the graph it is declined that the prediction accuracy of solar radiation by decision tree reaches the maximum value of.

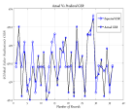

Figure 9 Actual and Predicted GSR

The graph is drawn for actual and predicted GSR .

C Calculation of Error

The developed decision tree model is analyzed in this section. The generalization ability is carried for the prediction of 50% data samples. The absolute error, mean absolute error, root mean square error is calculated for the given data set. The data set with minimum absolute error and root mean square error is said to have maximum efficiency.

a) Calculation of Mean Absolute Error

The difference between the actual and predicted value is said to be mean absolute error.

$$\text{Absolute error}=\frac{\sum_{i=1}^{d}\left|y_i-y_i^{'}\right|}{d}$$

b) Calculation of Mean Square Error

The square value of absolute error is called mean square error

$$\text{Mean square error}=\frac{\sum_{i=1}^{d}\left(y_i-y_i^{'}\right)^2}{d}$$

c) Calculation of Root Mean Square Error

The root value of mean square error is called root mean square error

$$\text{Root mean square error}=\sqrt{\frac{\sum_{i=1}^{d}\left(y_i-y_i^{'}\right)^2}{d}}$$

d) Calculation of Relative Absolute Error

The relative absolute error takes the total absolute error and normalizes it by dividing by the total absolute error of the predictor

$$\text{Relative absolute error}=\frac{\sum_{i=1}^{d}\left|y_i-y_i^{'}\right|}{\sum_{i=1}^{d}\left|y_i-\bar{y}\right|}$$

e) Calculation of Relative Square Error

The relative square error takes the total squared error and normalizes it by dividing by the total squared error of the predictor.

$$\text{Relative square error}=\frac{\sum_{i=1}^{d}\left(y_i-y_i^{'}\right)^2}{\sum_{i=1}^{d}\left(y_i-\bar{y}\right)^2}$$

f) Calculation of Root Relative Square Error

The square root value of relative square error is said to be root relative square error

$$\text{Root relative square error}=\sqrt{\frac{\sum_{i=1}^{d}\left(y_i-y_i^{'}\right)^2}{\sum_{i=1}^{d}\left(y_i-\bar{y}\right)^2}}$$

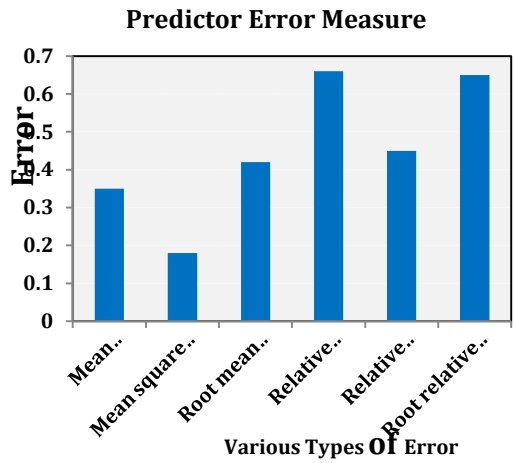

Figure 9Calculation of Error Values

The calculated error value of the samples is represented in the table.

Table3 Estimation of decision tree error

S.NO	Error	Generalization ability
1	Mean absolute error	0.35
2	Mean square error	0.18
3	Root mean square error	0.42
4	Relative absolute error	0.66
5	Relative square error	0.45
6	Root relative square error	0.65

IV CONCLUSION

Decision tree is the most popular machine learning algorithms for solving classification and regression problem. In this Work the prediction of solar radiation model is developed by the proposed decision tree algorithm. The executed model is more useful for the prediction of solar radiation in efficient manner and the consumption of electricity by the equipment is properly designed. Decision tree technique is suitable for the application of solar energy devices and it have lot of design features than other machine learning algorithm.

The decision tree algorithm for prediction of solar radiation is performed by using the tool MATLAB, by considering 365 data samples of solar radiation. The data sample of 365 is split into different ratios as training and testing data. The ratio of 10% testing and 90% training data is chosen for prediction of solar radiation. The different type of error is estimated for the ratio selected for the solar radiation prediction.

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AUTHORS PROFILE

Ms.R.Saranya has completed her UG in the field Electrical and Electronics Engineering in NSN College of Engineering and Technology ,from Anna university, Chennai, India and she pursuing her Post Graduate in the field of Power Systems Engineering in M.Kumarasamy College of Engineering, Anna University, Chennai, India. Her area of interest is Power Systems

Mr.N.Selvam has completed his UG in the field Electrical and Electronics Engineering in Chettinad college of Engineerin and Technology from Anna university,Chennai, India and he completed his Post Graduate in the field of Power Systems Engineering in M.Kumarasamy College of Engineering, Anna University, Chennai, India. He has presented papers in various National and Internatinal conferences. He published 9 International Journals. He currently working as a Assistant Professor in the Department of Electrical and Electronics Engineering in M.Kumarasmay College of Engineering.Karur,India.