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Design and Performance Analysis of Parabolic Dish Indoor Solar Cooker using Solar Thermal Simulator

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ABSTRACT

The present work in on indoor solar cooking application. The solar cooking can be classified as indoor and outdoor cooking. A parabolic dish indoor solar cooking system is proposed to design for cooking approximately 200 meals per day. The performance of the system is predicted using solar thermal simulator 2.0 and compared with theoretical analysis. The estimated energy requirement was found to be 42 kWh per day whereas in preliminary design analysis a 12 Sq.m dish collector is selected which would generates about 57.6 kWh of energy per day. The simulation predicts 61.1 kWh of energy output per day. Assuming 7 hours of system running with an operating pressure of 2 bar.

Keywords : Solar Energy, Indoor Solar Cooking, Simulator.

I. INTRODUCTION

The depletion of non-renewable energy resources and increasing energy consumption is a severe concern. In many developing countries cooking sector is considered as the vital energy consuming sector as majority of the population rely on the traditional methods of cooking such as coal and wood, which are unreliable, inefficient and a source of pollution [1-4]. To meet this growing demand, the alternative sustainable energy resources must be focussed. Solar energy is one such energy resource which constitutes the abundant renewable energy supply on the earth and in most of the locations, the available potential is much larger than its present consumption. Cooking is a daily household activity which consumes more than 40 % of the total energy consumption of the country [5-8]. The utilization of solar application not only satisfy the growing energy demand but also a preventive measure to global warming. Solar cooking application would be most suitable to institutional and community cooking such as college, schools, canteen, jails and hospitals where energy requirements is in bulk. The solar cooking may be classified as indoor and outdoor solar cooking. In this paper the design and performance analysis of parabolic dish indoor solar cooker is presented. System is designed for 200 meals per day. The system performance is simulated using solar thermal simulator 2.0 software developed by Indian institute of technology Bombay.

II. SYSTEM DESIGN

The system is designed based on the energy requirements for cooking 200 meals per day .The indoor solar cooking system consist of a parabolic dish collector which concentrates the solar radiation on to a helical tube receiver which is located at focus of parabolic dish in which water is heated to a high temperature and stored in a insulated hot water accumulator and then to is supplied to cooking vessel when required. The parabola coordinates was obtained from parabola calculator which is an open source software shown in Figure 1. The initial specification was obtained by parabolic equation.

$$X^2 = 4fY \qquad (1),$$

Where f is the focus, X & Y are the co-ordinates.

The aperture area estimation is given by

$$A_a = \frac{\pi {D_a}^2}{4} \qquad (2)$$

Where A_a is aperture area, D_a is aperture diameter. The height of the parabolic dish, h, is defined as the maximum distance from the vertex to a line drawn across its aperture. In terms of focal length and aperture diameter, the height of the dish is given by

$$h = \frac{{D_a}^2}{16f} \qquad (3)$$

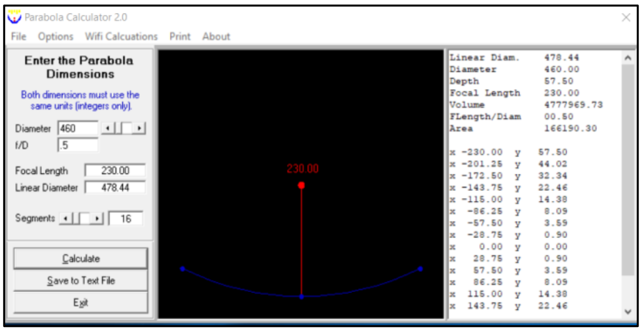

Figure.1 Parabola dimensions obtained using Parabola calculator 2.0.

According to the design calculation the solar cooking system consist of single dish collector which would be built in 10 segments.

III.PERFORMANCE ANALYSIS

The system performance is predicted using solar thermal simulator developed by Indian Institute of Technology Bombay (IITB). The solar thermal simulator solves energy and mass balance equations for user defined plant configurations [2].The simulation scheme is shown in Figure 2.

The heat gain by collector Q_{gain} and efficiency of collector $\eta_{collector}$ is given by

$$\eta_{collector} = A - B\left(\frac{T_m - T_a}{DNI.Cos\theta}\right) - C.\left(\frac{(T_m - T_a)^2}{DNI.Cos\theta}\right) \qquad (4)$$

$$Q_{gain} = m_{in}(h_{out} - h_{in}) = \eta_{collector}\, DNI.Cos\theta.A_p \qquad (5)$$

Where, DNI =Direct normal irradiance (W/m2), A = optical efficiency, B = first order loss co-efficient based on aperture area (W/m2-K), C = second order loss co-efficient based on aperture area (W/m2-K2), m = mass flow rate (kg/s), h = enthalpy (J/kg).The simulation is carried out by considering ASHRAE. The thermal performance prediction is carried out for Nagpur location 21°N79°E

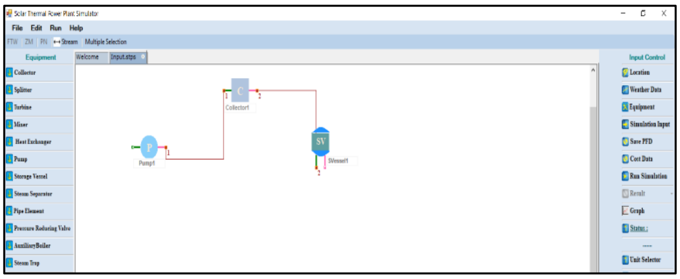

Figure 2: Simulation performance of the system.

The direct normal irradiance (DNI) for a day is shown in. Figure 3.

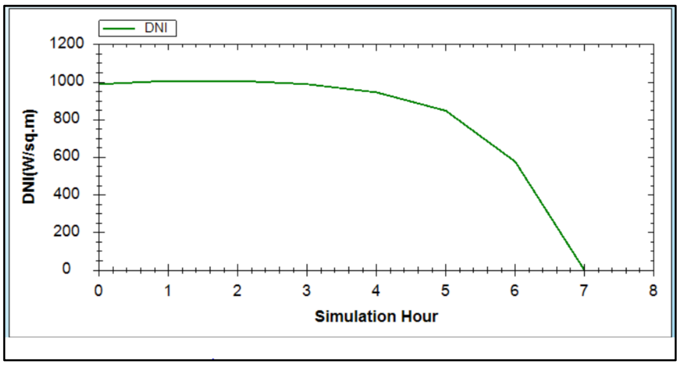

Figure 3: DNI at the location of the system

IV. RESULTS AND DISCUSSIONS

The simulation results and theoretical analysis is compared.

Theoretical analysis

Estimation of energy required for cooking 200 meals per day was found to be approximately 42 kWh. The energy generated by the collector is calculated using the mathematical relations, Assuming Direct normal irradiance (DNI) =700 W/m2. Sunshine hour=7 hours and collector efficiency =60%. The aperture area (A_a) of collector was found to be 11.77 m 2 in the preliminary design analysis.
Collector energy =DNI x Aa x sunshine hours
=700 x 12 x 7 =57673Wh=57.673 kWh.
The estimated required energy for cooking 200 meals per day was found to be 42 kWh whereas the available energy at the dish collector is 57.673 kWh per day.

V. Simulation Results

The indoor solar cooking system is proposed for 200 meals per day. The system performance is simulated for a year using solar thermal simulator which would be compared to experimental trials.Figure.4 shows outlet temperature for a day and Figure.5 shows the energy gained by dish collector for a respective day.

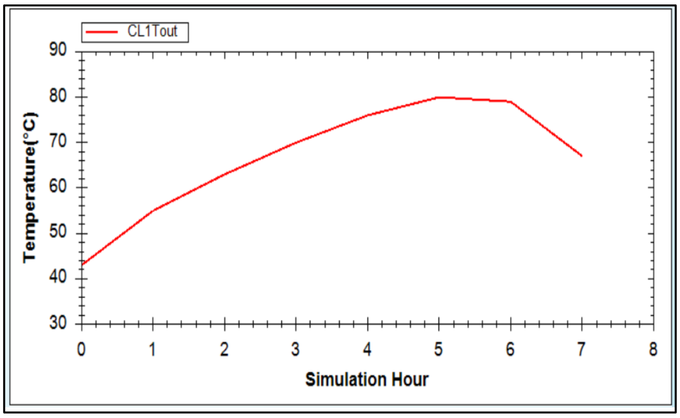

Figure 4: Simulation performance of the system.

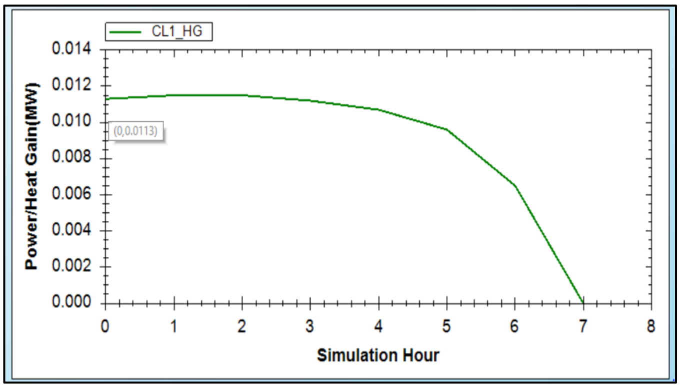

Figure 5: Simulation performance of the system.

VI. CONCLUSION

The indoor solar cooking system is proposed for institutional cooking to cook approximately 200 meals per day. The preliminary design analysis is based on the estimated energy requirement of 42 kWh per day. The 12 Sq.m dish collector theoretically would generate about 57.6 kWh of energy per day whereas 61.2 kWh per day of energy was obtained by simulation. Further it is planned to fabricate the system on the site of installation and compare the system performance with simulation for round the year.

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