International Journal of Innovative Scientific & Engineering Technologies Research 12(3):50-54, July-Sept, 2024

© SEAHI PUBLICATIONS, 2024 www.seahipublications.org ISSN: 2360-896X

Steam Generation Capability of Small Scale Parabolic Dish Concentrator for Process Heat and Electricity Generation in Nigeria

Shamsuddeen Abdulkarim Jibia[1], Bello Ibrahim Ahmed[1], Adamu Nazifi[1], Abubakar Haruna Ndagi[1], Ibrahim Dayyabu[1] and Abdulkarim Hamza El-ladan[1]*

[1] Ibrahim Shehu Shema Center for Renewable Energy Research, Umaru Musa Yaradua University, Katsina, Nigeria
abdulkarim.hamza@umyu.edu.ng *

ABSTRACT
Solar thermal based steam generation systems will be of great interest considering their high potentialities in areas with good solar irradiation most especially in rural communities of Africa, the availability of excellent solar resources in sub-Saharan Africa including the northern part of Nigeria (Katsina) where the current research is carried out motivated the researchers to carry out this preliminary research work. The work intends to compare several solar thermal concentrators (parabolic dish, scheffler dish, spot Fresnel lens and parabolic through) based on the same geometrical configuration for photo thermal conversion to produce process heat, generate steam for electricity generation with tesla turbine, purify waste water, and for sterilization in both clear days, cloudy days and hazy days to establish performance base on the three scenarios. The preliminary result presented in this work using 1.35 m parabolic dish indicates short boiling period for clear days, longer boiling periods for cloudy days as well as stagnation temperature. HANNA (HI 8757) K-type thermocouple thermometers were used to measure the ambient temperature, the Stagnation temperatures and the water temperatures respectively. The photo thermal efficiency for the system is …% at …C ambient , thus the concentrator indicates promising potentialities for steam generation.
Keywords: parabolic dish, stagnation temperature, ambient temperature, process heat, solar, photo thermal, steam, process heat**.**

1. INTRODUCTION

Solar thermal based steam generation systems will be of great interest considering its high potentialities in regions with high solar irradiation most especially in Africa, the availability of excellent solar resources in sub-Saharan Africa including the northern part of Nigeria (Katsina) where the current research is carried out motivated the researchers to carry out this research work. However, among the available renewable energy resources in Nigeria and Africa at large, Solar energy is regarded as the greatest and most abundant potential source of energy most especially when harnessed with efficient collector. One sun (1000W/m^2) as it is, cannot provide enough power for process heat or steam generation unless a very good collector is used [1,2]. The work presented here is aimed to compare the potentialities of many solar thermal collectors in the photo thermal conversion efficiencies in Katsina for the generation of process heat, steam generation for electricity generation using tesla turbine, water purification for drinking, sterilization [2] as well as other heating applications. Results presented here is a preliminary result based on 1.35 m parabolic dish collector, the future work will cover various solar thermal collectors (Scheffler dish, parabolic trough, spot Fresnel lens and many more maintaining same geometrical configurations.

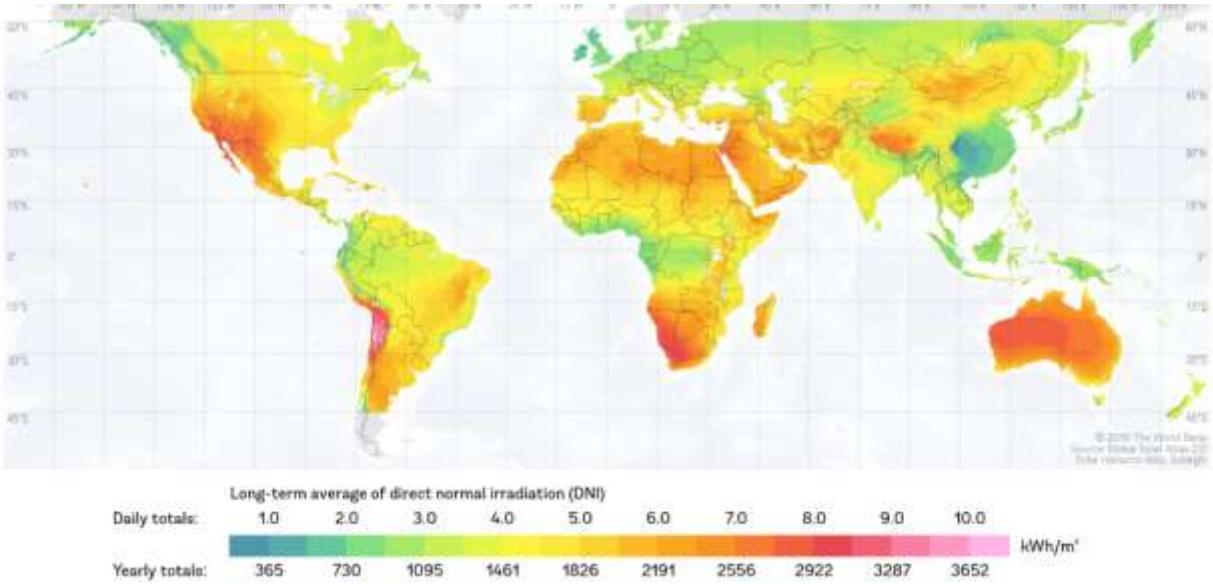

Fig. 1 global horizontal irradiation of solar energy distribution.

2. LITERATURE REVIEW

2.1 Introduction

The solar flux reaching the earth surface is in dilute form and do not have enough power to evaporate water effectively, Solar concentrators such as parabolic dish, parabolic trough collector and spot Fresnel lens can be used to harvest the solar radiation to achieve high power energy delivery [1]. Solar energy is considered as one of the greatest renewable energy sources with greatest potentialities to achieve sustained and high intensity energy output and up to 85% solar thermal efficiency at only $10kWm^{-2}$ can be achieved, it is a promising source of renewable energy, as the hourly incident solar flux on the surface of the earth is greater than annual global energy consumption [2]. Solar–thermal conversion efficiency is reported to have approach 100% under 1 sun illumination (1 kW m^{-2}) using various photo thermal materials and systems [3].

2.1 Concentration ratio

Parabolic dish is considered to have the highest utilization efficiency where there is no loss due to the aperture projection effect, solar collectors are key element in solar thermal energy systems in generating high temperatures, this is achievable in concentrating the solar radiation by reflecting the flux incident on the aperture area (reflective surface, A_a) onto a smaller receiver area (A_r) thus, defining the concentration ratio of the system [3,6]. The Concentrator ratio CR is use to determine the amount of light energy concentrated by a given solar collector, it is the area of the collector aperture (A_a) divided by the surface area of the receiver (A_r), thus, $CR = A_a/A_r$ Where; A_a is the area of the concentrator, A_r is the area of the receive [4].

2.2 Thermal Efficiency of Concentrating Solar Collector

The efficiency is defined as the ratio of the thermal power absorbed by the heat transfer fluid to the direct normal irradiance on the aperture area, Therefore, the thermal efficiency was determined using equation

$$\eta = \frac{(Twf - Twi)MwCw\ x100}{IbAc}$$

Where, η is the Thermal efficiency in %

3. METHODOLOGY

The experiment was carried out at the Ibrahim Shehu Shema Center for Renewable Energy Research, Umaru Musa Yaradua University Katsina, on a clear day and a cloudy day for comparison. A 1.35 m satellite parabolic dish covered with reflecting film is attached to a manual two axis tracking arrangement to serve as the solar collector for photo thermal conversion process through the receiver, the receiver (calorimeter) is made from 1.5 mm thick metal sheet with steam outlet, two k-type thermocouple sensors are attached to the calorimeter, one to the lower part to measure water temperature and the other to the upper part to measure steam temperature. The calorimeter is weighed empty and then filled with about a liter of water and measured again, it is finally set at the focal point of the collector for onward heating [5]. The work presented in this paper as depicted in graphical abstract and figure 2, showing the experimental methodology employed for the work based on semi-automated measurements of stagnation temperature at the focal point of the concentrator, ambient temperature and solar irradiance as a function of time. The receiver surface is exposed to aperture area of the parabolic dish collector to carry out water boiling test for steam generation and the respective water temperature, steam temperature, stagnation temperature an d the ambient temperatures were measured using k-type thermocouple and recorded between 12.00 noon to 1.00 pm local time at 5 min interval to establish the thermal efficiency of the system at both clear and cloudy days' conditions for comparison.

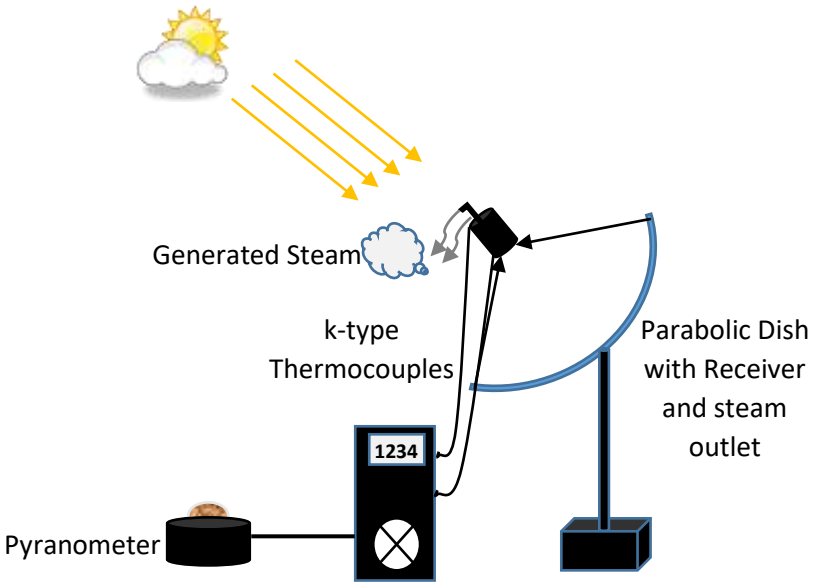

Fig. 2 system set up for data collection

4. RESULTS AND DISCUSSION

4.1 Water Boiling Test

The result of the water boiling test is presented in Figure 3, showing the boiling temperature reaching 99°C in 30 min in clear day with average ambient temperature ~ 35°C at an average corresponding global solar radiation is 910 W/m^2 at 12:00 noon – 1:00 pm as shown in figure 3, while figure 4 indicates lower and fluctuating water temperature in cloudy day, the graph in figure 5 indicates the correlation between ambient temperature, water temperature and stagnation temperatures in cloudy day showing a very clear fluctuation in stagnation temperature showing cloudy conditions affecting the performance of the concentrating system.

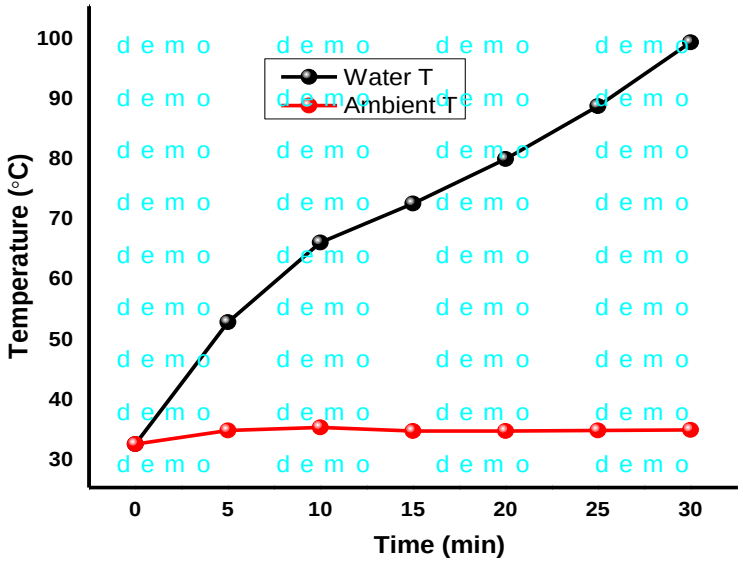

Fig. 3 correlation between water temperature and ambient temperature in clear day

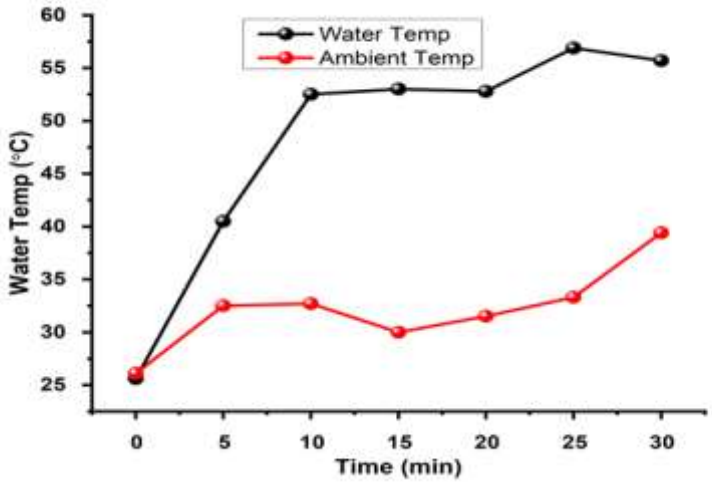

Fig. 4 correlation between water temperature and ambient temperature in cloudy day

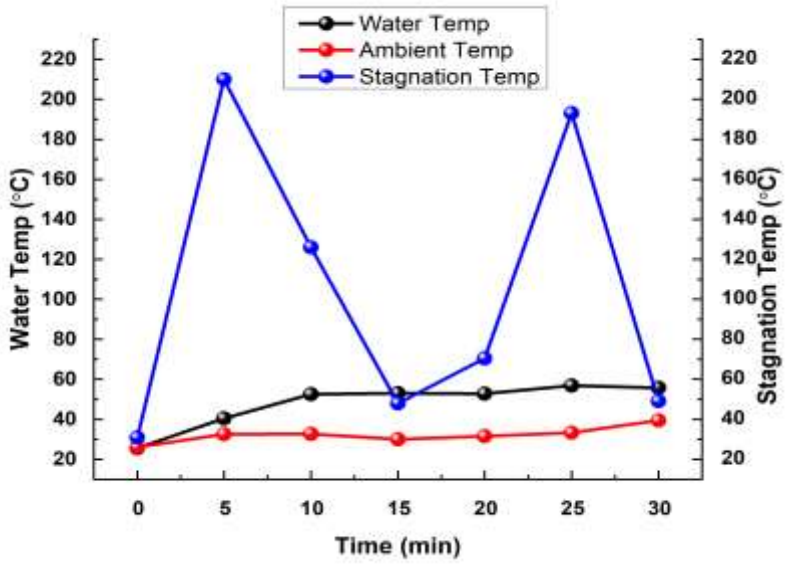

Fig. 5 correlation between ambient temperature, water temperature and stagnation temperatures in cloudy day

4.1 Concentration Ratios

The geometrical Concentration ratio using the relation $CR = A_a/A_r$ was calculated to be about 72x

4. CONCLUSIONS

From the results obtained from the set of experiments as shown above indicates that the performance of the concentrating system is grossly affected by cloudy weather conditions with water temperature fluctuating between 50-55°C while in clear day the water boils within 30 minutes, the stagnation temperature result is also a clear indicator of the effect of cloudy conditions. Future experiments with other collectors and more conditions will reveal a better candidate for photo thermal conversion in both cloudy and clear sky conditions which will lead to better choice for application in process heat, steam and electricity generation.

ACKNOWLEDGMENTS

This research work was funded by the Tertiary Education Trust Fund (TETFUND) No. 6 Zambezi Crescent off Aguiyi Ironsi Abuja, Nigeria.

REFERENCES

[1] A. H. Elsheikha, S. W. Sharshirc, M. K. Ahmed Alid, J. f, Shaiboe, M. Elbager, M.A. Edreisg, J. T Abdelhamidi, J, C. Duk, Z. Haioua, Thin Film Technology for Solar Steam Generation: A New Dawn, Solar Energy 177 (2019) 561–575 .

[2] H. Ghasemi, G. Ni, A. M. Marconnet, J. Loomis, S. Yerci, N. Miljkovic, G. Chen, Solar Steam Generation by Heat Localization, Nature Communications, DOI: 10.1038/ncomms5449

[3], Y. H. Mahmood, R. A. Munef, and A. A. Bazzaz, Modulating a Solar Parabolic Dish to Produce Boiled Water, Journal of Environmental Science and Engineering A 4 (2015) 225-232 doi:10.17265/2162-5298/2015.05.002

[4] M. Gwania, G. A. Abubakarb, M. Abbasc, M. Na Allahd, J. Danyaroe. Design, Fabrication and Experimental Study of Solar Parabolic Dish Concentrator for Remote Area Application, International Journal of Sciences: Basic and Applied Research (IJSBAR) ISSN 2307-4531

[5] G. Muthua, S. Shanmugama, AR. Veerappana, Solar Parabolic Dish Thermoelectric Generator with Acrylic cover, 4th International Conference on Advances in Energy Research 2013, ICAER 2013, Energy Procedia 54 (2014) 2 – 10

[6] A. B Bande, M. M Garba, S. Aliyu, B. S Hamza. and A. Shehu, Determination of Thermal Efficiency and Cooking Power of Parabolic Solar Concentrating System with Thermal Compensator for Domestic Applications, Bima Journal of Science and Technology, Vol. 6 (3) Dec, 2022 ISSN: 2536-6041