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ANFIS model for prediction of water temperature for Scheffler solar reflector

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Abstract: A soft computing prediction model for Scheffler reflector is made to predict the temperature of water obtained by absorption of solar energy. In this model Adaptive Neuro Fuzzy Interface System (ANFIS) based on 1st order of the Takagi–Sugeno model is used which predicts system behavior. Input parameters used in the model are intensity of radiation, ambient temperature and time of experimentation and the output parameter is generated water temperature. The model gave excellent prediction ability for Scheffler reflector.

Keywords: Scheffler reflector, ANFIS, prediction model

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1 Introduction: Scheffler reflector, named after its inventor Wolfgang Scheffler is a solar concentrating device which focuses the sunlight of a large area to a fixed place by tracking the movement of the sun. That fixed place called receiver contains a working fluid which gets heated can be used for domestic purposes. By slight variation in its design, Scheffler reflector can be used to for steam generation, cooking, baking breads, water heating, oil extraction, distillation, sterilization purposes, etc. [1-2]. This technology can also be incorporated to generate electricity using Sterling Engine. Till now a lot of research has already been carried out on concentrated solar powers. By using energy balance, Yao et al. [3] made a model and simulated a 1MW solar thermal receiver system in China. They also developed mathematical models of the basic components in the CSR and linked them to be a whole plant model. Ruelas et al. [2] developed a mathematical model to estimate the intercept factor for Scheffler reflector and incorporated it with a 3kW Sterling engine. They also compared the efficiencies of Scheffler reflector and parabolic trough and observed a 7% increase in Scheffler reflector's efficiency.

Tyagi et al. [4] performed exergy analysis of concentrating type solar collector and found that at a particular value of solar intensity, exegetic efficiency of the solar collector varies with concentration ratio and mass flow rate. Harris and Lenz [5] proposed a model to analyze the thermal behavior of a parabolic dish concentrator by using the view factor to estimate the amount of radiation falling on the receiver cavity in cylindrical, conical, elliptical and spherical receivers. Badescu [6] provided additional results for various concentrator geometrical shapes. Performance of the radiation concentrated by a parabolic dish receiver for various geometries was determined by Shuai et al. [7] using the Monte Carlo method. Optimal size of the aperture opening area of a spherical cavity coupled to a parabolic dish was determined Kumar and Reddy with the help of CFD (computational fluid dynamics).

2. Material and Method:

The experiment was carried out at Birla Institute of Technology, Mesra Ranchi at the latitude of 23.340 N, 85.310 E during the month of March-April.

2.1 Experimental Setup

a) Quick Details:
Input voltage: 230V AC (-20%/15%)
Output voltage: 24V -5%DC
Output current: 14.8A (max.)
Output power: 350W (max.)
Max no of 24V DC worm gear motors can be connected in parallel: 5
Motor +ve to red connector & motor –ve to black connector.
b) Environmental specification:
Temperature: operating 0 to 800^0C
storage: -20 to 900^0C
c) DC worm gear motor specification

Size of motor	17 cm
Nominal voltage	24 V DC
Output power	60 W
No load speed	60+3 RPM, 60-3 RPM
Load speed	55+3 RPM, 55-3 RPM
No load current	<1.2 A, =1.2 A
Load current	<2.5 A, =2.5 A
Load torque	>4 N-m, =4 N-m
Breaking torque	>3 N-m, =30 N-m
weight	<2 Kg
Protect feature	Drip proof, water proof.
Protection grade	Industrial grade

2.2 Instrumentation: In this experiment, the global and diffuse radiation is measured by Tenmars, TM206, solar power meter. The range of this is 0–1999 W/m^2, and its accuracy is +-10 W/m^2. The temperature and relative humidity are measured by Lutron, HT-305. The range of relative humidity is 10–95 % and its accuracy is 0.1 %. The range of temperatures –20 ^{o}C to 60 ^{o}C and its accuracy is 0.1 ^{o}C.

2.3 Experimentation

2.3.1. Working principle: The system uses the solar concentrating system of 16 m^2 area. Solar concentrator is the technology to capture the solar radiation as much as possible. As the name implies, concentrator collect the solar radiation from all the directions and concentrate at one point so that the total energy available is maximum. The system is capable of attaining maximum 500 ^{o}C temperature at the focus.

Parabolic dish type collectors are generally used for focusing the solar energy that is incident on the dish. A mirror is used to concentrate sunlight on an insulated receiver placed at the focal point, which transfers heat from the receiver to working fluid flowing in the header.

The system is capable of tracking the sun automatically throughout the day. The process of energy generation is natural, eco-friendly and last longing.

Figure (1): Experimental setup of Scheffler concentrator placed in BIT Mesra, Ranchi.

2.3.2 Observation table:

Sr. no	Area (A)	V T	Wind Speed (km/hr)	Humidity (Y) %	Time	Atm. Temp 0C	Acc Due to gravity (g)	Water Temp 0C	Altitude Angle (Degree)	Radiations On Dish (W/m^2)	Heat Gain (KJ)
1	2.7	2	1.08	10	09:30	32.3	9.81	33	18.5	787	0
2	2.7	2	1.8	10	09:35	32.4	9.81	39	18.5	780	50.244
3	2.7	2	11.88	10	10:00	33.4	9.81	61	18.5	781	242.854
4	2.7	2	12.24	10	10:05	32.9	9.81	62	18.5	784	251.228
5	2.7	2	23.2	10	12	36.7	9.81	90	18.5	860	485.700
6	2.7	2	5.2	10	12:05	36.5	9.81	89	18.5	873	477.326
7	2.7	2	15.5	10	02:00	39.8	9.81	88	18.5	825	468.95
8	2.7	2	2.6	10	02:05	39.4	9.81	85	18.5	815	443.83
9	2.7	2	4.7	10	03:30	36.1	9.81	80	18.5	741	401.96
10	2.7	2	9.8	10	03:35	35.1	9.81	79	18.5	735	393.586
11	2.7	2	0.8	10	04:00	36.4	9.81	78	18.5	748	385.212
12	2.7	2	1.6	10	04:05	36.3	9.81	78	18.5	745	385.212

2.4 ANFIS: The algorithm used in this prediction model is based on Takagi-Sugeno model [8]. Due to its advanced ability to learn on its own, the errors obtained in steady state are very low.

Complex dynamic system can be predicted by this model. The model uses the following basic rule.

Rule 1. If a is Z1 and b is Y1, Then f1 = p1a + q1b + r1
Rule 2. If a is Z2 and b is Y2, Then f2 = p2a + q2b + r2

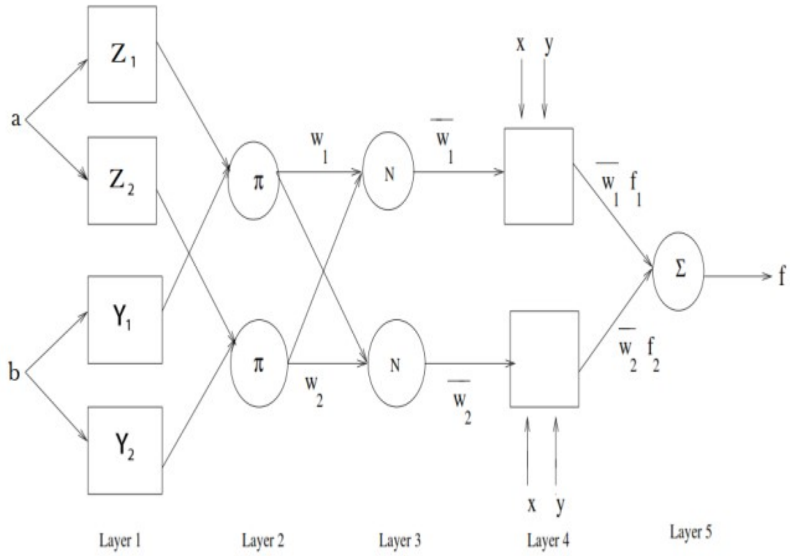

Figure (2): Architecture of the ANFIS

For the final result, average of both the rules is taken.

The five layers of the ANFIS structure are as follows:

Layer 1: Node function for each node i is:

$O_i^1 = \mu Z_i(a)$; i = 1, 2........... (1)

$O_i^1 = \mu U_i(a)$; i = 1, 2 .... (2)

Layer 2: The output of each node in this layer is the multiplication of all the signals coming to and is represented by:

$O_i^2 = w_i$; i = 1,2 ....(3)

Layer-3: The output of each i^{th} node of this layer is given by:

$O_i^3 = w_i$; i= 1,2...................(4)

Layer-4: The output of each node in this layer is given by:

$O_i^4 = w_i f_i$, i = 1, 2 ....(5)

Layer-5: It gives the sum of all the incoming signals:

$O_i^5 = \Sigma w_i f_i$, i = 1, 2.............. (6)

3. Result: Figure 1 shows the variation in intensity of Radiation throughout the day of experimentation which was carried out on a clear day. It can be observed that the radiations are maximum during 12 pm to 2 pm.

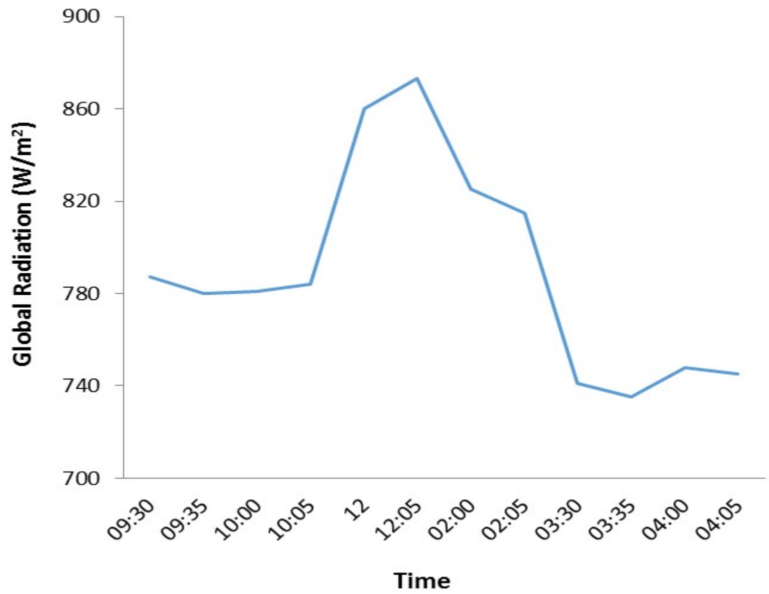

Figure (3): Variation of global radiation with time.

This Figure shows the variation of ambient and water temperature. Initially, heat is transferred to increase the temperature of water to a certain level then the heat is used to maintain that temperature. Temperature of water varies according to the ambient temperature and the intensity of radiations.

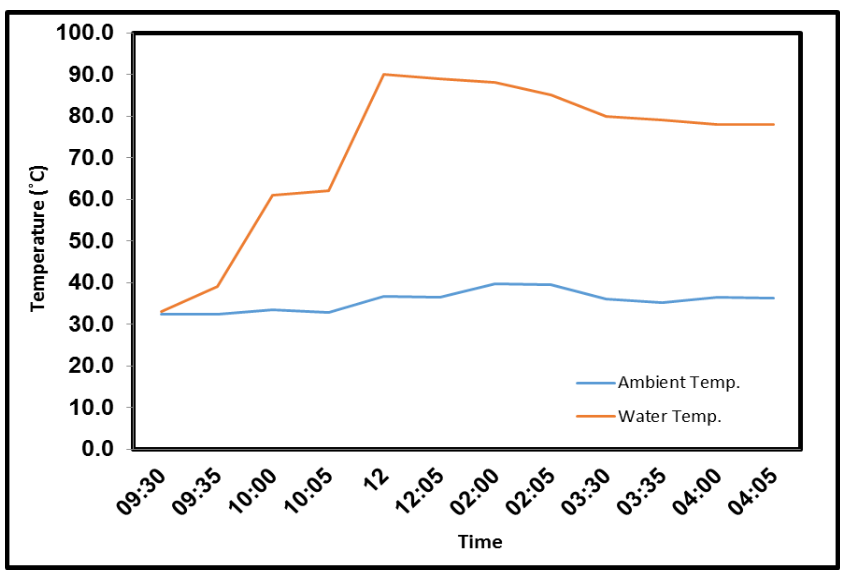

Figure (4): Variation of temperature with time.

Experimental data is used to train the ANFIS model for Scheffler reflector. The error found for the prediction of water temperature obtained is only 0.055 %. It uses hybrid algorithm which takes comparatively less time for computation than others. Figure (5) is the snapshot for training of the model. Figure (6) shows the rules used in the model.

The error obtained with this prediction model is 0.13 %, which shows the accuracy of the model.

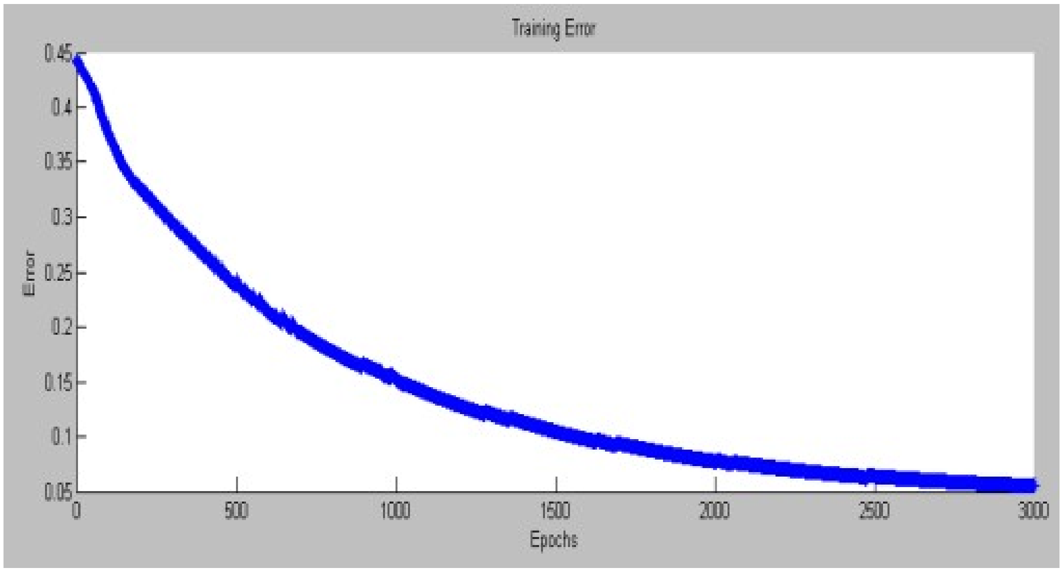

Figure (5): Training of ANFIS model.

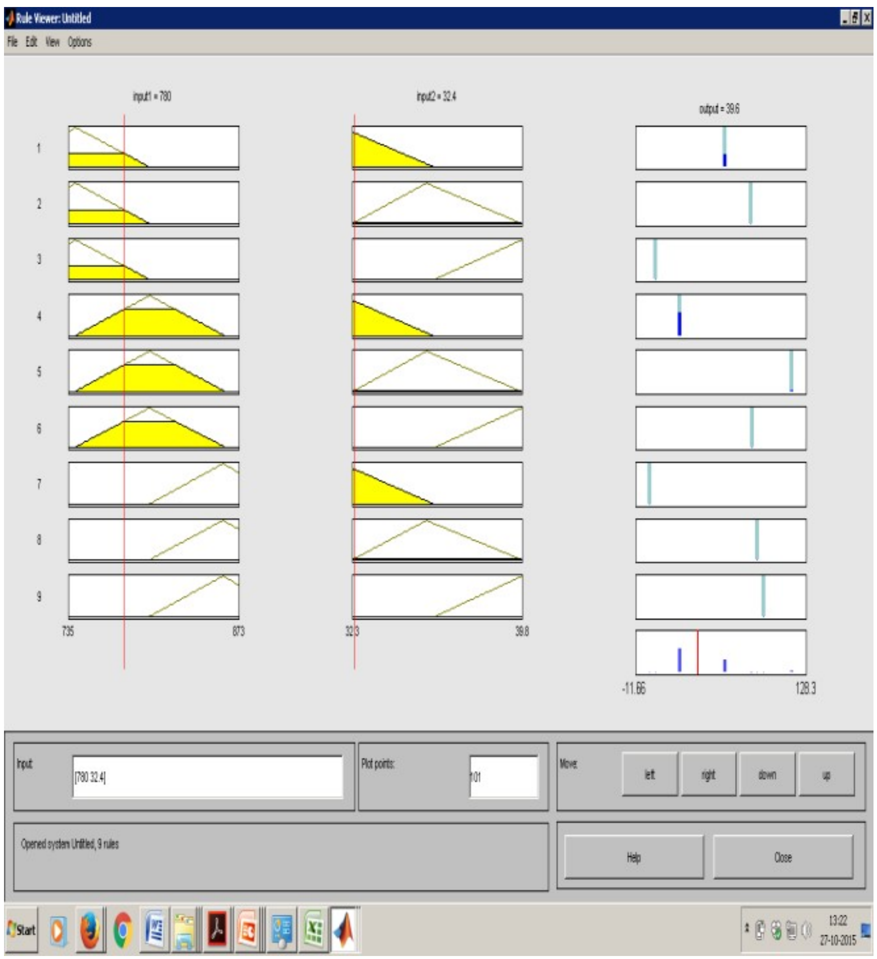

Figure (6): Photo of rule viewer.

4. Conclusions: ANFIS prediction model is made to determine the output temperature of water in Scheffler Reflector. Successful validation of the model was done with the use of experimental data. The above done work will result in the elimination of the tedious experimental work that used to be done. Apart from this, it'll not only cut down the time invested in the experimentation phase of the project but also allow the researchers to examine throughout the year without being interfered by the seasonal changes.

5. References:

1. R. Patil, G. Awari, M. Singh, J. Therm. Sci.15 (2011) 599–604.
2. J. Ruelas, N. Velázquez, J. Cerezo, J. Appl. Energy 101 (2013) 253–260.
3. Z.H. Yao, Z.F. Wang, Z.W. Lu, X.D. Wei, Rene Energy 34 (2009) 2437-3446.
4. S.K. Tyagi, S. Wang, M.K. Singhal, S.C. Kaushik, S.R. Park, J. Therm. Sci. 46 (2007) 1304 1310.
5. J. Harris, T. Lenz, J. Solar Energy 34 (1985) 135–42.
6. V. Badescu, J. Space Technol.14 (1994) 331–7
7. Y. Shuai, L. Xia, G. Tan, J. Solar Energy 82 (2008) 13–21.
8. T. Takagi, T. Sugeno, IEEE Transaction on Systems, Man and Cybernetics 15 (1985).

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