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Performance Improving Methods for Series Solar Flat Plate Collectors and Introduction of New Verification Tool

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ABSTRACT— Now a day's different types of solar flat plate collectors are in use. Out of which only few type of good design collectors proved their performance by producing better results of expected level. In this paper a new set of collectors are combined as mean to improve performance of series FPC collectors available in market now a days. In addition artificial neural network (ANN) model was developed and optimal solution for producing maximum efficiency was obtained using C++ algorithm. Our C++ program produces error free optimal results in an easy manner. With this tool future neural network process becomes simpler.

KEYWORDS: SFPC, ANN, C++, MATLAB, NEW TOOL etc…

I. INTRODUCTION

A. Solar Water Heater

The basic source that supplies energy to convert coldwater in to hot water in solar water heater is the sun. Solar water heaters broad classifications are the flat plate collector and the parabolic collector. Besides while converting cold water in to hot water using one collector is known as single system and while using multiple collectors it is called as series collectors. Single system is suitable for home applications and not for industrial purposes while series system suits to both. When solar water heater performs as a single system it produces higher efficiency but not the higher temperature .In order obtain such suitable criteria two are first connected to improve the outlet temperature of single system further and then extended to the N^{th} number. It is clear that when two or more collectors are connected in series it is called as series solar flat plate collector.

G.N.Tiwary[2] performed varieties of experiments on series flat plate collectors by connecting 2 to N^{th} number of collectors both as partially and fully covered (mixed combination).But the experiments he made are using identical collectors which means he used up to N numbers of same design configured collectors.

Sivakumar.P,Christ Raj.W , M.Sridharan, N.Jaya malathi [8] modeled and fabricated a new type solar water heater of area 2035*1035*100mm as a mean of improving efficiency of a single system. It consists of 3 header tubes & 8 riser tubes along with slight changes in the flow pattern (Zig-Zag pattern). Their modeled produces a higher performance in terms of high temperature and efficiency when compared with the collectors available in the market now days with same area, material and cost.

Soteris A. Kalogirou [1] surveyed various types on solar thermal collectors. In addition environmental problems related to the use of conventional sources of energy and the benefits offered by renewable energy systems are discussed. The various types of solar thermal collectors including FPC, compound parabolic, evacuated tube, parabolic trough, parabolic dish and heliostat field collectors were followed by an optical, thermal and thermodynamic analysis of the collectors and a description of the methods used to evaluate their performance.

Sivakumar.P,Christ Raj.W , M.Sridharan, N.Jaya malathi [12] made an theoretical discussion as mean of improving efficiency of series system further. In such work they connected two un identical collectors (Conventional and Zig-zag pattern). By connecting two different collectors they expect higher performance in terms of outlet temperature as compared to the conventional series system available in the market. This paper converts their expected

results in to actual or real time values.

B. Artificial Neural Network

ANN is artificial neural network. It is one of the optimization techniques used more commonly and frequently. In machine learning and computational neuroscience, an artificial neural network, often just named a neural network, is a model inspired by biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using connectionist approach to computation. In most cases a neural network is an adaptive system changing its structure during a learning phase. Neural networks are used for modeling complex relationships between inputs and outputs or to find patterns in data.

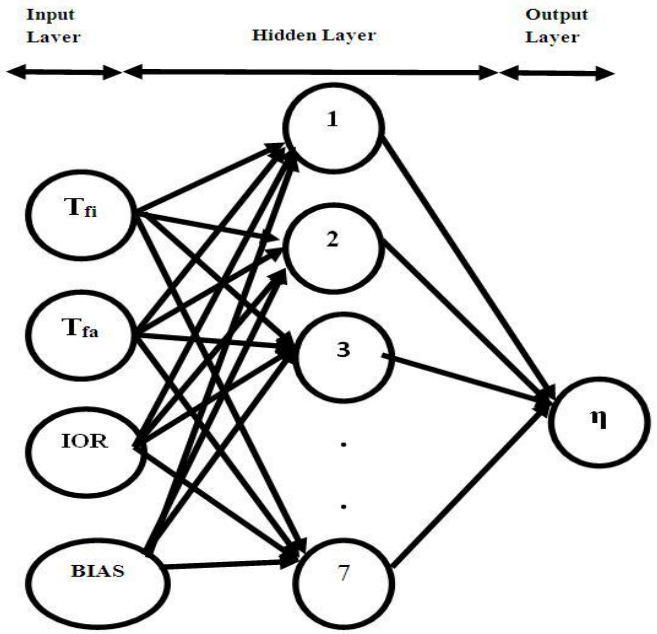

Figure: General Components of ANN Model

Its basic model consists of three layers namely input, hidden and output layer. The number of hidden layer can be increased further to obtain more accurate results. Its learning method consists of three types they are supervised, unsupervised and reinforcement learning. The main applications of ANN are in image processing, robotics etc. Development of ANN model is base on various parameters like variable selection, training of data, validating of data, testing of data, number of hidden layers and nodes, number of output nodes, method of learning etc. One drawback to using artificial neural networks, particularly in robotics, is that they require a large diversity of training for real-world operation.

Stephan Dreiseitl, Dongming Wang [6] found out the difficulty of coding and simulating neural network by hand and generate C++ algorithm for error free solution. In their work they replaced back propagation solver of ANN toolbox with C++ program. This effort produces error free solution in complex engineering applications. In addition it forms the strong easy basics for research as research tool.

Rushi prasad [9] in his computational work he links the gap between energy engineering and computer science engineering by determining the performance of single flat plate collector by programming in C language which forms basis for C++ language. This work introduces programming concept in to both energy as well as the thermal sector with its advantage of instant result.

E.Balagurusamy [10] introduces all concepts of object oriented programming language with his work. In addition concepts of his book form the strong basis for mat lab programming.Syntax, Operators, Arrays etc all the basic things needed for writing back propagation algorithm are explained in simple format and it is very useful for the mat-lab beginners.

M.Sridharan et.al [12] makes use of the concepts of [6] & [9] and applied to their work in this paper. As a mean of which he developed a separate C++ program for performance calculation of series solar flat plate collectors. At the end prediction response of artificial neural networks term mean square error was also obtained through this program. Mean Square Error (MSE) which is nothing but difference between experimental and prediction response. Optimal results obtained with zero MSE become possible with this tool at less number of input data.

C. Disadvantages of ANN Model

- Large number of data needed for training ,
- Time consuming ,
- Results can be obtained with minimum MSE not with zero MSE,
- Direct testing of input data cannot be possible,
- Prediction response can be obtained only by setting ranges of variation etc.

Since it is cleared from the above figure that the mat lab software back propagation algorithm are extension of C & C++ language but its time consuming and complexity of getting inputs in the form of three mode namely train, validate and test made this tool usage more complicate.
An alternate way to obtain instant results with nil error is the direct programming via C++ software.

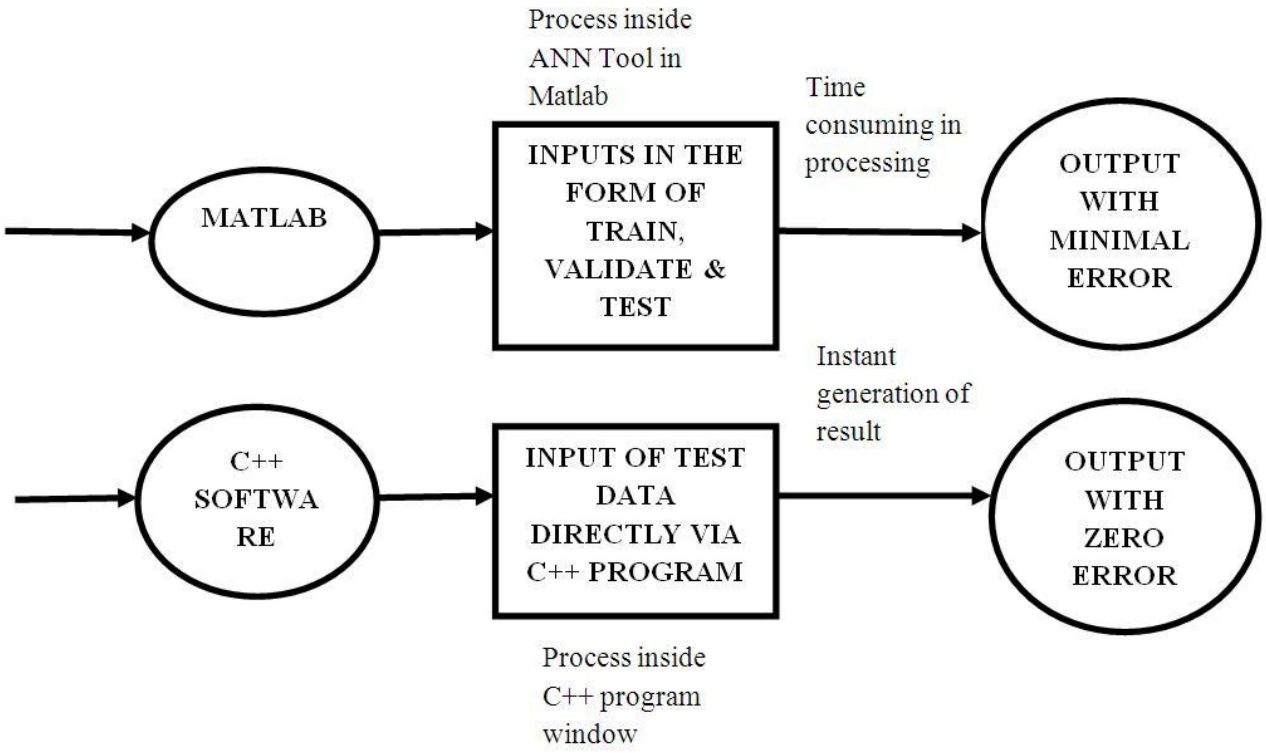

Figure: Drawbacks of ANN Back propagation algorithm and Advantages of C++ Programming.

II. EXPERIMENTAL SETUP

The figure 1 and 2 below shows the experimental setup of existing identical and new non identical collectors.

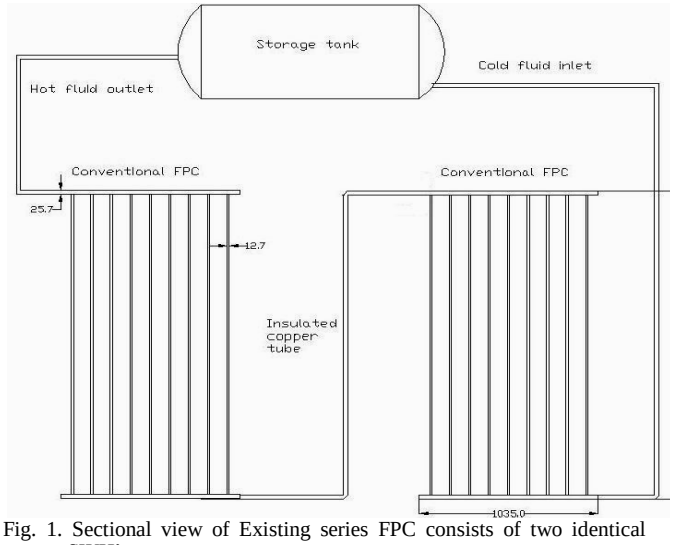

Fig. 1. Sectional view of Existing series FPC consists of two identical SWH's.

A large bank of collectors can be formed by series, parallel, or mixed combination of collectors in one or multiple rows.

In case of series connected test rig two or more collectors are connected & exposed to a same environmental condition.

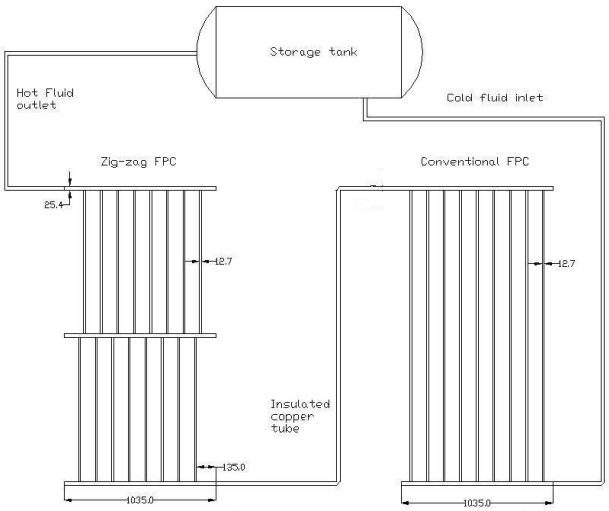

Fig. 2. Sectional view of new series FPC consists of Zigzag & Conventional type SWH's.

In this process inlet water temperature is maintained with a controlled flow rate. The inlet and outlet temperatures are continuously monitored for each of collector separately.

A. Formula for Performance Calculation Of SFPC

From [4] and [12] we have formula to determine useful heat energy collected by N numbers of collectors,

$$Q_{UN}=m*C_f*0.1*(1-\exp\{-(NA_cU_LF^1/mC_f\})*(q_{ab}^1-U_L(T_{fi}-T_a)) \quad (1)$$

Formula to determine efficiency of SFPC,

$$\eta_{SFPC} = Q_{UN} / Ac*I \quad (2)$$

III. OBJECT ORIENTED PROGRAMMING LANGUAGE

Since C++ is one of the object oriented programming languages. Its syntax are simple & similar to the C language. While MATLAB makes use of C Language & C++ as a back programming solver, some optimization Techniques like ANN (Artificial Neural Network) has C++ as a back propagation code for solving ANN algorithm. In addition to that C++ is an advanced & object oriented programming language while comparing to C.

It helps us to make a variety of thermal optimization project using ANN with simple calculation of solar water heaters efficiency using C++ coding.

A. Objective of the Computer Software Programming

The main Objectives of the developed program are:

- To develop a generalized computer program that relates Object oriented programming with Thermal sector.
- To predict the performance results of a fixed solar water heater with FPC and to study the Effect of parameters like inlet fluid temperature, efficiency, water flow rate with the Developed program.
- To study overall performance of the flat plate collector used in solar water heater over
- Whole day.
- To code the basic back propagation program for ANN (Artificial Neural Network) USING C++.
- To reduce manual effort and also to reduce time consuming in calculating results by Manual mean using calculator.

B. Advantages of the computer Program Developed

- No need to train and validating data, straight away testing is possible.
- High degree of accuracy.
- Reduced manual effort.
- Quicker results can be obtained in easier manner.
- Reduced time consumption.
- Error free solution etc.

C. Limitations of the computer Program Developed

- The program is restricted to the performance of non-tracking solar water heaters with flat
- Plate Collector using closed system only.
- Results are taken and calculated for a trial of one whole day only. Advantages of the computer Program Developed.

D. Back propagation algorithm

Step 1: Start the process
Step 2: Declare the variables
Ap,Q_{UN},Cp,m,n,Tfi,Ta,FR,s,Ac,I,Ul,at,N,MSE,Y_{exp}, Y_{pre} of the type double.
Step 3: Specify the value for m, Cp, A, A_c and A_p.
Step 4: Calculate $S=I*\alpha*\tau$
Step 5: Calculate Q_{UN} where
$(Q_{UN})=(1.409)*((I*at)-(U_l*(T_{fi}-T_a)))$;
Step 6: Calculate η where $\eta= Q_{UN}/Ac*I$
Step 7: if η>100 then go to step 3.
Step 8: Calculate MSE= (1/N)*(Yexp-Ypre);
Step 9: Display the result.
Step 10: Compare the result.
Step 11: if MSE>0 then go to step 8
Step 12: Stop the process.

E. Flow Chart

A flowchart is a type of diagram that represents an algorithm or process, showing the steps as boxes of various kinds, and their order by connecting them with arrows. This diagrammatic representation illustrates a solution to a given problem. Process operations are represented in these boxes, and arrows; rather, they are implied by the sequencing of operations. Flowcharts are used in designing and documenting complex processes or programs. Like other types of diagrams, they help visualize what is going on and thereby help the viewer to understand a process, and perhaps also find flaws, bottlenecks, and other less-obvious features within it. The two most common types of boxes in a flowchart are:

- a processing step, usually called *activity*, and denoted as a rectangular box
- a decision, usually denoted as a diamond.

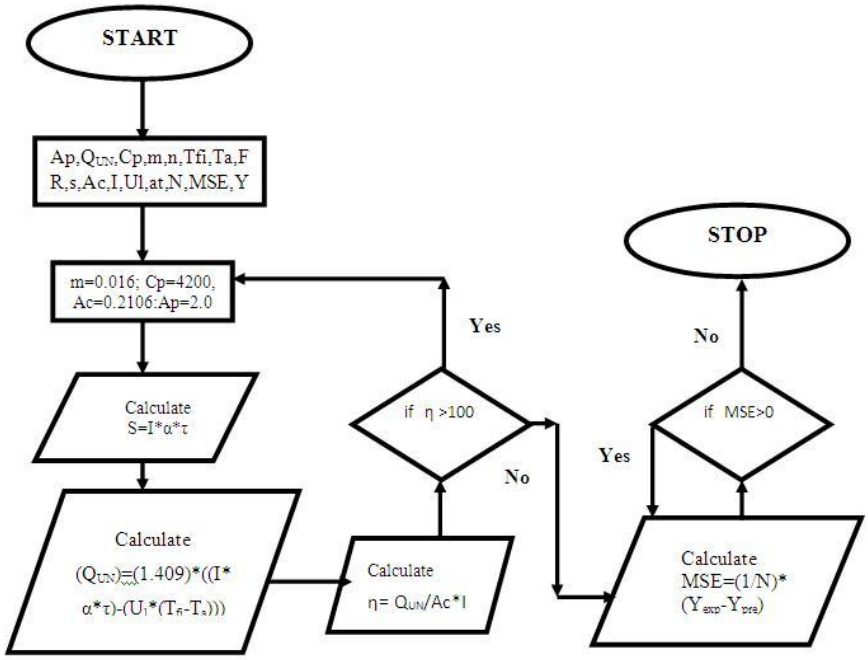

Fig. 3.Flow chart for C++ program used to verify experimental and theoretical values.

TABLE: I COMPARISON OF EXPERIMENTAL RESPONSE AND PREDICTIONAL RESPONSE OF NEW SET OF SERIES COLLECTORS.

Run		Input Variable			Experimental Response	Predictional Response	
Trial	**Type**	**$\Delta T=T_{fi}-T_{fa}$**	**m (Kg/s)**	**IOR (W/m^2)**	**η (%)**	**η (%)**	**MSE**
1.	Test	8.5	0.016	4200	50.21	50.21	0.0
2.	Test	9	0.016	4200	50.58	50.58	0.0
3.	Test	8	0.016	4200	51.12	51.12	0.0
4.	Test	6	0.016	4200	51.68	51.68	0.0
5.	Test	12.5	0.016	4200	49.24	49.24	0.0
6.	Test	19	0.016	4200	46.51	46.51	0.0
7.	Test	19	0.016	4200	44.61	44.61	0.0

IV. RESULTS & DISCUSSIONS

A. Result 1

Experiments are to be conducted between existing series connected FPC & new combination of series connected efficiency. Thus considerable improvements are obtained as expected with the new series connected solar water test rig by neglecting losses. The maximum collector efficiency was obtained at 13.00 hrs. Among the two experimental setup, the conventional SFPC (case 1) recorded maximum efficiency and minimum outlet temperature as compared to the new set of SFPC throughout the day, also the Zig-Zag pattern SFPC (case 2) recorded the minimum collector efficiency throughout the day but the higher inlet and outlet fluid temperature as compared to the old set of SFPC.

Maximum of 91˚ C was obtained at the time of 13.00hrs with new set of SFPC and higher efficiency of 51.63% was obtained with old SFPC. The reason from the formula it is clear than efficiency depends on the difference between inlet fluid temperature (T_{fi}) and ambient temperature

(T_{fa}).Thus new set of series flat plate collector proved to be the best, better, efficient, reliable and more accurate with reduced losses as compared to the identical conventional collectors available in the market.

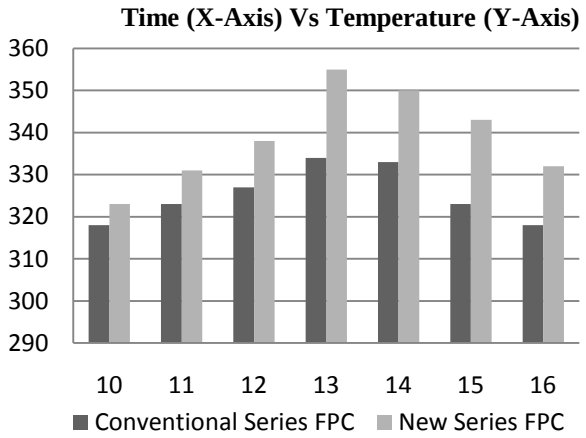

Fig. 4.Variation of Fluid Outlet temperature with respect to time for Existing and New SFPC.

It is cleared from the Figure A & B that the maximum temperature is observed at the time 13.00 hour in all the two cases. In addition variation in performance of Zig-zag SFPC and conventional SFPC was also clear. Hence new set of SFPC are more suitable for industrial applications than the old set of SFPC.

B. Result 2

Efficiency of collector η was considered as response (target) .To avoids over fitting, both input variables and response has to be normalized before training. In order to build ANN model our code was developed using C++ software and standard functions included in neural network tool box. C++ is one of the object oriented programming language used to back propagating the algorithm. As it can be observed from figure 4 the connection between the inputs, the neurons and the output consist of MLP (3:7:1).It should be pointed out that the biases connected to the artificial neurons from the hidden and output layers plays a similar role to the offset terms in multiple regression models.

C. Discussions on Number of Neurons vs. Mean Square Error

Figure C obtained from mat lab 6.5 shows variation of mean square error with respect to the number of neurons in the hidden layer and also clears that results are obtained with zero error as a mean on programming back propagation algorithm with C++ algorithm.

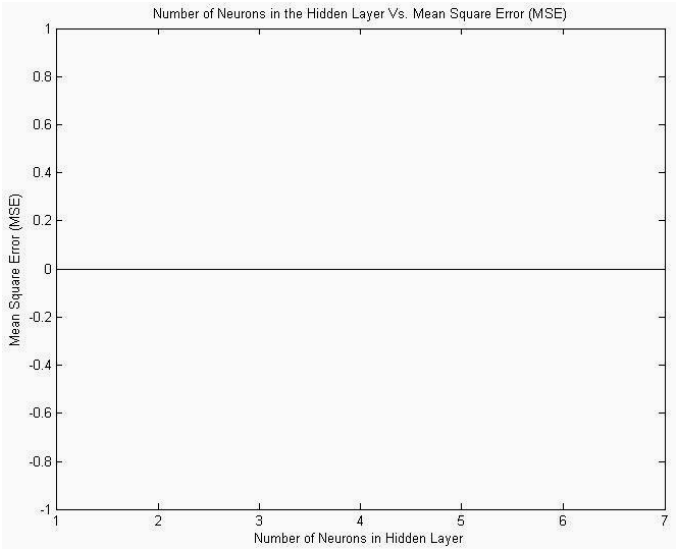

Fig. 5. Variation of Number of Neurons vs. Mean Square Error

D. Discussions on Experimental response Vs. Prediction Response

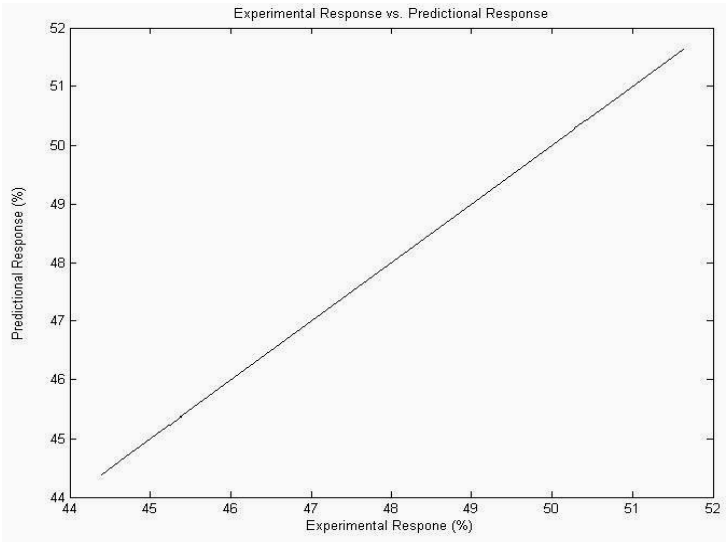

Fig. 6. Variation of *Experimental response Vs. Prediction Response*

V. CONCLUSIONS

The different solar water heaters with flat plate collectors with 3 header & 8 riser tube (figure 2) was compared with conventional single closed system (figure 1).From the experiments conducted it is observed that the outlet temperature of the fluid is a function of intensity of solar irradiation and the time period of exposure of FPC to solar radiation. For all the cases of FPC, the maximum collector efficiency was obtained at 13.00 hrs. Among the two experimental setup, the conventional FPC (case 1) recorded minimum efficiency throughout the day, also the Zig-Zag

pattern FPC (case 2) recorded the maximum collector efficiency throughout the day. This resulted in better rate of heat transfer. Further the performance of the FPC can be improved by using different surface coatings on the riser tubes and header tubes, using nano materials as heat transport medium and also by using N number of collector as Zig-zag collectors. Since optimization using new tool is simpler with zero MSE. Thus it forms basis for variety of computational thermal science project.

NOMENCLATURE

A_{p-} Area of absorber plate, m^2

A_{c-} Area of collector, m^2

β -Collector tilt angle, degrees

N-Number of covers

T_{c-}Thickness of cover, m

U-Overall heat transfer coefficient, W/m^2K

U_{L-}Over all heat loss co-efficient of collector, W/m^2K

K_c -Thermal conductivity of cover, W/m^2K

Q_{UN}-Useful energy gain, W

S- Flux absorbed by collector, W/m^2

FR- Heat removal factor

I-solar radiation (W/m^2)

R- Gas constant (kJ/kg-K)

S- Flux absorbed by collector, W/m^2

FPC-Flat plate collectors.

SFPC-Series flat plate collectors.

ANN-Artificial neural network.

BPA-Back propagation algorithm

Greek symbol

η – Efficiency of collector (%)

τ-Tranmissivity

α-Absorptivity

τα - Optical efficiency of collector

Subscript

c -Collector

i-Inlet

o- Outlet

s-Storage tank

w-Water.

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