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RESEARCH ARTICLE

FUZZY LOGIC AND NEURAL NETWORKS BASED SOLAR RADIATION PREDICTION

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ABSTRACT

Predictions of incoming solar energy are acquiring more importance, because of strong increment of solar power generation. Predictions is very useful in solar energy applications because it permits to generate solar data for locations where measurements are not available. In existing systems, solar radiation is predicted using fuzzy logic and neural networks separately. So that Mean absolute percentage error is greater than 10%. In our proposed method, Fuzzy logic and neural networks are combined together using Takagi Sugeno Kang (TSK) method. TSK method is very efficient than mamdani method. Previous year solar radiation data is collected from National Environmental Agency and using this values neural networks was trained. The graph between measured and predicted data values was plotted. Error is calculated using the difference between desired and output value. Prediction using combination of fuzzy and neural network model having Mean Absolute Percentage Error (MAPE) is less than 10%.So that this method will reduce the mean absolute percentage error is much smaller compared with that of the other solar radiation method

INTRODUCTION

Solar energy is clean energy because there are no carbon emissions during its generation. Photovoltaic and solar thermal are the main sources of electricity generation from solar energy. Large scale grid-connected PV power plants have been built using PV. PV will be a very important generation source for the microgrid (MG). However, due to the variability of solar irradiation and ambient temperature, the power output of PV plants is nondeterministic and stochastic. The statistical knowledge of the characteristics of the sequences for example of the daily solar radiation is necessary for the design and the computation of the performances of the solar systems. These sequences of radiation can be obtained starting from existing measurements, but unfortunately the networks of measurements of the solar radiation are still currently little developed. The weather conditions such as temperature and irradiance are important factors in the performance of any photovoltaic module. An accurate measurement of the effective irradiance level and different PV output voltage or current will affect the accuracy of the forecasted solar power. If the maximum power tracking algorithm is used, the PV output power will be highly related to the solar irradiance. Solar irradiance in moderate climates is mostly characterized by short time fluctuations. It is necessary to forecast the solar irradiance for solar power output.

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To generate the solar irradiance data based on stochastic methods such as autoregressive (AR), autoregressive moving average (ARMA), autoregressive integrated moving average (ARIMA) and Markov chain methods were developed. This methods are based on probability values, so it does not give good accuracy. It is very difficult to predict the solar radiation using stochastic methods. To overcome this difficulties, solar radiation was predicted using Fuzzy logic. In fuzzy logic clustering process is used to classify the different DNI values. Fuzzy logic is not as good as that of neural networks in one weather condition. So that neural networks are used to predict the solar radiation. Neural networks are used to learn the behavior of solar irradiance and they are subsequently used to simulate and predict this behavior. Neural networks does not require the knowledge of internal system parameters, less computational effort.

In order to overcome this problem, Artificial Intelligence (AI) techniques have been applied with success for modeling and forecasting of solar radiation data .With special abilities in simulating and mapping complicated systems automatically, neural networks are used to learn the behavior of solar irradiance and they are subsequently used to simulate and predict this behavior. The advantage of Artificial Neural Network (ANN) simulation over standard mathematical models is that it does not require the knowledge of internal system parameters; involves less computational effort; and offers a compact solution for multiple-variable problems.

However, the sky conditions are defined by fuzzy clustering: an input datum may belong to different conditions simultaneously, pertaining to each condition at different temperature behavior. Neural networks cannot tell the difference between them. A fuzzy model of solar irradiance on inclined surfaces has been developed by Gomez and Casanovas. The fuzzy model includes concepts from earlier models, though unlike these models, it considers non-disjunctive sky conditions. The only disadvantage is that the accuracy of forecast results based on fuzzy logic is not as good as that of neural networks in one weather condition.

TSK Algorithm

Let $Z = \{z_t\}$ to be the database representing the set of the available observations $Z_t = (x_t, y_t)$ (t=1,….N). The Takagi-Sugeno fuzzy model (TS) consists of aggregating of c fuzzy rules with the following structure:

R_k: If x_t is A_k then $y_{t,k} = \beta_0 + x_t' \beta_k$ k=1,2…c and t=1,2,…N

R_k: (k=1,2…c) indicates k^{th} fuzzy rule, x_t is the input variable ($x_t \in R^n$). $y_{t,k}$ is the output of the rule k relative to the input x_t and A_k is a fuzzy set and $\beta_k = (\beta_1, \beta_2, \ldots \beta_n)$.

The output y_t relative to the input x_t obtained after aggregating of c TS fuzzy rules, can be written as a weighted sum of the individual conclusions.

$$\widehat{y_t} = \sum_{k=1}^{c} \pi_k (x_t) \widehat{y_t}, k$$

$$\pi_k = \frac{\gamma_{k\mu_{A_k}}}{\sum_{j=1}^{c} \gamma_{j\mu_{A_j}}} (x_t)$$

μ_{Ak} –membership function related to the fuzzy set A_k, $y_k = g(\rho_k)$ and $g(x) = 1/1+e^{-x}$.

Function g enables the weights ρ_k to be normalized in the sense that γ_k will always satisfy the following condition.

$0 \le \gamma_k \le 1$, k=1,2,….c

The latter constraint enables to interpret γ_k as an intensity parameter. The normalized intensities are noted γ_k^*:

$$\gamma_k^* = \frac{\gamma_k}{\sum_{j=1}^{c} \gamma_j}$$

The rule's influence is given according to the value of γ_k^*, when the intensity γ_k^* is close to 0, we can say that c-1 rules are still sufficient in computing of the GTS system output. The membership functions are selected Gaussian types:

$\mu_{Ak}((x_t) = \exp(-1/2 \; \| x_t - m_k \| s_k^2))$

$\| x_t - m_k \| s_k^2 = (x_t - m_k)' S_k' S_k (x_t - m_k)$

The centres m_k matrix S_k are initialized by projection of the partition obtained from GK algorithm.

$S_k = (F_k^{(x)})^{-1/2}$ and $m_k = V_k^{(x)}$

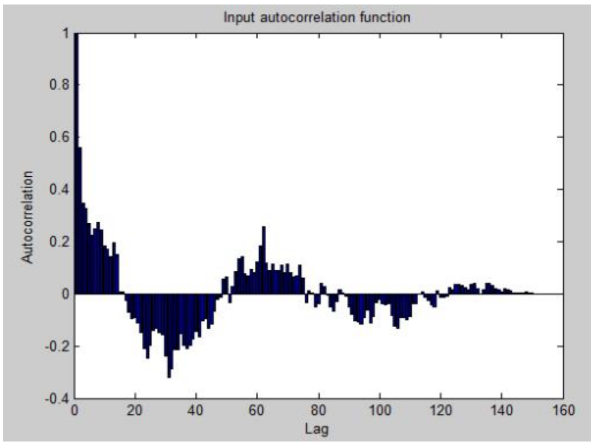
$F_k^{(x)}$ and $V_k^{(x)}$ are the projections of the variance covariance matrix and cluster centres k respectively on input space.

MATERIALS AND METHODS

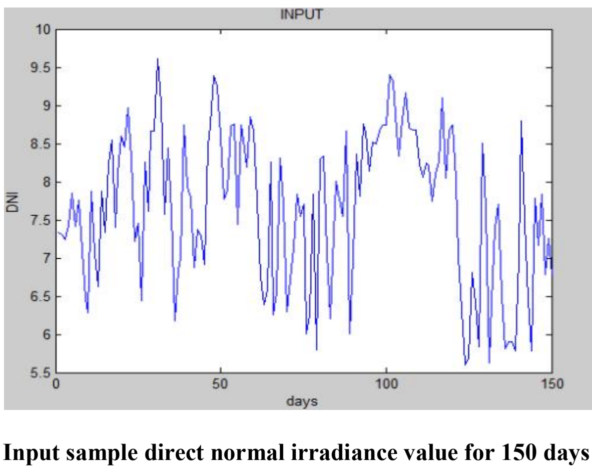
This paper proposes a new solar radiation forecast technique based on neural networks and fuzzy logic. The main idea of this technique is to achieve good accuracy at different sky conditions. The direct normal irradiance (DNI) data will be classified as different fuzzy sets based on the fuzzy rules. The past and future DNI data information can be obtained from National Environment Agency (NEA). The historical solar radiation data will be used to train the basic neural networks. The fuzzy model can tell the difference between the different DNI and it will forecast the solar radiation together with trained neural networks. In the mathematical modeling of PV, neural network and fuzzy logic are also introduced. The equivalent circuit of PV and its output power formulation are introduced.

Prediction of Solar Radiation

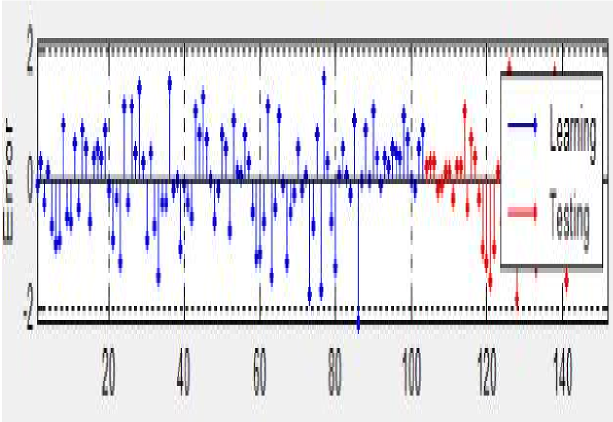
The prediction is very useful in solar energy applications because it permits to generate solar data for locations where measurements are not available.



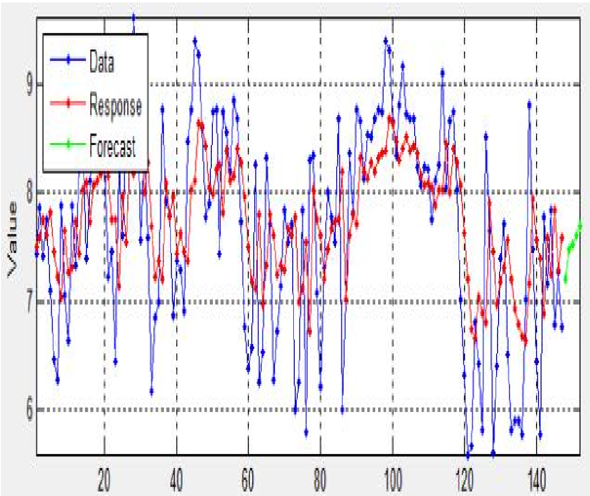
Input autocorrelation Function



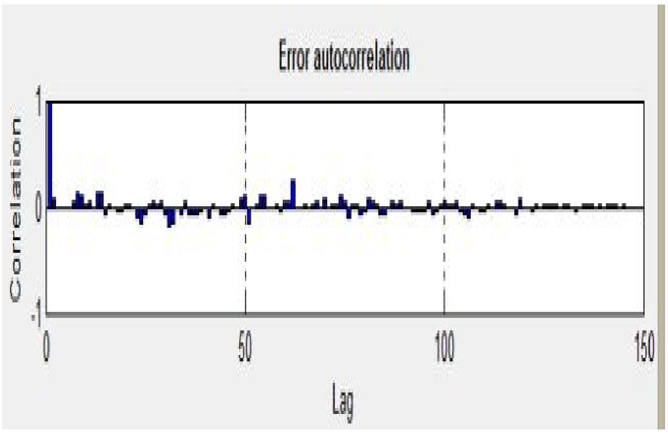
Input sample direct normal irradiance value for 150 days



Days Learning and testing error



Days Measured and Predicted output



Auto correlation

MAPE=6.78
R^2 =0.24888
DW =1.9725

In this section, we used the identified TS fuzzy model to predict the daily solar radiation. For that we use the test set of which the data are not using during the training phase.

Solar radiation is predicted using Takagi sugeno Kang method. It will combine both fuzzy logic and neural networks. Neural networks is used to give the weight age to the system. Here three months solar radiation data was collected from National Environment Agency. Using three months data it will calculate next three month values and also next five forecated values. Graph was plotted between measured and predicted values. Mean absolute percentage error is calculated using certain formula. We remark that the predicted and the measured data have similar behaviours, and then we can conclude that the developed TS fuzzy model is adequate to fit the daily solar radiation data.

Conclusions

Fuzzy logic and neural networks based solar radiation prediction is explained in this project. By using fuzzy logic, the clustering process is optimized and a reduced number of sky classes can be determined. The proposed method can be used for both hourly and day-to-day solar radiation forecast. Once the Direct normal irradiance information for the future period can be obtained from C-WET, the solar radiation can be forecasted by the proposed method and with reasonably good accuracy. Mean absolute percentage error is reduced to lower than 10%. The different sky conditions will not affect the accuracy of the forecasted results very much.

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