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Testing and Analysis of Two Axis Tracking Mechanism for Parabolic Dish Collector using Artificial Neural Network

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Abstract

High concentration parabolic dish is common in the applications of collecting solar energy. For maximizing the collector efficiency; collector is required to face towards the sun all the time which is called as "tracking". High degree of sun-tracking accuracy is required to ensure that the solar collector is capable of harnessing the maximum solar energy throughout the day. In order to maintain high output power and stability of the solar power system, a high-precision sun-tracking system is necessary to follow the sun's trajectory from morning to evening. In the morning once dish is set to appropriate position. Speed reduction gear train is used to control the speed and movement of system and proper tracking is achieved throughout the day. *Azimuthal Tracking* serves the purpose of tracking from sunrise to sunset azimuthally i.e. East –West direction. In *Altitude Tracking* Parabolic collector is to track the sun is from sunrise to noon and then in afternoon up to sunset. Dish will move in upward direction towards North direction and then in downward direction towards South direction.

An experimental study was performed to investigate the effect of using a continuous operation two-axes tracking on the solar energy collected for ten days by varying length of connecting rod and as a result, the collected energy was measured and comparative analysis is being carried out by Artificial Neural Network (ANN). It is perceived that result obtained by tracking mechanism and ANN is analogous.

Keyword- *Parabolic Dish Collector, Tracking Mechanism, Azimuthal Tracking, Altitude Tracking, ANN*

I Assembly of Tracking Mechanism:

Motor shaft is coupled to worm which houses on bearing. When motor shaft rotates it tends to rotate worm which reduces the speed by worm wheel. Shaft of worm wheel acts as worm for second set which further reduces speed by second set of worm wheel. shaft of second worm wheel is connected to gear pinion which reduces speed by helical gear, shaft of which is connected to axle and freewheel

which restricts motion in reverse direction . On this axle frame is mounted with parabolic dish along with focusing plate, set of wheel, connecting rod. One end of connecting rod is connected to dish and

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another to horizontal shaft on another end of horizontal shaft bevel gear is rolling on bevel which is passing through axle . All the parts i.e. parabolic dish, azimuthal tracking mechanism and altitude tracking mechanism are assembled (Fig.1)

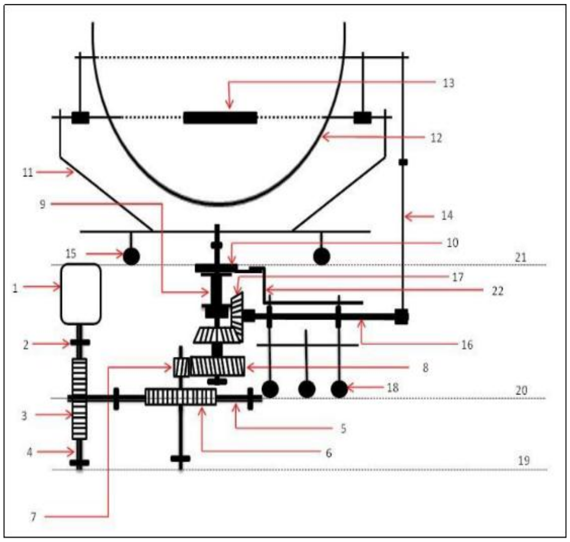

Fig. 1: The Tracking Mechanism (Assembly of setup)

Part List:

1. Motor
2. Bearing
3. Worm wheel (1)
4. Worm (1)
5. Worm (2)
6. Worm wheel(2)
7. Helical pinion
8. Helical gear
9. Axle
10. Freewheel
11. Frame
12. Parabolic dish
13. Focusing plate
14. Connecting rod
15. Set of 4 wheels (for frame)
16. Horizontal shaft
17. Bevel gear
18. Set of 4 wheels(for connecting shaft)
19. Ground level
20. Lower bed
21. Upper bed
22. Lever

II Testing:

Testing is carried out by considering various parameters Dish should be rotated in Azimuthal direction as well as in altitude direction so that maximum heat is captured at focal point. Apart from this year round tracking should also be done (Provision for seasonal adjustment) various reading have been taken at focal point. Readings for 10 days were taken for time period 8.00 a.m. to 4.00 p.m. for temperature, lift and Inclinations Also graph were plotted for Temp. Vs Time, lift Vs Time and Inclinations Vs Time

Notations used:

1. Temperatures:

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- T_{Room}: Temperature of surrounding environment.
- $T_{Amb.}$: Temperature of ambient air within the parabolic dish.
- T_{Focus}: Temperature of focusing plate.

2. Lift:

- Pin : Lift obtained in pin from base
- Other: Lift of the parabolic dish from base from where horizontal angles are measured.

III **Analysis using Artificial Neural Network (ANN):**

Neural Network Toolbox (photo frame 1) provides functions and apps for modeling complex nonlinear systems that are not easily modeled with a closed-form equation. Neural Network Toolbox supports supervised learning with feed forward, radial basis, and dynamic networks. It also supports unsupervised learning with self-organizing maps and competitive layers. With the toolbox you can design, train, visualize, and simulate neural networks. You can use Neural Network Toolbox for applications such as data fitting, pattern recognition, clustering, time-series prediction, and dynamic system modeling and control. To speed up training and handle large data sets, you can distribute computations and data across multicore processors, GPUs, and computer clusters using Parallel Computing Toolbox.

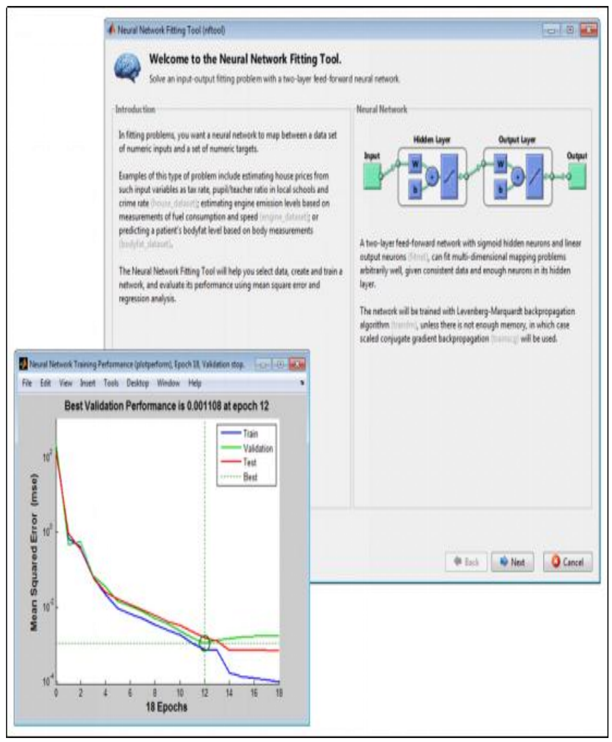

Photo frame 1 Artificial Neural Network (ANN)

Neural Network Fitting Tool:

In fitting problems, one wants a neural network to map between a data set of numeric matrix of inputs INPUT is 17x8 matrix representing 17 samples of 8 elements, and a set of numeric targets (Focus Temperature) OUTPUT is 17x1 matrix representing 17 samples of 1 elements. The Neural Network Fitting Tool will help us select data, create and train a network, and evaluate its performance using mean square error and regression analysis.

Investigation:

The observations discussed in readings shows seventeen readings of a day and nine columns representing different parameters. Here temperature is also considered a parameter as the working of tracking mechanism depends on time of day also. Out of these nine parameters, eight are assumed here as independent parameters and are used as INPUT data for carrying out analysis .And the ninth parameter i.e., T_{focus} is assumed here to be the dependent parameter. Any change in any of the independent parameter would result into change in the dependent parameter. The T_{focus} parameter is hence used here as TARGET data.

Thus, the INPUT parameters are:

1. Time
2. Pin lift
3. Dish lift
4. Angle between pin and connecting rod
5. Angle between pin and vertical plane
6. Angle between dish and horizontal plane
7. Room temperature
8. Ambient temperature

And the TARGET parameter is: Focus Temperature

Artificial Neural Network tool of MATLAB will now be used to calculate the maximum possible focus temperature for any set of the INPUT values given. This is achieved by using Neural Network Fitting Tool.

Procedure

1. Insert all the independent values in the workspace and save it as INPUT _OUTPUT.

The INPUT _OUTPUT matlab file contains 17 × 8 entries, i.e., 17 rows (observations) and 8 columns (parameters).

Insert the observed values of T_{focus} in the workspace and save it as INPUT _TARGET. The INPUT _TARGET matlab file contains the target values of 17 × 1 entries, i.e., 17 rows (observations) and 1 column (dependent parameter).

Now the analysis of the data can be done in two ways. They are as discussed below:

(a)Individual training of data using Network Fitting Tool:In this method, the INPUT DATA and OUTPUT DATA are used to form a neural network. These data are then used to train the neural network. Once the INPUT and TRAGET

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data are fed, they are converted into row format. The data usage is classified as:

Training: These are presented to the network during the training, and the network is adjusted according to its error.

Validation: These are used to measure network generalization, and are used to halt the training when the generalization stops improving.

Testing: These have no effect on training and so provide an independent of network performance during and after training.

Here, out of 17 samples 70% (11 samples) are used as training data. 15% (3 samples) are used as validation data and remaining 15% (3 samples) are used as testing data as seen in

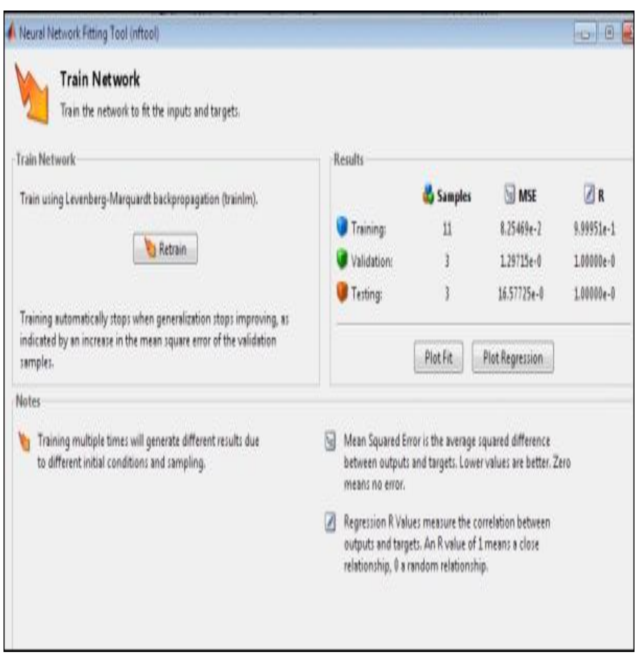


Photo frame 2: Training, Validation and Testing

photoframe2

The number of neurons in network's hidden layer is then set. Here we are using 20 numbers of hidden neurons. Thus, the neural network is generated and trained.

The training process is continued till the Mean Square Error (MSE) is as less as possible. Mean Squared Error is the average squared difference between outputs and targets. Lower values are better. Zero means no error.

Regression (R) Values measure the correlation between outputs and targets. An R value of 1 means a close relationship, 0 random relationships. The training should be continued till the value of R is closest to 1.

(b) 50 Iterations program for Error Calculation using ANN:

The limitation of traditional method of re-training and calculating the error using Network Fitting Tool is that it is time consuming and that in re-training process it is not necessary that result will be improved after re-training. Hence a program of 50 iterations, that is calculating the errors and re-training the neural network for 50 times, is used here. Based upon the RMS value of error in iterations, the iteration with minimum RMS error is selected. The procedure in this process is similar to the previously discussed method. The INPUT and TARGET data is inserted into the workspace. Then the MATLAB program for 50 iterations is executed.

The results from either of the two described method are then used to obtain the ANN values of target data (i.e., T_{focus}).

The further analysis is as described in the next sections.

Exploration

The analysis is concerned with the use of T_{focus} values as obtained from the Neural Network Fitting and that of obtained from the observations. The difference between the two values gives the error because of the Tracking mechanism.

Thus, we will be concerned on following parameters as explained below:

Error= T_{focus}-TF_ANN

Where, T_{focus} is the temperature obtained in the observations,

and, TF_ANN is the target temperature obtained from the Neural Network Fitting Tool.

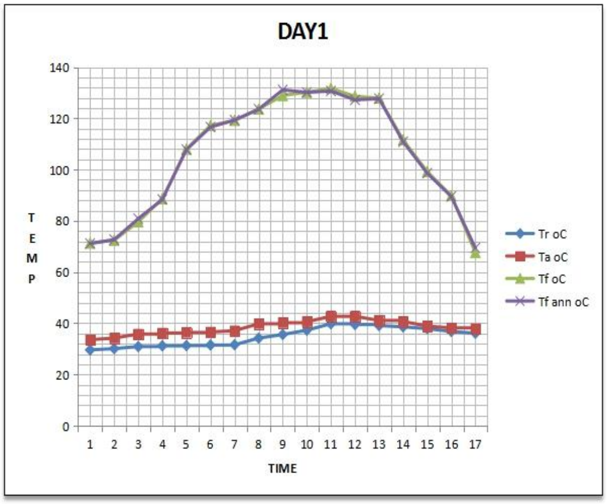
Percentage Error= $\frac{Error}{Tfocus}$ **× 100** (%)

For all ten days for which test reading has been taken is analysed by ANN error and percentage error is calculated Also graphs were drawn for Temperature Vs Time also for percentage Error w.r.to time

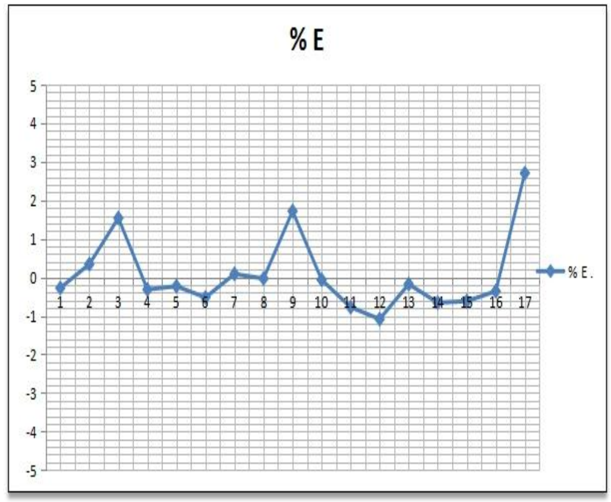
Day1:	Condition :Length of connecting Rod :54.5mm										
	lift		Angles			Temp					
Time	Pin	Other	Pin and connecting rod	Pin and vertical plane	Dish and horizontal surface	TRoom	TAmb	Tfocus	Tfocus ANN	ERROR	% ERROR
T	Lp_1	Lp_2	Θpc	Θvp	β	Tr	Ta	Tf	Tf ann	E	% E
Mins	Cm	Cm	(Degrees)	(Degrees)	(Degrees)	°C	°C	°C	°C	°C	

0	46	19.3	35	30	49	29.6	33.6	71.3	71.10362	-0.19638	-0.27543
30	46.3	20.2	35	30	48	30.1	34.2	72.4	72.64754	0.247542	0.341909
60	46.7	20.5	34	29	47	30.9	35.8	79.6	80.82509	1.225085	1.539052
90	47.1	21.1	34	29	46	31.2	36.2	88.6	88.31975	-0.28025	-0.31631
120	47.3	21.6	33	28	45	31.3	36.4	108	107.7507	-0.24927	-0.23081
150	47.5	22.5	33	27	42	31.5	36.6	117.2	116.5877	-0.61225	-0.5224
180	47.7	24.2	32	26	35	31.6	37.1	119.2	119.3032	0.103199	0.086577
210	47.9	24.9	32	25	24	34.2	39.8	123.6	123.5609	-0.03913	-0.03166
240	51.1	49.2	30	24	4	35.6	40.2	128.9	131.1167	2.216709	1.719712
270	51.1	49.6	30	24	2	37.3	40.6	130.2	130.1186	-0.08143	-0.06254
300	50.7	48.1	29	25	4	39.8	42.7	131.7	130.6779	-1.02211	-0.77609
330	50.1	44.7	29	25	5	39.5	42.7	128.6	127.2055	-1.39454	-1.0844
360	50	42.1	28	26	6	39.1	41.1	127.9	127.6731	-0.2269	-0.17741
390	48.7	39.2	27	27	8	38.6	40.7	111.6	110.8654	-0.73456	-0.65821
420	48.4	36.2	27	28	13	37.9	38.9	99.2	98.5854	-0.6146	-0.61955
450	48.1	30.9	26	29	16	36.8	38.2	89.8	89.47664	-0.32336	-0.36009
480	46.8	27.1	26	29	20	36.1	37.9	67.6	69.42785	1.827851	2.703921
									∑E=	-0.15439	

Table 2: $Tfocus_{ANN}$ and % Error, Day1 ,%Error range: 2.703921 to -1.0844



Graph 1: Temperature Vs. Time, Day 1



Graph 2: Percentage Error, Day 1

Conclusions:

Parabolic dish collector is very effective resource to collect solar energy in turns saves large amount of conventional energy in the form of fuel. The readings were taken for 10 days.. At the focal point temperature achieved is maximum **(149.7^{0}C**) at 12.30 p.m whereas atmospheric temperature recorded was 34.2^{0}C and temperature difference observed is more than 110^{0}C. The maximum focus temperature is mostly achieved at afternoon for sufficient amount of time (on an average for 2-3 hours).By using ANN it is observed that Focus temperature obtained by tracking Mechanism and Focus temperature obtained by ANN is nearly same. Error and percentage error are very less i.e in the range of -5 to +5 The model is significant at 95% level of confidence. Further, the ANN analysis shows that the tracking mechanism is sufficiently effective in tracking the Sun; it is following the desired path.

In a nutshell, it is concluded that the developed tracking mechanism is very efficient and effective in tracking the Sun throughout the day. The limitation of concentrating collector of tracking is resolved by this project. This unique project will bring a phase change in energy utilization

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