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An Implementation of Double Slope Basin Solar Still Plant Design to Predict the Distillate Yield and Instantaneous Efficiency

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Abstract— ***70% of the earth is covered with water but not all the available water is drinking water. Among only 3-5% of water is drinkable. In addition of due to global environmental changes and effect of global warming researchers are motivated to find the alternative sources of water purification. In this context the water distillation plants are helpful for providing the pure drinkable water. The proposed work is an effort for designing the solar distillation plant. Among them double slop water treatment technique is efficient as compared to single slop water still plants. Therefore the proposed work is intended to design a double slop distillation plant. In addition of to monitor the plant performance a predictive technique using the liner regression is proposed. The proposed technique usages the temperature attributes and corresponding obtained distillated yield and instantaneous efficiency. According to the obtained experimental results the proposed technique found superior as compared to traditional predictive techniques.***

Keywords— ***Decision making, prediction, Solar Still Plant, fuzzy logic, regression analysis***

I. INTRODUCTION

Drinking water is a primary need for human and other creatures living. The entire world covered with 70% of sea water in addition of 3-5% of water is available in reservoirs, rivers and other sources. But not all available amount of water is drinkable. In addition of due to global warming and environmental effects the drinking water crisis is rising. Therefore a significant amount of efforts are initiated to deal with such kind of drinking water issue. The presented work in this paper is a study and system designing for improving the productivity of single slop water distillation plant. In this context to improve the production of distilled water the double slop water plant design is proposed for designing. In addition of to monitor the performance of designed double slop water distillation plant a regression analysis based technique is proposed. That technique is a predictive data model which first establishes the relationship among the available attributes and target distillation yield and instantaneous efficiency. Additionally during the prediction the system requires the input attributes. This paper contributes on following objectives:

1. Designing a double slope basin solar still plant
2. Performing experiments and collection of data with the help of designed double slop water plant
3. Applying linear regression based predictive techniques, to predict performance and productivity

Therefore, to demonstrate contributions first a review on existing techniques is presented. During this we conclude different models that are helpful for prediction of distillated yield. Further, a comparative study on single slop solar plant and double slop solar plant is presented. Additionally using experimentation the attributes and target yield values are observed. Finally a regression based algorithm is proposed to predict distillated yield.

II. LITERATURE REVIEW

This section offers a review on recently contributed and developed techniques for predicting the yields.
Fausto Cavallaro [1] presents his work on Takagi-Sugeno Fuzzy Inference System for Developing a Sustainability Index of Biomass. This modelling builds a synthetic index to assess sustainability of production for energy. ***Qasem Abdollah Nezhad et al. [2]*** Investigate on fuzzy logic controllers based on Takagi -Sugeno & Mamdani model. They introduced Takagi Sugeno model and comparing it with other controllers. ***Tomohiro Takagi et al. [3]*** offers a Fuzzy Identification Systems and Applications to model and Control. They demonstrate it with two industrial processes first water cleaning process and a converter in steel-making process. The model is described by IF-THEN rules. The key feature of this model is to express the local dynamics by a linear system. ***Plamen Angelov et al. [4]*** provides On-line Design of Takagi-Sugeno Models. The presented approach is based on TS model, which evolve structures and learn recursively. The model decomposed into two sub-problems one is on-line recursive clustering, and other is estimation of the consequent part of parameters.
Fuzzy Logic techniques were proposed for power demand prediction [5]-[6]. That has been applied successfully to a number of applications. This work presents model FLS, comprising the control rules and sets of variables related to fuzzy sets, to handle partial memberships issue, and enabling to express human concepts [7]. Jigeesh has offers preliminary work to simulate a solar water desalination using fuzzy rule based system [8]. ***Shanmugan, [9]*** discussed Fuzzy modeling of floating cum tilted – wick solar still. This Fuzzy modeling and simulation has been developed to qualitative interpretation and analysis.

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A set of fuzzy rules have been developed based on general analogy between changes in solar radiation intensity, yield of distillate output change in weak. ***Panchal [10]*** study effect of different parameter on double slope solar still productivity. The aim of study is to find effect of parameters on performance of solar still using water depth, sprinkler and various dies. They proved that black die will increase output of solar still, sprinkler increase condensation rate with lower water depth. Black die is a good to increase distilled output with low water depth.

Shanmugam et al. [11] discussed a Fuzzy modelling of single slope single basin solar still. Authors developed thermal analysis of solar still with fuzzy logic. Experimental observation has been carried out on 9 May 2012 in Dhanalakshmi college of Engineering Chennai Tamilnadu. Qualitative interpretation and fuzzy rule have been developed between change in radiation intensity, yield of output Mamdani model has been used to predict distillate output. ***Hrushikesh Kulkarni et al. [12]*** performed experimental evaluation of still using phase change. The different designs of solar still with PCM are analysed. Phase change and thermal energy storage materials also play an important role to enhance internal energy of system. Top cover cooling is also one of the methods to induce faster condensation. ***J.I. Orisaleye et al. [13]*** developed and evaluate solar water still with characterization of water quality before and after distillation.

III. DOUBLE SLOP SOLAR PLANT DESIGN

This section introduces the design of proposed double slop solar water distillation plant. The figure 3.1 contains the functional model of the plant. We discuss the components of the plant one by one. Still basin is the part of system in which distilled water is captured. It must absorb solar energy. Hence it is necessary the material have high heat absorbing ability and less reflectivity. These are the criteria's for selecting the basin materials. We can use Leather sheet, Ge silicon, Mild steel plate, reinforced plastic or galvanised iron (GI). We have used blackened GI sheet with thermal conductivity = 300W/m^{0}C with 3mm thickness. The box size is 119*80*30 cm. The Side Walls generally provides rigidness to the still. But technically it provides thermal resistance that taken place from system surrounding. It must be made from the material that is having low thermal conductivity and rigid enough to sustain its own weight and the weight of the top cover. Different kinds of materials can be used such as wooden, concrete, thermocol, RPF (reinforced plastic). For better insulation we have used composite wall of thermocol (inside) and wood (outside). The thermal conductivity is 0.6W/m^{0}C with 8 mm thickness and thermocol's thermal conductivity is 0.02W/m^{0}C which is 15 mm thickness. The top cover is a passage from where irradiation occurs on the surface is top cover. It is the surface where condense water is collected. So the features of the top cover are:

- Transparent to solar radiation
- Non absorbent and Non-adsorbent of water
- Clean and smooth surface.

The materials which can be used for this purpose is like Glass or Polythene. In this experiment the glass of 5mm thickness is used for top cover and a rubber tube is applied with it as border frame. Channel is formed to slide drops over inclined top cover and falls. That helps to fetch out pure water. The materials that can be used here are P.V.C., G.I., or RPF. Supports for top cover is provided for supporting the top cover is optional. We have used fibre stick as a support to hold glass of size 5 mm X 5mm. The only change in our model is that we have to make the model as vacuumed as possible. So we have tried to make it airtight by sticking tape on the corners of the glass and edges of the box.

Figure 3.1 Experimental double slop solar still

In our previous research study we prepared a single slop solar water still plant which is developed with a single slop on the other hand the double slop is prepared in this model which can having the larger heat absorbing area therefore that scale the productivity of the previous water plant. During this experiment we consider the time between 12 to 4 PM in summer season. Using the experiments the following observations are collected as reported in table 3.1.

Table 3.1 example dataset

S.no.	Time	Temperature of Water(°C)	Solar Radiation(W/M^2)	Atmospheric Temperature(°C)	Distilled yield(Lit.)
1	12:00 PM	43°C	900	30°C	00
2	01:00 PM	44°C	1000	33°C	0.005
3	01:10 PM	45.9°C	1050	35°C	0.009
4	01:20 PM	45.9°C	1100	34°C	0.015
5	01:30 PM	46°C	1050	33°C	0.020

The table contains observations for different temperature attributes. Finally the experiments are conducted with developed plant. The total 7 days samples are collected and in a single day 20 observations are collected. Thus entire dataset contains total 7*20= 140 instance for experimentation.

IV. PREDICTIVE DATA MODELLING

This section provides understanding of proposed regression based model for predicting performance of solar still.

The proposed technique is not need to be additional preparation for learning and prediction. The model usages the traditional technique of linear regression for producing the predictive precise outcomes based on the previously made observations. Basically regression analysis is used to find equations that can best fit with the data. Once we have the regression equation, we can use this model for prediction. In this work linear regression analysis is performed. In this context correlation coefficient is used to predict outcomes and a scatter plot of the data appears to form a straight line, here we can use a simple linear regression to find a predictive function. The equation for a line is

$$y = mx + b$$

To calculate linear regression, and find the equation

$$y' = a + bx$$

Linear regression is a way to model relationship between two variables. You might also recognize the equation as the slope formula. Where Y is dependent variable, X is the independent variable, b is the slope of the line and a is the y-intercept.

$$a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{n(\sum x^2) - (\sum x^2)}$$

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x^2)}$$

The above given equation can be used for predicting the single variable and which is computed using single independent variable. But the collected dataset contains two independent variables to predict the target variable therefore the multiple regressions with two predictor variables is suitable for computation. That is given using following equation:

$$y' = b_0 + b_1 x_{i1} + b_2 x_{i2}$$

The "b" values are called regression weights and are computed in a way that minimizes the sum of squared deviations using;

$$\sum_{i=1}^{N} (Y_i - Y_i')^2$$

It is calculated in similar manner as in simple linear regression. The difference is that in simple linear regression only two weights, the intercept (b_0) and slope (b_1), were estimated, while in this case, three weights ($b_0, b_1, and\ b_2$) are estimated.

V. RESULTS ANALYSIS

This section offers detail about conducted experiments and measured accuracy of predicted distillation yield. The accuracy of the multiple liner regression technique is described in this section. The accuracy of an predictive system is the ratio of total correctly predicted outcomes and total outcomes produced. The following equation can be used for measuring accuracy in percentage.

$$accuracy\ (\%) = \frac{total\ correctly\ predicted}{total\ samples\ for\ prediction} X100$$

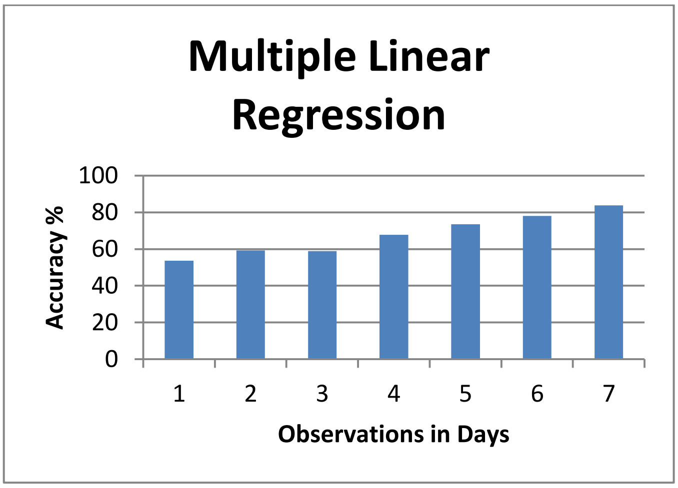

Figure 5.1 accuracy (%)

The prediction accuracy of proposed multiple linear regression based technique is reported in figure 5.1. It is a line graph which is constructed using experimental observations. The X axis of this line graph shows size of dataset is used to train the model and Y axis shows corresponding accuracy. The measured accuracy is reported here in percentage (%). Based on the experiments we found the technique is accurately predicting the yield. Initially the performance of system is low but as the amount of training samples increases the accuracy of system is increases. Additionally, it is also find that the outliers can impact on the performance of technique. It is a kind of noise which deviate the performance of prediction. Therefore in near future it is required to implement the regression technique with some outlier detection methodology. In addition to that the time utilization of the implemented system was also measured using the flowing formula:

$$time\ usage = end\ time - start\ time$$

The time usages of algorithm are also measured to demonstrate the performance of an algorithm in terms of time complexity. The figure 5.2 shows the performance of algorithm in time complexity.

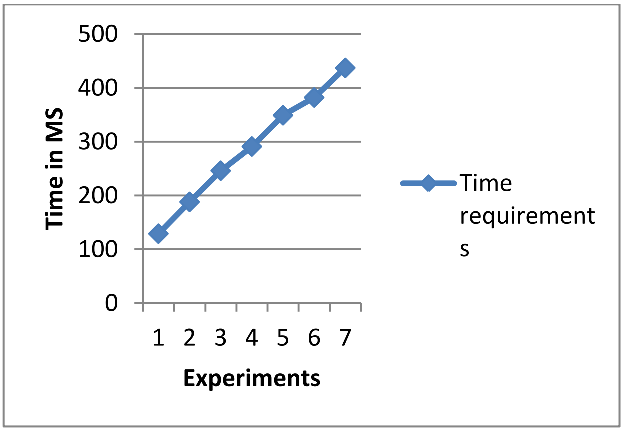

Figure 5.2 time consumption

The time requirements of the proposed system are explained in figure 5.2. According to the shown outcomes the time requirements of the each experiment is an increase, which is because in each experiment the amount of data is increased.

Thus, time consumption of the algorithm depends on the amount of data submitted to be process.

VI. CONCLUSIONS

The summary of efforts of doubles slop solar water distillation plant is provided in this section. Additionally future scope of the work is offered.

A. Conclusion

The regression based techniques are utilized in various machine learning and data mining applications. That is used in various places for prediction, measuring pattern, computing relationship among variables, for filtering specific pattern of data, noise estimation and removal and many more. In this presented work we provide the technique for prediction. That prediction model is basically used for measuring performance of double slop based solar water still plant. In this context first an experimental water plant is established and observations collected with digital equipments which precisely provide measurements of required attributes. Finally these attributes are used with linear regression concept to predict performance of producing distilled water.

The multiple linear regression is used with entire learning data. According to the collected observations we have two independent variables namely water temperature and solar radiation. Additionally we need to predict a dependent variable distilled yield. By solving the equation of multiple linear regressions we can easily calculate the yield. The implementation of proposed prediction system is performed with WEKA tool and with the help of JAVA. After implementation of system is evaluated and shown in table 6.1.

Table 6.1 performance summary

Parameters	Conclusion
Accuracy	The accuracy of the system is found acceptable but sometimes it deviate from it's actual behaviour due to lake of experimental observations. According to current obtained patterns the performance of solar based systems are affected by various other influencing parameters such as: 1. Materials used in still plant 2. Insulation of still plant 3. Weather conditions 4. Equipments of measuring temperature attributes
Time consumption	The time complexity shows the delay in prediction after producing input to algorithm, the time consumption depends on the amount of data submitted for processing or analysis, thus according to the existing scenarios the time requirement of the proposed algorithm is acceptable for future extension of work

According to results in table 6.1, the proposed regression based technique is found efficient. Therefore this is helpful for predicting the performance of a water treatment plant.

B. Future work

The main aim of the proposed work is to predict distillation yield of the double slop based solar still plant. Thus a multiple regression based technique is proposed for accurately predict distillate yield for double slop solar water plant. In near future the following work is proposed.

1. The proposed technique is accurate technique of prediction but need significant amount of data for predicting more precisely the distillation yield.
2. This technique will be enhanced by implementing the technique of outlier detection and removal technique for noise on collected observations.

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