Creating a TRNSYS Model of Spiral Flow Flat Plate Solar Water Heater (SFSWH) and Comparing Unique Results with Parallel Flow Flat Plate Collector

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Abstract— A unique SFSWH system is proposed for domestic hot water in Kovilpatti, TamilNadu, 9° 10′N 77°52′E. This SFSWH system is successfully simulated in TRNSYS Software and the results are clarified with the similarities of parallel flow solar water heater. Firstly, a complete model of spiral flow flat plate collector is formulated in TRNSYS software and taking into an account of heat transfer, outlet temperature and efficiency which are theoretically compared with parallel flow flat plate collector by means of TRNSYS simulation program. The SFSWH system performs a function with the assist of NASA surface Meteorology and solar energy year readings and with the assist of ISRO's solar calculator application relative to Kovilpatti, Tamilnadu, India. To prove the accuracy of TRNSYS model of the SFSWH, an experimental setup is done at kovilpatti and required results were obtained under kovilpatti weather conditions. The validation of this SFSWH TRNSYS model simulation program is completed by checking the similarities between the predicted results from software with original results. This SFSWH TRNSYS model result shows the SFSWH is functioned more effectively compared with conventional parallel flow water heater. Thus TRNSYS model is reliable and which alternates the experimentation.

Keywords— SFSWH - Spiral Flow Solar Water Heater, TRNSYS.

I. INTRODUCTION

The largest energy resource, which is available as renewable energy in the earth is nothing but a solar energy. Global warming makes the world to understand about the usage of renewable sources and gives the importance to reduce the hazardous environment created by the fossil fuels. The plenty of solar radiation available every day at kovilpatti as compared to other regions in Tamilnadu, India. The measurement of solar isolation on the flat surface of Kovilpatti is monthly average of 4.86 kWh/m²/day. SFSWH has the main part of black paint coated flat copper plate collector which receives the direct solar rays. The another part of black paint coated tubes which is set as a spiral form and conveys water from cold sump to hot water storage tank. The natural heat absorption by tube water from collector makes the high temperature water outlet. Transient simulation of systems is the simulation program, simply called as TRNSYS. This software gives the best simulation area for energy related systems. The complicated validation of new ideas in renewable energy systems (for example wind, solar, PV etc.) including their control areas can be done by TRNSYS. This software makes the easy way to extend the existing energy systems and makes the correct way of the user's optimized passive solar heating prototype. The TRNSYS model is validated with specific needs. We can make custom simulation for the user's requirement by creating the customized parts in TRNSYS software. S.Maheshwaran and K.Kalidasa Murugavel studied the behavior of spiral flow flat plate collector for kovilpatti (9o10'N, 77o52'E). Gurjot and Alan conducted an experiment as a hybrid model which is solar water heater with heat exchanger. Yanuar et al. did a work of heat exchanger with a spiral pipe using nano fluids. Mohammed et al. modeled and verified the project of 10 m^2 horizontal plate collector with storage capacity of 600 liters to the usage need of 25 persons. Their system covers winter season's hot water requirement with an annual solar fraction of 69% in addition with auxiliary electric heater.

II. METHODOLOGY

SFSWH model is created in TRNSYS platform of simulation program and the required data is collected and the given methodology is followed to achieve the simulation. Initially the simulation is created in TRNSYS platform and also the unique results are obtained by experimentally. The entire setup is created and unique results are compared.

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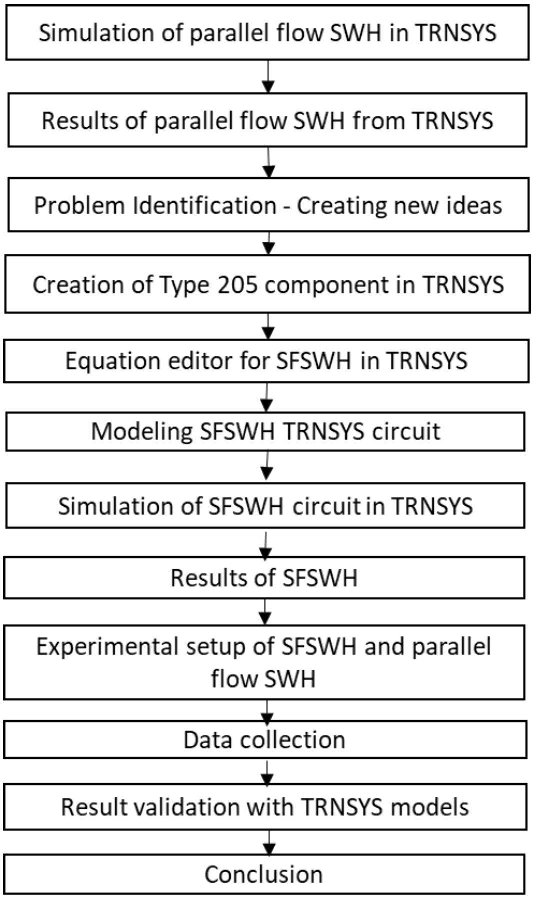


III. SIMULATION OF PARALLEL FLOW SWH IN TRNSYS

The parallel flow SWH system circuit is formulated in TRNSYS software with their all components. The output results of outlet water temperature for parallel flow SWH system is obtained from simulation.

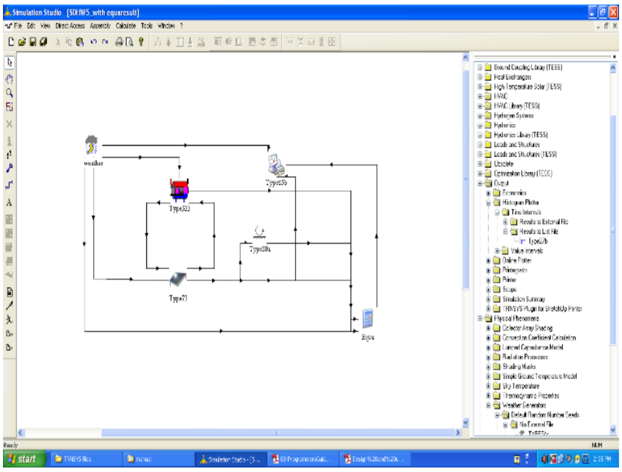


Fig. 1: Parallel flow SWH

IV. PROBLEM DEFINITION

Solar thermal behavior with all parameters can be validated and verified by the simulation program called TRNSYS. But this software package has a limitation of mentioning the type of flow for simulation of annual performance for flat plate solar water heater in TRNSYS software. Usually, TRNSYS has the theoretical flat plate collector – Type 73 component commonly used in the simulation circuit system to mention the parallel flow SWH which does not give the actual output for spiral design.

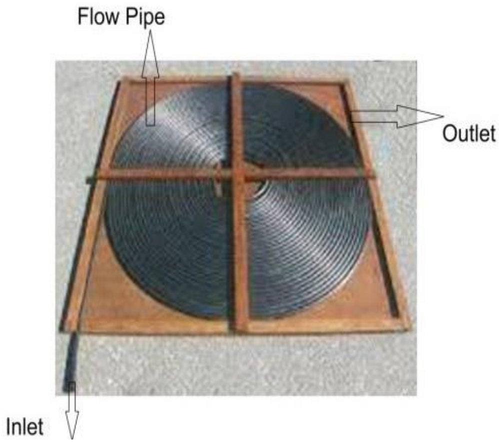


Fig. 2: Spiral Flow Design

The outlet temperature from spiral flow design in flat plate collector has the maximum value compared to parallel flow design. This is not achieved by Type 73 component in TRNSYS simulation program. So we need to create a new spiral flow model named as SFSWH TRNSYS model.

IV. CREATING NEW IDEAS

A. *Creation of Type 205 component in TRNSYS*

The component Type 205 is created by assigning different variables related to SFSWH. The variable button of a proforma needs some of the weather data related to kovilpatti. The links between component Type 109 (weather data reading and processing) and Type 1b and Type 205 are easily ensured by connecting one output with another input. Once, the component Type 205 is created we need to open it in TRNEdit. It reads the Type 205 component as TRNSED file. We can follow the default setup or we can modify the setup with programming language of FORTRAN.

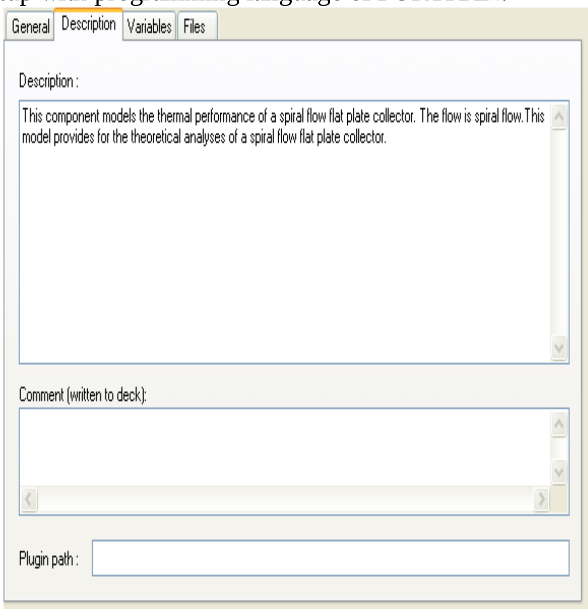


Fig. 3: Description of abstract

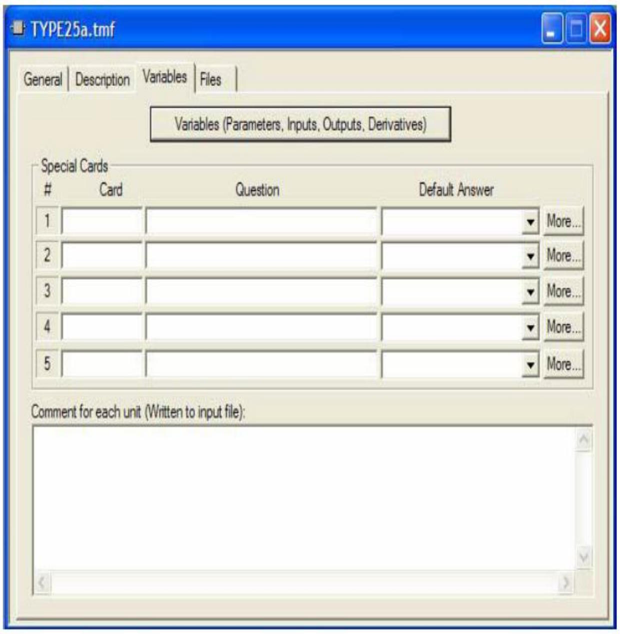


Fig. 4: Variables Tab

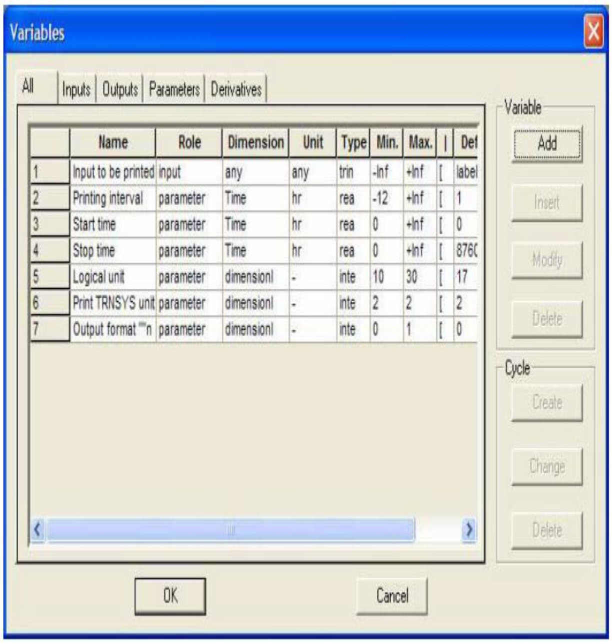


Fig. 5: Variables button

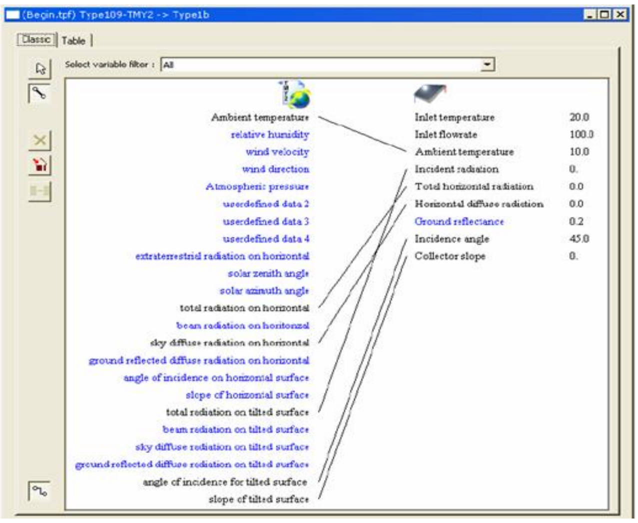


Fig. 6: Connections of components

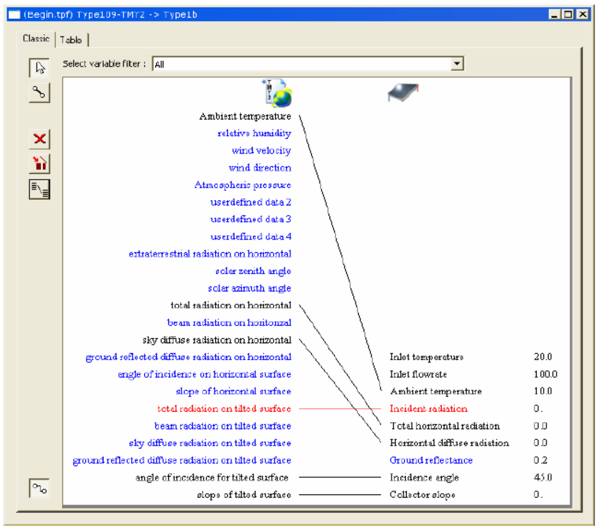


Fig. 7: Connections between weather and Type 205 component

B. Equation editor for SFSWH in TRNSYS

Even though the kovilpatti weather data gives the major role, the flow parameters are also considered in an account with the spiral flow equation. The equation editor setup is designed to predict the exact results based on the formulae.

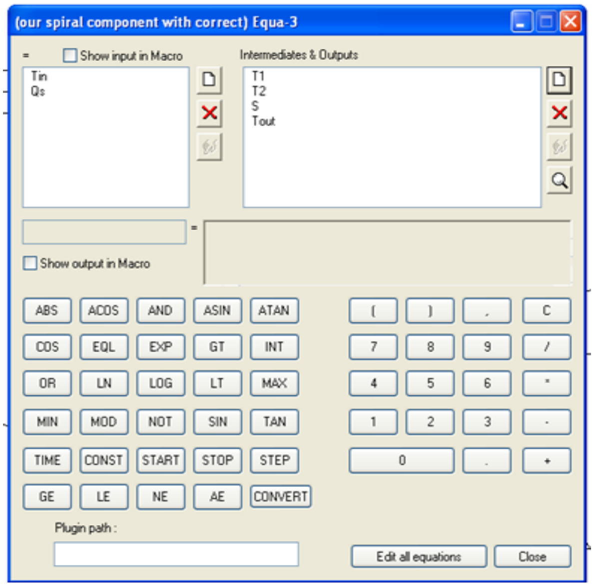


Fig 8: Equation Editor in TRNSYS Software

D = Diameter of inner pipe

ΔP = Pressure drop

L = Pipe length (experimental portion)

k = Consistency of fluid

n = power law index

u = average velocity

Δh = head gradient

H{x} = heat transfer co efficient at any point x in inlet

T{x} = Temperature of water at any point x

Qs = heat flux

$\{(D)*(\Delta P)\}/\{4*(L)\} = (K)*\{[(8*u)/D]\ n\}$

$n= \{(d \ln (D\Delta P/4L))\} / \{(d \ln (8*u/D))\}$

Darcy Equation gives coefficient of friction.

{f}=

{(D/L)}*{(2g/u2)*Δh}
{h(x)} = (Qs)/ {(T¬s(x) - Tb(x))}
{T(x)} = (Tb, i)+ {(Qs.P/m*Cp)}
Qs= {((m)*(Cp)*(Tb, o-Tb, i))/A}

V. SIMULATION OF SFSWH CIRCUIT IN TRNSYS

The entire SFSWH circuit is drawn in the TRNSYS platform. The required data is feed to the individual components which are key role to the simulation. The weather data, supporting equations, links between the weather data with components like that all essential steps are taken to fit the SFSWH model in the TRNSYS simulation program. The arrow mark shows the direction of data transfer from one component to another component. For example, Type 109 component (weather data) is directly connected with Type 205 component. The actual weather data is directly feed into the component like if the level of radiation is high and then outlet temperature also increases with respect to the connection of links in variables proforma. This simulates the actual working condition in the software. After the simulation, the SFSWH results such as outlet temperature is very high compared to parallel flow SWH.

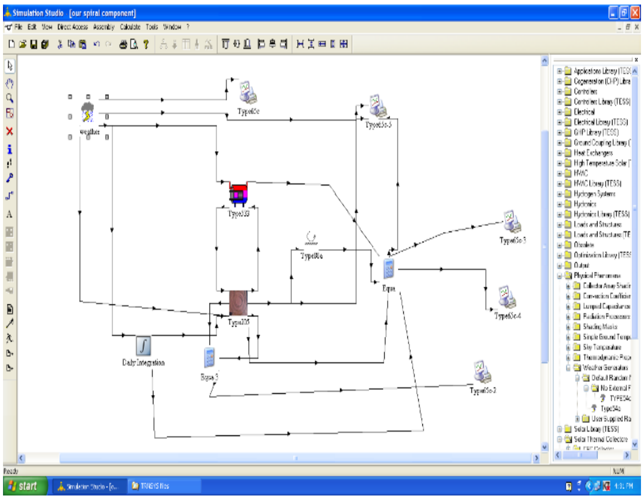


Fig. 9: SFSWH TRNSYS model

VI. EXPERIMENTAL ANALYSIS WITH DATA COLLECTION

The SFSWH and parallel flow SWH models are lively created and continuous monitoring is done to compare the unique results with the simulation software. The setup specification is as mentioned in Table.

Table.1: Component specifications

Tank capacity	53 litre
Spiral flow pipe	Copper (length=9m)
Outer radius	16mm
Inner radius	14mm
Absorber plate	Aluminium sheet
Glass cover	5 mm thickness (100 cm*100 cm)
Insulation	Thermocol, Coconut Fiber

The readings are obtained half an hour base while the experimentation is going on.

1. Inlet temperature.
2. Outlet temperature.
3. Ambient temperature.
4. Glass temperature.
5. Solar intensity.

There are two measurements were taken for the different flows. Reading of the experimentation is taken by author. The parallel flow SWH and SFSWH readings are taken at the location of kovilpatti, Tamilnadu. The figure shows the complete setup of parallel flow SWH. The outlet temperature of parallel flow SWH is in Table.

Fig. 10: Experimental setup – parallel flow SWH

Table. 2: DATA COLLECTION: PARALLEL FLOW SWH

Time	T in [^{o}C]	T out [^{o}C]	Level of Radiation (solar) [w/m^2]	T out - T in [^{o}C]
7.00	25	26	122	1
7.30	27	28	126	1
8.00	27	31	130	4
8.30	30	36	138	6
9.00	31	41	140	10
9.30	33	46	153	13
10.00	32	49	250	17
10.30	31	51	301	20
11.00	32	53	666	21
11.30	33	55	540	22
12.00	33	59	570	26
12.30	34	60	664	26
13.00	35	65	698	30
13.30	34	69	928	35
14.00	36	73	930	37
14.30	35	70	840	35
15.00	34	67	762	33
15.30	33	61	698	28
16.00	31	57	653	26
16.30	29	51	520	22
17.00	28	49	495	21

The figure shows the complete setup of SFSWH. The outlet temperature of SFSWH is in Table.

Fig. 11: Experimental setup - Spiral flow water heater

Table.3: DATA COLLECTION: SFSWH

Time	T in [°C]	T out [°C]	T Glass [°C]	Level of Radiation (solar) [w/m²]	T out by Thermometer [°C]	T out - T in [°C]
7.00	23	24	24	176	23	1
7.30	24	25	28	154	24	1
8.00	24	33	31	255	29	9
8.30	25	38	29	305	35	13
9.00	27	42	32	540	39	15
9.30	29	51	40	586	46	22
10.00	30	58	55	642	52	28
10.30	33	65	77	705	62	32
11.00	34	70	83	812	69	36
11.30	35	76	63	853	72	41
12.00	37	80	77	890	76	43
12.30	38	86	83	905	80	48
13.00	41	87	78	860	82	46
13.30	43	90	76	810	85	47
14.00	44	93	77	709	86	49
14.30	42	89	69	693	81	47
15.00	38	82	71	535	76	44
15.30	37	79	68	555	79	42
16.00	37	63	62	429	63	26
16.30	36	57	55	370	57	21
17.00	34	53	48	199	53	19

Natural circulation of parallel flow SWH and SFSWH is tested in kovilpatti at an interval of 30 minutes on that particular day (summer) between hour 7.00 to hour 17.00. Digital multimeter is used to measure the level of radiation (solar). Thermocouple K type is purposefully used to take the temperature readings at cold water inlet and hot water outlet as well as which is used to measure the temperatures at storage tank and ambient air.

VII. RESULTS

The results obtained from TRNSYS and experimental test are plotted below.

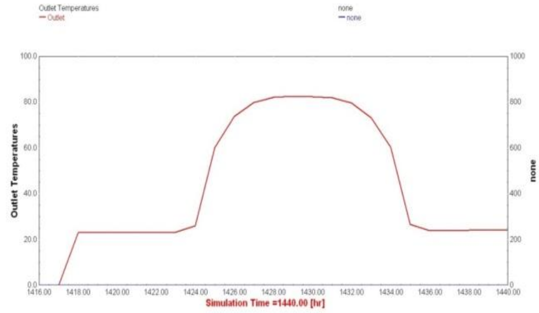


Fig 12(a) Parallel flow-Outlet Temperature

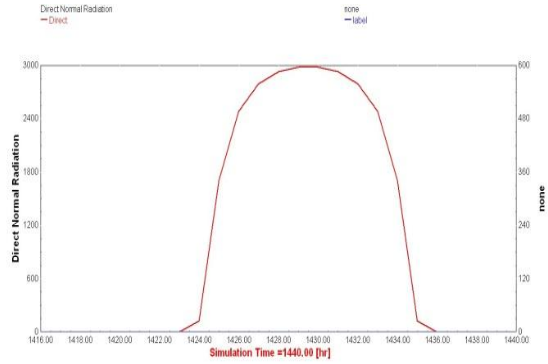


Fig. 12(b) Parallel flow-Direct Normal Radiation

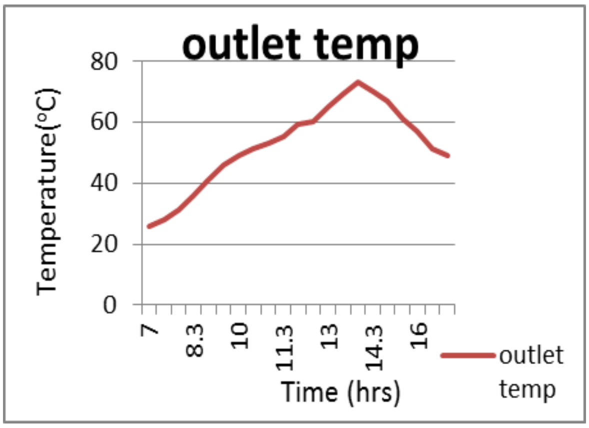


Fig. 12(c) Parallel flow-Outlet Temp. from actual reading

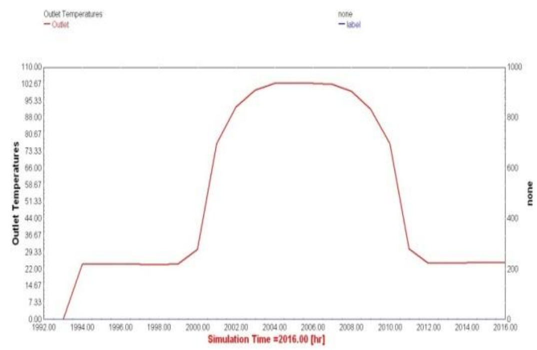


Fig. 13(a) Spiral flow-Outlet Temperature

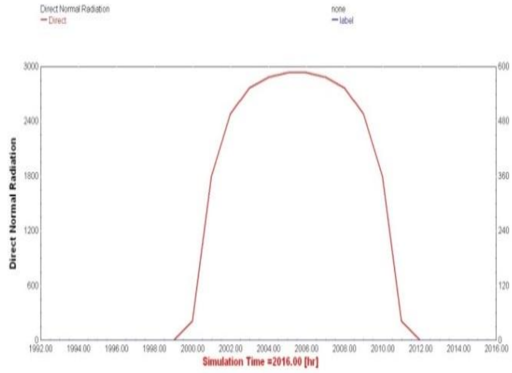


Fig. 13(b) Spiral flow-Direct Normal Radiation

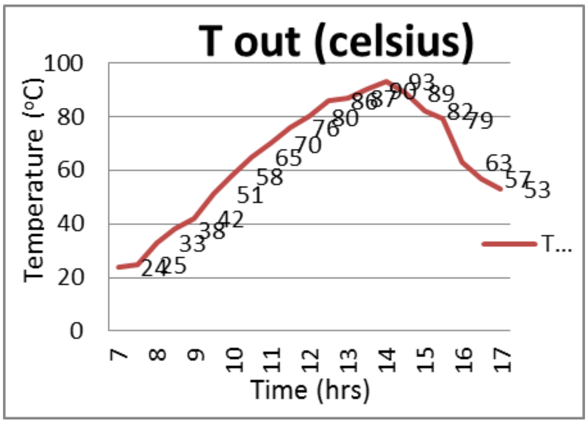
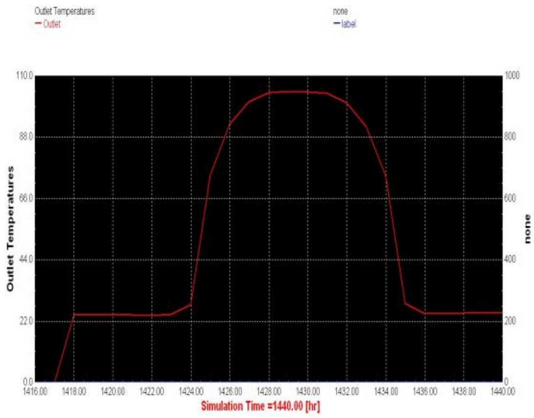
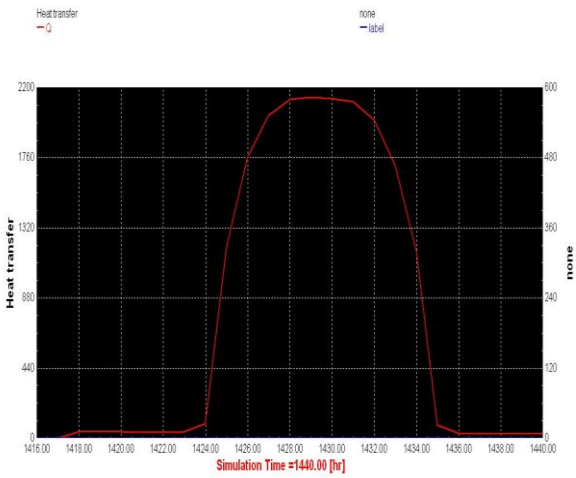


Fig. 13(c) Spiral flow- Outlet Temperature from actual reading





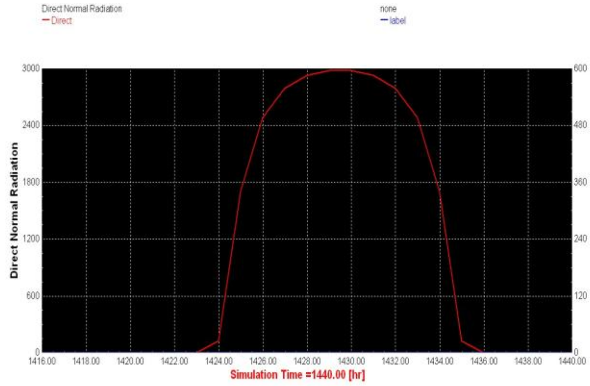


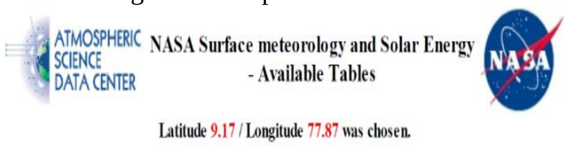
Fig. 14 Spiral flow - Outlet Temperature from SFSWH TRNSYS MODEL

VIII. CONCLUSION

The flow system of a parallel flow and spiral flow flat plate collector is tested experimentally and constructed in TRNSYS platform at kovilpatti. The level of radiation (solar) and air determines the water temperature while the experiment. At noon, the efficiency of the SFSWH is greater compared with the efficiency of parallel flow SWH. During experimentation, the parallel flow SWH gives the outlet temperature as 73oC for 930 w/m2 level of radiation (solar) and SFSWH gives the outlet temperature as 93oC for 709 w/m2 level of radiation (solar). TRNSYS output shows maximum outlet temperature in parallel flow system is 83oC and in SFSWH is 102.67oC. While considering two results, the SFSWH gives the maximum outlet temperature. Thus SFSWH is preferred than parallel flow SWH for kovilpatti region in Tamilnadu. From this we can make the note that the SFSWH TRNSYS simulation model predicts the results in software without doing a real time experimentation. Thus the model system in TRNSYS is reliable as much as compared with experimentation.

IX. APPENDIX

The following data are input to TRNSYS weather data.



Geometry Information

Elevation: 307 meters Taken from the NASA GEOS-4 Model elevation

Northern boundary
10

Western boundary Center
Eastern boundary
77
Latitude 9.5
78
Longitude 77.5

Southern boundary
9

Monthly Averaged Insolation Incident on a Horizontal Surface (kWh/m^2/day)

Lat 9.17 Lon 77.87	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	De
22-year Average	4.95	5.73	6.27	5.53	5.23	4.26	4.19	4.48	4.92	4.30	4.15	4.

Monthly Averaged Midday Insolation Incident on a Horizontal Surface (kW/m^2)

Lat 9.17 Lon 77.87	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	De
22-year Average	0.67	0.76	0.83	0.75	0.68	0.54	0.54	0.60	0.68	0.60	0.56	0.

Monthly Averaged Diffuse Radiation Incident on a Horizontal Surface (kWh/m2/day)

Lat 9.17 Lon 77.87	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	1.70	1.78	1.91	2.27	2.22	2.22	2.23	2.30	2.25	2.10	1.90	1.73	2.05
Minimum	1.43	1.44	1.64	2.12	2.11	2.18	2.16	2.26	2.08	1.98	1.82	1.55	1.90
Maximum	1.87	2.06	2.14	2.34	2.25	2.12	2.15	2.18	2.24	2.07	1.89	1.80	2.09
22-year Average K	0.55	0.59	0.60	0.52	0.50	0.41	0.40	0.43	0.47	0.43	0.45	0.50	0.49
Minimum K	0.43	0.40	0.53	0.46	0.37	0.33	0.33	0.32	0.37	0.36	0.37	0.39	0.39
Maximum K	0.63	0.67	0.67	0.58	0.55	0.49	0.51	0.49	0.56	0.53	0.51	0.58	0.56

Monthly Averaged Direct Normal Radiation (kWh/m2/day)

Lat 9.17 Lon 77.87	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	5.26	6.00	6.27	4.61	4.33	2.99	2.83	3.09	3.80	3.28	3.58	4.44	4.20

Monthly Averaged Air Temperature at 10 m above the Surface of the Earth (°C)

Lat 9.17 Lon 77.87	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	24.1	25.8	27.0	26.0	25.5	24.8	24.6	24.8	24.9	24.5	24.0	23.8	25.0
Minimum	20.5	21.6	23.1	23.3	23.4	23.0	22.6	22.6	22.6	22.2	21.3	20.7	22.2
Maximum	28.2	30.1	31.4	29.3	28.2	27.0	27.0	27.3	27.7	27.3	27.2	27.3	28.2

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