THE PREDICTION OF SOLAR RADIATION USING FUZZY LOGIC: A CASE STUDY

JWAN ABDULKHALIQ MOHAMMED[*] and BERIVAN HADI MAHDI[**]
[*] Dept. of Computer Science, College of Science, University of Duhok, Kurdistan Region-Iraq
[**] Branch of Basic Science, College of Agriculture, University of Duhok, Kurdistan Region-Iraq

ABSTRACT

Solar energy is used in many applications such as producing agricultural food, renewable energy, and heating and lighting systems… etc. Nowadays, countries all over the world, especially the developing countries are facing a great challenge which is providing sustainable energy for consumers. Electricity is the most common type of energy that is used by consumers in which oil or nuclear power is used to produce sufficient amount of electricity for the constant increase of the population in the present. However, both oil and nuclear energy negatively affect the global warming; therefore, solar energy is aspired by many countries to decrease the effects of the global warming and produce renewable sources of energy. The aim of this study is to predict the use of solar radiation for solar energy to produce electricity in Duhok city due to the fact that "national electricity" is not enough for the great number of consumers; as a result, people depend on "local or private generators" which mainly depend on oil to produce electricity. Fuzzy logic approach is used to estimate the solar radiation. The four fuzzy systems are created using the available data in Duhok City in 2016. Daily observations for temperature, humidity and wind speed for four seasons are analyzed to estimate the solar radiation. The predicted outputs of fuzzy logic system are compared with the actual solar radiation. In addition, the fuzzy system approach is evaluated using Mean Absolute Percentage Error (MAPE) and Absolute Percentage Error (APE). The outcomes of MAPE and APE are 5.86%, 1.54%, 2.76% and 1.52 for four seasons (winter, summer, spring and fall), respectively. According to the results, the performance of fuzzy system is reasonably effective in predicting the solar radiation.

INTRODUCTION

Forecasting defined as the process of predicting the value of a variable or variables in the future (Yazdani et al., 2014). Solar radiation is defined as "the radiation, or energy emitted by the sun in the form of electromagnetic radiation in the wavelength range of the measuring instrument". One of the most significant green sources is solar radiation which is recently used in some countries. Solar radiation is usually measured very well in sunny and clear days than cloudy days. Coops and others (Coops et al., 2000) have conclude that the location of a specific area and meteorological parameters or weather conditions affect the solar radiation. Consequently, the precise prediction of any energy production in solar systems includes the precise estimation of solar radiation which relies on various atmospheric parameters. Recently, many research studies have been evolved to attempt to estimate solar radiation utilizing artificial intelligence mechanisms and meteorological parameters such as wind speed, temperature and humidity ...etc. One of the significant mechanisms is fuzzy logic.

A membership function in fuzzy sets is used as the representation of continuous nature of data. One of the controlling technologies in Artificial Intelligence (AI) is the theory of fuzzy set which is broadly used in load forecasting. For instance, normal linguistic variables can be modeled at cognitive level, which are ambiguous at the cognitive level (Pujar, 2010; Ibrahim, 2003). There are many uncertainties in load forecasting like the difference in temperature, rainfall, wind speed, atmosphere pressure and solar radiation which cannot be numerically specified precisely (Mordjaoui et al., 2010). For this reason, the most convenient method to be used, under such conditions, is the fuzzy logic approach.

In the literatures many techniques of forecasting have been evolved. These comprise artificial neural network (ANN), the ARMA model, exponential smoothing, data mining models, linear regression and fuzzy logic (Filik et al., 2011; Ismail et al., 2011). Amongst these techniques, ANN and fuzzy logic are widely utilized. Because of the distinct characteristics of fuzzy logic, the fuzzy logic overcomes ANN (Karwade and Ali, 2015). For example, there is a reasonable variation among the weather factors and solar radiation; the fuzzy logic system can treat the variation with low estimation error.

In this paper, solar prediction for future planning utilizing fuzzy logic system is suggested and the following aims can be fulfilled; the first aim is to develop a rule base to identify precise solar prediction and the second aim is to develop a fuzzy logic model to predict a future solar. Fuzzy logic approach is utilized to show the highly non-linear relationships (using membership function) between weather factors and their outcomes on the highest load on a month basis of the year (Fan et al., 2007). There are many factors that affect solar radiation such as temperature, humidity, wind speed, cloud cover, pressure … etc. However, temperature, humidity and wind speed were utilized as inputs to the fuzzy logic because they have direct influence on solar radiation when the solar radiation is an output.

METHODOLOGY
Description of Study Area

Duhok governorate is located in north of Kurdistan, region of Iraq, (43.20 – 44.10) longitude, (36.40 – 37.20) latitude, close to both Syrian & Turkish borders. Duhok city is surrounded by two series of mountains, Zawa Mountain from the south and Bekher Mountain from the north, while it is rather plain from east and west sides. Basically, there are four seasons in Duhok city –KRG and the climate of Duhok is moderate; it is sunny hot in summer, cold and wet in winter and spring and fall are partly sunny and wet. In general, summer and winter are longer than the other seasons, where summer starts from June to the beginning of September and winter starts from October to the end February. Thus, fall is September and spring starts from March to the end of May.

Method of Data Collection

The data (the inputs and output parameter) is gathered from the Weather Station of College of Agriculture in Sumel, University of Duhok for four seasons in Duhok city in 2016 for four seasons (winter, summer, fall, and spring). This was the only available data for the study. This data are temperature, humidity and wind speed for inputs and solar radiation for output.

Fuzzy System (FSs)

FSs are also known as fuzzy model, fuzzy logic controller and rule-based system. FSs consist of multiple-valued logics in which more than two values can be true. The values of variables can be approximate between 0 and 1 depending on reasoning. The main notion of fuzzy set was initially introduced by Lotfi Zadeh in 1965 (Ali et al., 2016). The theory of fuzzy set can be regarded as a generalized classical set theory (Jantakoon, 2016). Generally, in the classical set theory, there are two options for an element which may belong to a specific set or not. Thus, the crisp value is the aspect that determines the degree of being a member in a particular set. Yet, the degree of a membership of an element in fuzzy set theory may vary permanently. The scope of the fuzzy set is between {0,1} (Zadeh, 1965). In fuzzy logic, linguistics terms are used to express the values of variables. The input and output variables are connected utilized fuzzy IF-THEN rules, where the IF part represents the fuzzy antecedent and the Then part represents the fuzzy consequent, that also takes the form of fuzzy set. The format of creating rules is similar to human reasoning because it is based on the 'IF-THEN' expressions.

FSs include four major phases, the fuzzification, the fuzzy rule base, the fuzzy inference engine and the defuzzification. The block diagram in Figure 1 shows the procedure of the fuzzy system.
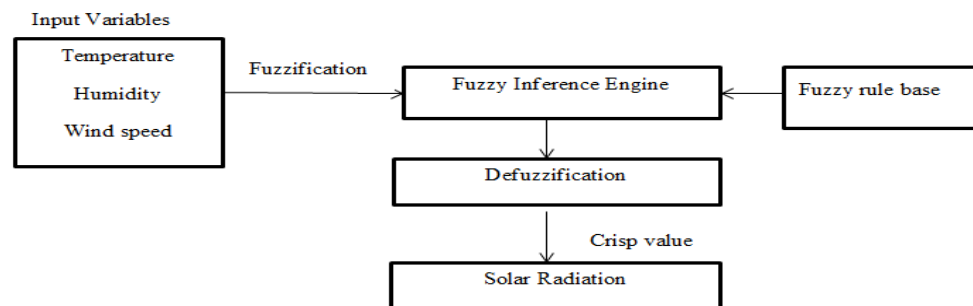
Figure (1): The process of fuzzy system

The first phase is fuzzification method which converts the crisp values into fuzzy values using membership functions. Triangular membership functions are used in this study for input and output variables. The second phase, the fuzzy rule base is formed using the fuzzy operator and input and output variables. The fuzzy system includes input variables which are temperature, humidity and wind speed. Output is solar radiation. The AND and OR operators are used to correlate the input variables (Bunnoon, 2011). The third phase is the fuzzy inference engine which includes the application of the membership functions of inputs and the fuzzy rules base to maintain the membership function of output. This operation is called the implication method through which a fuzzy set of output by giving a number for each input. Then, the aggregation process is applied to join membership functions of each rule and get one output fuzzy set (Yazdanbakhsh and Dick, 2017). The final phase is defuzzification method which converts the output fuzzy set into a crisp value using Center Of Area method (COA) which is the most common defuzzification method (Swaroop and Abdulqader, 2012). Three well-known models exist in FSs which are Sugeno-type, Mamdani-type and Tsukamoto-type. This study concentrates only on Mamdani-type because it is more convenient for the aims of this study.

Fuzzification

Fuzzification is the operation that converts crisp values of input variables into fuzzy values (Cornelis and Kerre, 2003). Linguistic terms are the use of words in artificial or natural language to represent information with several degree of ambiguity (Jeon et al., 2009).

In this study, solar radiation is an output, while temperature, humidity and wind speed are inputs. Each variable has its linguistic terms and it will be classified based on the degree of vagueness. Solar radiation is classified into VeryLow, Low, LittleLow, and Medium. Temperature is classified into Low, Medium, and High. Humidity is categorized into Dry, Medium, and Wet, and wind speed into VeryLow, Low, Medium, and High.

The below equation is a triangular membership function which is used to evaluate linguistic expressions for variables and their membership functions.

$$\mu_A(x) = \begin{cases} 0, & x \leq a \\ \dfrac{x-a}{m-a}, & a < x \leq m \\ 1, & x \geq b \end{cases}$$

Where a is the minimum limit, b is the maximum limit and m is the value between a and b.
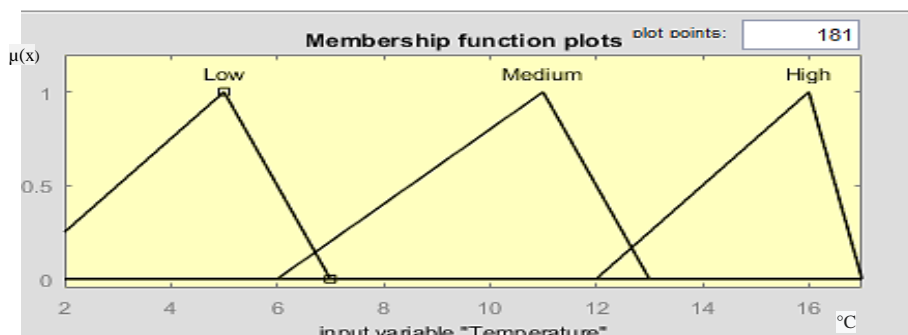
Membership Functions (MFs)

Membership function is the graphical representation which determines how each value in the input space can be transformed to membership value which is between 0 and 1. Input space is normally known as the universe of discourse (μ), that involve all of relevant elements for every specific application (Hong and Lee, 1996).

Hence, the solar radiation, temperature, humidity and wind speed are considered as the universe of discourse or fuzzy sets. Then, these fuzzy sets are categorized into linguistic variables which have been mentioned in the previous section (Cornelis and Kerre, 2003).

There are several sorts of MFs like gaussion, trapezoidal, triangular, sigmoid and bell-shaped. However, triangular membership functions have been used for this study due to their simplicity. In addition, simple formulas and computational efficiency are used in these MFs. Plus, they have straight lines segment, so they can be easily implemented in FSs (Bauer, 2018).

In this study, triangular membership functions are used to fuzzify the crisp values. Figure (2) showes the membership functions and ranges for each variable in the fuzzy system, the ranges of parameters have been adopted from the above mentioned weather station. Overlap among antecedent me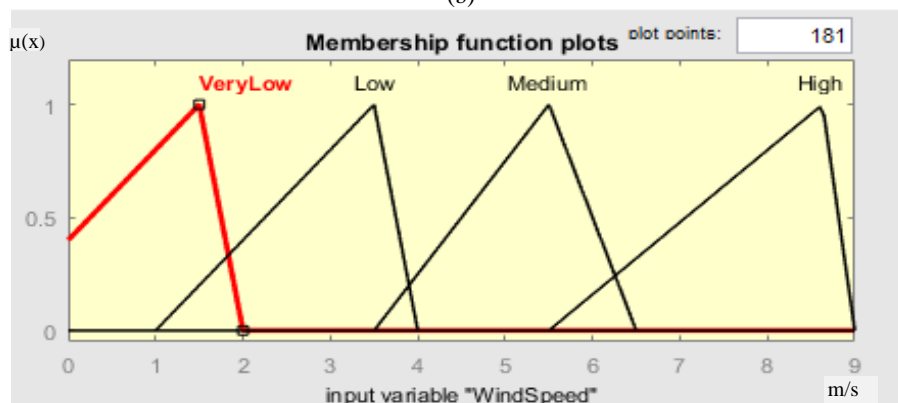mbership functions is essential to decrease the sensitive errors. As shown in the below figure (2), the overlap occurs between membership functions when their scopes partly cover each other. In other words, if a crisp number is entered to the system, it belongs to more than one fuzzy numbers.
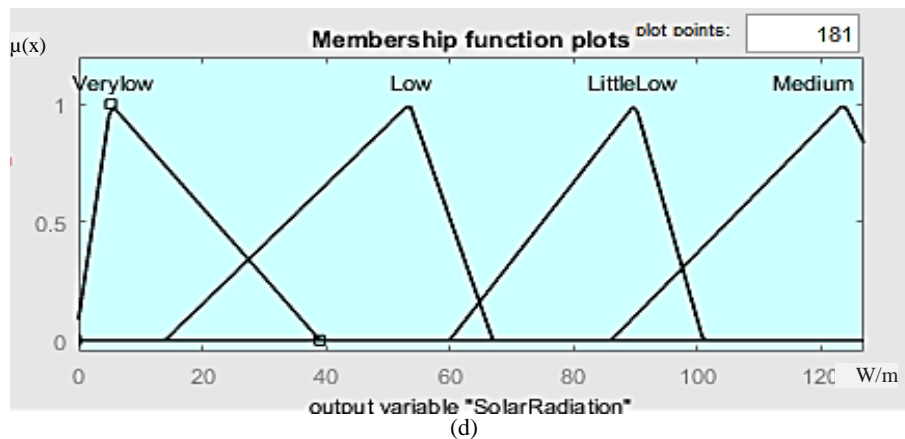

(a)

(b)

(c)

37

(d)
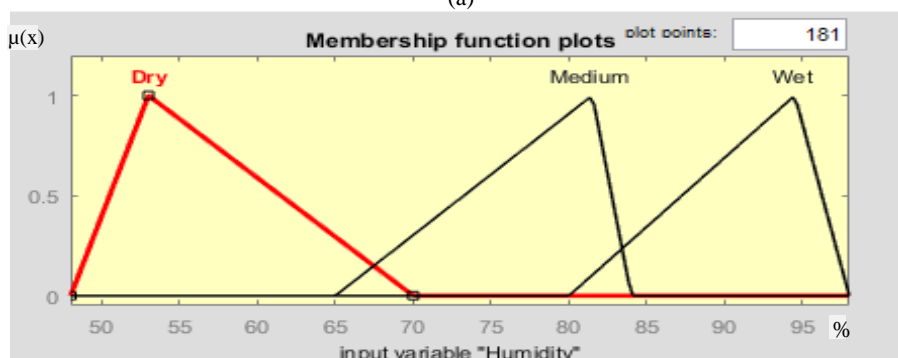
Fig.mbership function for temperature

(b): Membership function for humidity

(c): Membership function for wind speed

(d): Membership function for solar radiation

Rule base (RS)

This part of the fuzzy system considers one of the important steps for the whole procedure. The rule base links between input parameters and the required output. RS is used to demonstrate the connection between input and output for the real issue using "linguistic terms" (Cordón et al., 2001). Each rule in the rule base is written as shown in the following equation:

$$\text{"IF A IS C THEN B IS D"} \quad (2)$$

According to equation (2), the IF-THEN rule contains two parts, where A and B, are named antecedent (input parameter) and consequent (output) in the same order, while C and D are linguistic terms as mentioned in the fuzzy system section. However, in each part more than two variables can be connected using logical operators such as OR, AND and NOT (Surmann and Selenschtschikow, 2002).

In this work, the following steps are adopted:

1- Three input variables (temperature, humidity and wind speed) with logical AND operator are used for the antecedent part. For the consequent part only one output variable (solar radiation) is used. Equation (3) illustrates the two parts of the IF-THEN.

IF Temperature is Low AND Humidity is Medium AND Wind Speed is High THEN Solar Radiation is Medium (3)

Where Temperature, Humidity and Wind speed are linguistic variables and Low, Medium, High and Medium are linguistic terms.

2- The antecedent part is placed into the fuzzy inference engine. If the rule is fired, then the inference engine calculates the membership functions of the input variables using equation (1). According to equation (3), since AND operation is used then the minimum value of membership functions in the antecedent part will be taken. The result of this stage is produced first by using the implication method followed by an aggregation of the outputs of each rule to make a single fuzzy set (Jantakoon, 2016).

Defuzzification

The results of the fuzzy inference engine are fuzzy values which are produced using the aggregation of all membership functions that are operated by the inference engine. The defuzzification process is used to achieve crisp equivalent which is the output of fuzzy logic system (Ronald and Sari, 2014). There are several methods of defuzzification such as Center of Sums Method (COS), Center of gravity (COG) / Centroid of Area (COA) Method, Bisector of Area Method (BOA), Weighted Average Method and Maxima Methods. In this study, a numerical prediction is produced using the centroid of area (COA) which is the most popular method. COA is calculated using the following equation:

$$x^* = \frac{\sum_{i=1}^{n} x_i \cdot \mu(x_i)}{\sum_{i=1}^{n} \mu(x_i)}$$

(4)

Where x^* is crisp value, $\mu(x_i)$ is the membership function, n indicates the number of elements in the sample. This prediction is sensitive to all the rules applied.

Error Measurements

$$APE = \left|\frac{actual(i) - forcast(i)}{actual(i)}\right| \times 100\%$$

Where actual(i) represents the actual solar radiation in the sample, forecast(i) indicates the predicted solar radiation in FS

MAPE

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{actual(i) - forecast(i)}{actual(i)}\right| \times 100\%$$

Where actual(i) refers to the actual solar radiation in the sample, forecast(i) represents the predicted solar radiation in FS, and n represents the number of elements in the sample

RESULTS AND DISCUSSIONS

The inputs used for the prediction of solar radiation are: temperature, humidity and wind speed. To make one record in the fuzzy system,

There are two types of error measurements that are used to check the competence of fuzzy system, which are APE and MAPE.

APE

APE is an abbreviation for Absolute Percentage Error. The following equation is utilized to calculate APE:

(5)

MAPE is an abbreviation for Mean Absolute Percentage Error. It considers one of the most popular error measurements which evaluate the accuracy of prediction (Swanson et al., 2011). The following equation is used to compute MAPE:

(6)

the values of these inputs were organized as string split by a comma. Thereafter, such records were normalized and fuzzified to be utilized to create the rules for anticipation by the fuzzy system. The prediction of solar radiation is done for four seasons in Duhok city in 2016. The variation between the predicted and actual solar radiation is shown in Figures 3-6:
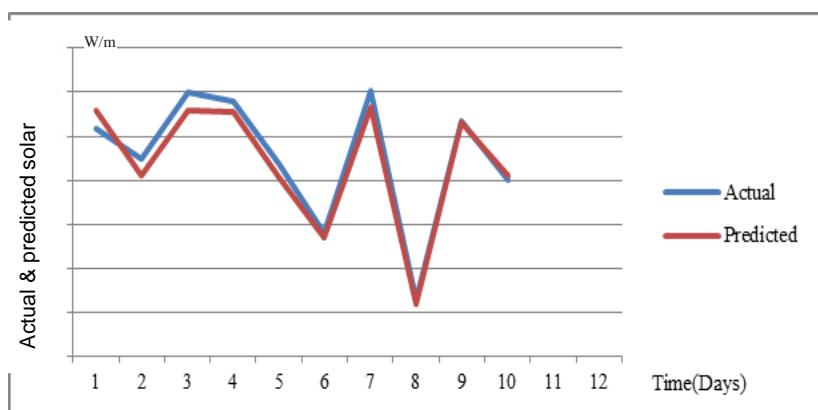

Fig. (3): The actual and predicted solar radiation for winter season in 2016
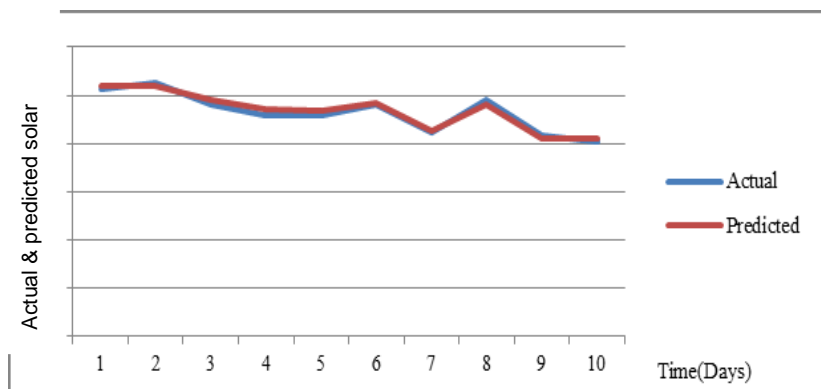
W/m

Fig. (4): The actual and predicted solar radiation for summer season in 2016
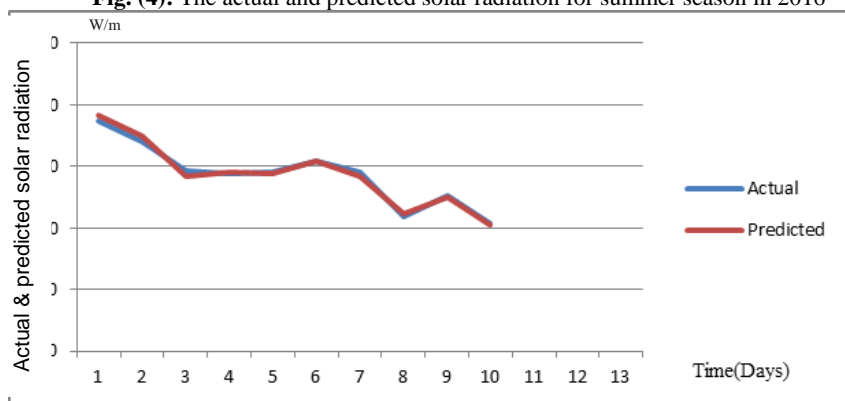
Fig. (5): The actual and predicted solar radiation for fall season in 2016
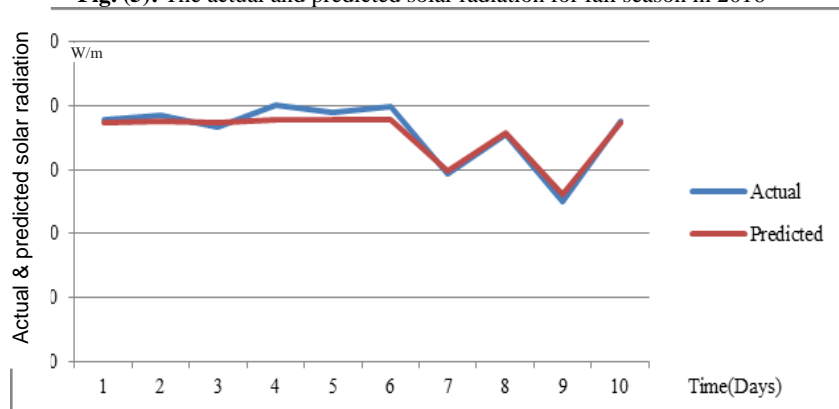
Fig. (6): The actual and predicted solar radiation for spring season in 2016

Figures (3-6) present the details of actual and predicted solar radiation for the four seasons in 2016. As shown in the figures 4 and 5, there is no difference between the actual and predicted solar radiation. However, figures 3 and 6 show that there is a little variation between the actual and predicted solar radiation.

Tables 1-4 present the actual and predicted solar radiation for four seasons in 2016 and the APE and MAPE are computed for the sample data set using the equations (3) and (4) respectively:

Table (1): Temperature, humidity, wind speed, actual and predicted solar radiation for winter in 2016

Temp °C	Humidity %	Windspeed m/s	Actual w/m	Predicted w/m	APE %
3.3	73.8	2.7	103.2	112	8.527131783
11.6	70	1	90	81.9	9
13.6	78	0.2	120	112	6.666666667
14.5	70	0.6	116	111	4.310344828
13.4	67	2	88	81.4	7.5
12.7	85	3.6	55.7	53.7	3.590664273
16.4	78.2	0.5	121	113	6.611570248
14.8	66	4.5	26	23.7	8.846153846
14.6	68.8	1.1	107	106	0.934579439
11.4	71	0.6	80	82.1	2.625
					58.61211108
				MAPE	5.861211108

Table (2): Temperature, humidity, wind speed, actual and predicted solar radiation for summer 2016

Temp °C	Humidity %	Windspeed m/s	Actual w/m	Predicted w/m	APE %
44.1	20.4	2.6	256	259	1.171875
44.2	19.8	5	263	260	1.140684411
43.3	24.7	2.4	241	246	2.074688797
43.2	21.6	1	230	235	2.173913043
44.7	18.4	1.6	230	234	1.739130435
42.6	21.5	1.9	240	242	0.833333333
45.5	20.6	1	212	214	0.943396226
44.6	16.2	4.5	246	240	2.43902439
45.4	15.4	3.1	208	205	1.442307692
45.9	16.3	4.4	202	205	1.485148515
					15.44350184
				MAPE	1.544350184

Table (3): Temperature, humidity, wind speed, actual and predicted solar radiation for spring 2016

Temp °C	Humidity %	Windspeed m/s	Actual w/m	Predicted w/m	APE %
23.2	65.8	1.1	189	187	1.058201058
23.9	55.8	1	193	188	2.590673575
21.1	72.5	1	183	187	2.18579235
18.2	72.7	1.1	201	189	5.970149254
22.2	71.6	1	195	189	3.076923077
22.7	69.3	1	200	189	5.5
15.3	84.7	2.4	147	149	1.360544218
22	57.2	4.9	178	179	0.561797753
18.3	80.6	2.6	125	131	4.8
15.5	82.7	0.8	188	187	0.531914894
					27.63599618
				MAPE	2.763599618

Table (4): Temperature, humidity, wind speed, actual and predicted solar radiation for fall 2016

Temp °C	Humidity %	Windspeed m/s	Actual w/m	Predicted w/m	APE %
33.7	19.6	5.6	187	191	2.139037433
36.2	19	1.2	170	174	2.352941176
33.3	33	1.5	146	142	2.739726027
31.9	34	2.3	144	145	0.694444444
30.2	37	1.9	145	144	0.689655172
29	30	1.1	154	154	0
29.3	24	1.3	145	142	2.068965517
30.8	31	1.3	109	111	1.834862385
30.2	30	1.4	126	125	0.793650794
29.6	34	1.2	104	102	1.923076923
					15.23635987
				MAPE	1.523635987

As evident from Tables 1-4, there have been few variations of the predicted solar radiation value from the actual. The APE and MAPE are used to evaluate the performance of fuzzy logic approach. The results of APE and MAPE were comparatively low for all seasons. Therefore, the prediction model is effective and dependable and can be utilized for solar radiation prediction

CONCLUSION

In this study, fuzzy system has achieved a good performance in predicting the solar radiation. The amount of accuracy for the four seasons was reasonably acceptable. However, the performance of this system can be improved, if more than one dataset are available. Fuzzy inference engine was the most effective part of the fuzzy system. This part is responsible for the application of implication method and aggregation method which consider the backbone of the fuzzy system.

REFERENCES
Ali, D., Yohanna, M., Puwu, M.I., and Garkida, B.M. (2016). Long-term load forecast modelling using a fuzzy logic approach. *Pacific Science Review A: Natural Science and Engineering*, 18(2), 123-127.
Bauer, I. (2018). Framing, overflowing, and fuzzy logic in educational selection: Zurich as a case study. *Geogr. Helv.,* 73, 19-30.
Bunnoon, P. (2011). Mid-Term Load Forecasting Based on Neural Network Algorithm: a Comparison of Models. *International Journal of Computer and Electrical Engineering*, 3(4), 600-605.
Coops, N. C., Waring, R. H. and Moncrieff, J. B. (2000). Estimating Mean Monthly Incident Solar Radiation on Horizontal and Inclined Slopes from Mean Monthly Temperatures Extremes. *International Journal of Biometeorology*, 44, 204–211.
Cordón, O., Herrera, F., and Villar, P. (2001). Generating the knowledge base of a fuzzy rule-based system by the genetic learning of data base. *IEEE Trans Fuzzy Systems*, 9, 103-108.
Cornelis C, Kerre E (2003) A fuzzy inference methodology based on the fuzzification of set inclusion. *In: Recent advances in intelligent paradigms and applications*, Physica-Verlag, 71–89
Fan, S., Methaprayon, K., and Lee, W.J. (2009). Multi-Region Load Forecasting Based on Weather and Load Diversity Analysis. *IEEE Trans. Ind. Appl.* 45(4), 1452-1459,
Filik ,U.B., Gerek ,O.N., and Kurban, M. (2011). Hourly forecasting of long term electric energy demand using novel mathematical models and neural networks. *International journal of innovative computing, information and control*, 7, 3545–3557.
Hong, T., and Lee, C.(1996). Induction of fuzzy rules and membership functions from training examples. *Fuzzy Sets System*, 84(1), 33-37.
Ibrahim, H.A. (2003). Fuzzy Logic for Embedded Systems Applications. USA: Butterworth-Heinemann.
Ismail ,Z., Mansor, R, and Ta'zim, J.D. (2011). Fuzzy Logic Approach for Forecasting Half-hourly.
Jantakoon, N. (2016). Statistics Model for Meteorological Forecasting Using Fuzzy Logic Model. *Mathematics and Statistics*, 4(4) , 95 – 100.
Jeon, G., Anisetti, M., Lee, J., Bellandi, V., Damiani,E, and Jeong, J.(2009). Concept of linguistic variable-based fuzzy ensemble approach: application to interlaced HDTV sequences.

IEEE Transactions on Fuzzy Systems, 17(6), 1245-1258.

Karwade, S.B. and Ali, M.S.(2015). Review Paper on Load Forecasting Using Neuro Fuzzy System. *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 10(3), 38-42.

Mordjaoui, M., Boudjema, B., Bouabaz, M., and Radouane, D.(2010). Short term electric load forecasting using Neuro-fuzzy modeling for nonlinear system identification. *LRPCSI Laboratory, University of 20August, Skikda*, 5,1-6.

Pujar, J.H. (2010). Fuzzy Ideology based Long Term Load Forecasting. *International Journal of Computer and Information Engineering*, 4(4), 790-795.

Ronald, C.P., and Sari, S.R. (2014). Long Term Load Forecasting in Tamil Nadu Using Fuzzy-Neural Technology. *International Journal of Engineering and Innovative Technology (IJEIT)*, 3(9), 5-8.

Surmann, H. and Selenschtschikow, A. (2002). Automatic generation of fuzzy logic rule bases Examples I. *In Proc. of the NF 2002: first international ICSC conference on Neuro-Fuzzy Technologies. Cuba*, 16-19 January, 75-81.

Swanson, D.A., Tayman, J., and Bryan, T. (2011). Mape-r: a rescaled measure of accuracy for cross-sectional subnational population forecasts. *J Popul Res*, 28, 225-243.

Swaroop, R., and Abdulqader, H.A.(2012). Load forecasting for power system planning using fuzzy-neural networks. *In Proceedings of the World Congress on Engineering and Computer Science, USA*. 1, 1-5.

Yazdanbakhsh O. and Dick, S. (2017). A systematic review of complex fuzzy sets and logic. *Fuzzy Sets Syst,*1,1-22.

Yazdani, M.G., Salam, M.A. and Q.M. Rahman (2014). Investigation of the effect of weather conditions on solar radiation in Brunei Darussalam. *International Journal of Sustainable Energy*, DOI:10.1080/14786451.2014.969266.

Zadeh, L.A. (1965). Fuzzy Sets. *Information and control*, 8, 338—353.

پوختە

وزەیا هەتاڤێ د زور بوارێن مفادار دا دهێتە بکارئینان وەکی بەرهەمئینانا بەرهەمێن کشتوکالی و خوارنێ، هەروەسا بەرهەمئینانا وزەیا نویکری و دسیستەمێن گەرمکرنێ و روناهیێ دا ... هتد. ل ڤی دەمی گشت وەلاتێن جیهانێ ب تایبەتی وەلاتێن نە زور پێشکەفتی روبروی ئاستەنگەکا زور گران بوینە ئەو ژی ڕێ دابینکرنا وزەیەکا بەردەوام بو بکارهێنەران. وزەیا کەهرەبێ بەرنیاسترین جورێ وزەیێ یە کو دهێتە بکارئینان ژلایی بکارهێنەران ڤە کو وزەیا پترولێ و ئەتومی دهێتە بکارئینان بو بەرهەمئینانا رێژەیەکا باش یا کەهرەبێ بو هژمارا مروڤان کو بەردەوام د بەرزبوونێ دا یە. لێ ئەڤ هەردوو ژێدەرێن وزەیێ یێن دیارکری (پترول و ئەتومی) کارتێکرنێن نێگەتیڤ هەنە ل سەر بلند بوونا پلەیا گەرماهیێ یا هەسارا ئەردی، و ژبەربەر ڤی ئەگەری زورربەیا وەلاتان هەول ددەن وزەیا هەتاڤێ بدەستخوڤەبیین بو نزمکرنا کارتێکرنێن دیاردا بەرزبوونا پلەیێن گەرماهیا هەسارا ئەردی (گلوبال وورمینگ) و بەرهەمئینانا ژێدەرێن وزەیەکا پاک و بەردەوام و نویکری. ئارمانج و مەرەم ژ ڤێ ڤەکولینێ پێشبینیکرنا رێژەیا تیشکێن هەتاڤێ یە وەك وزەیا هەتاڤێ بو بەرهەمئینانا وزەیا کەهرەبێ دناڤا باژێرێ دهوکێ دا، ژبەر کو کەهرەبا نیشتتیمانی نە د ئاستێ پێتڤی دایە و بەشی هەمی بکارهێنەران ناکەت، و دئەنجامدا بکارهێنەر پشتبەستنێ دکەن ل سەر کەهرەبا موەلیدێن تاکە کەسی یان ژی کەرتێ تایبەت کو هەردوو جور هەر پەترولێ بکاردئینن بو بەرهەمئینانا کەهرەبێ. د ڤێ ڤەکولینێ دا، سیستەمێ (فەزی لوجیك) هاتیە بکارئینان بو پێشبینیکرنا رێژەیا تیشکا هەتاڤێ. چوار سیستەمێن (فەزی لوجیك) هاتینە دروستکرن بکارئینانا داتایێن بەردەست یێن سالا 2016 ل باژێرێ دهوکێ. تومارێن روژانە یێن پلەیێن گەرماهیێ و رێژەیا شلیێ و لەزاتیا باێ هاتینە تومارکرن د ماوێ هەر چوار وەرزێن سالێ دا وهاتینە شیکرن و شروڤەکرن بو پێشبینیکرنا تیشکێن هەتاڤێ. دەرەنجامێن پێشبینیکری یێن سیستەمێن(فەزی

لوجيك) هاتينه به‌راوردكرن دگه‌ل ریژه‌یا تیشكێن هه‌تاڤێ یێن دروست. زێده‌باری ڤێ چه‌ندێ، پروگرامێ (فه‌زی لوجيك) پێ هاتییه هه‌لسه‌نگاندن بریكا (MAPE) و (APE)، ده‌رئه‌نجامێن ڤان هه‌ردوو ریكێن دياركری بو چوار وه‌رزێن سالێ (زڤستان، هاڤین، بهار، پاییز) ب ڤی شێوه‌ی بون(5.86%, 1.54%, 2.76%, 1.52%) ل دويڤ ریزبه‌ندا وه‌رزێن دياركری. ل دويڤ ده‌رئه‌نجامان، كارێ سيسته‌مێ (فه‌زی لوجيك) پێ كاريگه‌ره بو پێشبينيكرنا ریژه‌یا تیشكێن هه‌تاڤێ.

الخلاصة :

يتم استخدام الطاقة الشمسية في تطبيقات مفيدة عديدة مثلا في انتاج منتجات زراعية غذائية، انتاج الطاقة المتجددة ونظم التدفئة والانارة...الخ. حاليا، ان جميع دول العالم وخاصة الدول النامية تواجه تحديا كبيرا في تأمين مصدر من مصادر الطاقة المستدامة للمستهلكين. الطاقة الكهربائية هي من اكثر انواع الطاقة شيوعا واكثرها استعمالا من قبل المستهلكين، حيث يتم عادة استخدام البترول اوالطاقة النووية في انتاج طاقة كهربائية تكفي عدد السكان المستمر بالتزايد. لكن لاستخدام البترول والطاقة النووية تاثيرات سلبية على التغير المناخي والاحتباس الحراري لكوكب الارض. ولهذا فان اغلب الدول تطمح في تأمين وانتاج الطاقة الشمسية لتخفيف تأثيرات ظاهرة الاحتباس الحراري على كوكب الارض وانتاج مصدر لطاقة نقية ومستدامة ومتجددة. ان الهدف من هذه الدراسة هو التنبؤ بنسبة اشعة الشمس كمصدر للطاقة الشمسية في انتاج الطاقة الكهربائية في مدينة دهوك، وذلك لكون الطاقة الكهربائية المسماة ب(الكهرباء الوطنية) غير كافية للعدد الهائل للمستهلكين. وبالنتيجة، فان المستهلكين يعتمدون اعتمادا كبيرا على مولدات الطاقة الكهربائية الشخصية او مولدات الطاقة الكهربائية التي يمتلكها القطاع الخاص حيث يتم استخدام البترول في تشغيل هذه المولدات لانتاج الكهرباء. تم استخدام نظام المنطق المضبب في هذه الدراسة للتنبؤ بنسبة اشعة الشمس، حيث تم بناء اربعة انظمة مضببة باستخدام البيانات المتاحة لسنة 2016 في محافظة دهوك. تم تحليل القراءات اليومية للحرارة والرطوبة وسرعة الرياح لاربعة فصول لتخمين اشعة الشمس. كما تم مقارنة نتائج تنبؤ المنطق المضبب مع اشعة الشمس الفعلية. بالاضافة الى ذلك، تم تقييم النظام المضبب باستخدام ال (APE) و (MAPE). ان نتائج هاتين الطريقتين هي (1.52%, 2.76%, 1.54%, 5.86%) لاربعة فصول (الشتاء، الصيف، الربيع والخريف)، على التوالي. وبموجب هذه النتائج، فان اداء النظام المضبب هو فعال نسبيا في التنبؤ باشعة الشمس.