JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Comparative Analysis of Solar Chimney Power Plant Using Two Design Methods - Review

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Abstract: In earth's atmosphere, the sunlight is available in abundance which could be used in generating power using solar chimney power plant. The current research studies various researches conducted in improving design of solar chimney using numerical and experimental techniques. The performance of solar chimney can be significantly improved by optimizing design of solar collectors, chimney diameter, bend radius and entry height. The power generated by chimney is significantly affected by air velocity inside chimney.

Key Words: Solar chimney, CFD, thermal analysis

1. INTRODUCTION

The solar chimney power plant (SCPP) consists of three essential parts: a solar collector, a chimney, and a power conversion unit. The schematic of a SCPP is shown in Figure 1. Sunlight transfers through the transparent collector cover and heats the ground below. The ground temperature increases and heats the air above it through heat convection. The air temperature increases, leading to the decrease of air density. The density difference then is generated between the ambient air and the air in the solar collector. With the chimney, the air flows towards to the center of the solar collector under buoyancy effect. The air flows through the chimney and runs out of the SCPP at the top of the chimney.

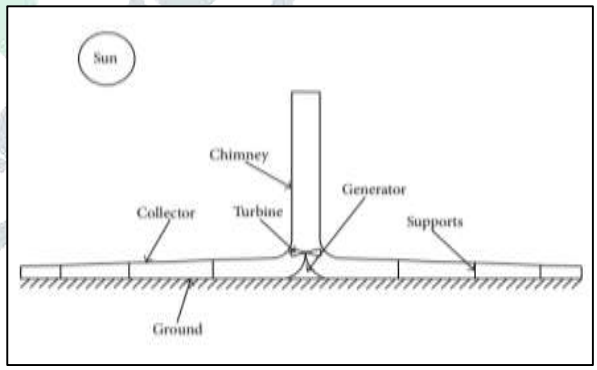

Figure 1: Schematic of a conventional solar chimney power plant (SCPP)

2. LITERATURE REVIEW

Yuen Zheng et.al [2018] This research work had focused on improving the efficiency of the collector of inclined SCPP through the use of underneath air-vents. The study employed numerical method using a Computational Fluid Dynamics software, Star-CCM+. In the system modelling and simulation, radiation modelling principles were adopted under condition of steady state. The study revealed that with the use of underneath air-vents, there was 4.25%

and 4.64% reduction in convection and radiation heat transfer respectively from the collector cover to the ambient at 1000 W/m2 . It was also observed that the air mass flow rate was increased by 210% and consequently the power output of the plant improved by 60%.

Liu et.al [2018] In this work, a PV / T power plant with solar chimney (SCPVTPP) was proposed. Mathematical models were established for the solar collector PV / T, the chimney and the energy conversion unit, respectively. Then the interpretations of the SCPVTPP designed were simulated. It was found that the photovoltaic cells maintain the highest temperature in the solar collector. The increase in temperature of the photovoltaic module had significant influences on its power generation. Without cooling, the photovoltaic power capacity had an average decrease of 28.71%. The contradictory influences of the increase in temperature and the cooling of the air flow lead to a decrease of 11.81% of the average power capacity.

Sivaram et.al [2018] In this work, a mathematical model based on the one-dimensional energy and mass balance was developed by the solar chimney. The airflow characteristics such as exit velocity and temperature are evaluated based on the inclination angle of the sensor, solar radiation, ambient temperature and wind speed. The model is validated by comparing the obtained performance parameters with the experimental results as well as with the experimental data of various geometric ranges and environmental conditions of the literature. For the sun chimney with an inclination angle of the absorber of 30 ° there is an average difference of 8% for the exhaust air velocity and 1.35% for the exhaust air temperature. a sensor surface of 0.41 m2 and a chimney height of 0.24 m. The average daily and maximum experimental airflow rates in April are 0.5 and 0.88 m / s, respectively. The optimum operating conditions are an inclination angle of 75 °, an absorption area of 0.63 m2 and a chimney height of 0.48 m.

Ayadi et.al [2017] The objective of this work was to study and optimize the characteristics of a chimney power plant (SCPP) using numerical and experimental methods. The numerical simulations were simulated using the Ansys Fluent commercial CFD code. The effect of the collector ceiling height on the performance of the solar chimney is realized. The local characteristics of the airflow within the SCPP system have been presented and analysed, such as; the characteristics of temperature, speed, pressure and turbulence. The results confirmed that the height of the collector roof is very influential in the optimization of the SCPP. In fact, an increase in the power generated is recorded while the height of the roof of the collector is reduced. Since the optimization of the chimney device is characterized by high costs, this document could be a solution to improve the power generated by an existing chimney solar system.

Hassan et.al [2017] In this study, effects of collector's slope and diverging chimney on performance of SCPP were numerically investigated. This study comprised the validation of CFD simulations performed on Manzanares prototype with reported experimental results. The validated CFD approach that incorporates RNG k-ε, solar charge, DO radiation model was used to study the effects of different collector slopes and divergent chimney angles on airflow and heat transfer in the SCPP, with the goal of improving your performance. Numerical results showed that by increasing collector's slope there was a gradual increase in air velocity. But at collector slopes higher than 60, the air flow has not remained uniform and the air return, vortices were detected below the collector due to density gradients formed by uneven temperature distribution, which could block the air from entering the chimney, thus reducing the overall performance of the SCPP.

Mekhail et.al [2017] In this study a very small model of the chimney height of 6 m was installed, the collector diameter of 6 m and the chimney diameter of 0.15 m. The mathematical model, based on the thermodynamic analysis of the flow within the SCPP, was used to predict its performance. The city of Aswan is one of the hottest and sunniest cities in the world. These climatic conditions make the city an ideal place to generate electricity for the Solar Chimney power plant (S.C.P.P). The experimental performances and the theorems calculated by the mathematical model were in good agreement. This model was used to predict the production of a larger model of chimney height 20 m, collector 30 m 2 and chimney diameter of 1 m, which is still under construction. The results revealed that the largest model can produce a theoretical power of about 600 times the smallest. This study helps to select the power of the generator for the largest model.

Zou et.al [2017] In this work, a three-dimensional space acoustic model was established to investigate crosswind and ambient pressure influences on the thermal performance of the solar chimney with hybrid cooling tower. The results of the numerical analysis showed that the autonomous production capacity of the system HCTSC decreased with increasing wind speed, and s reached a minimum at a side wind speed of 8 m / s. If the side wind speed was low (took the heat dissipation capacity of the HCTSC system with increasing wind speed. In strong winds (more than 4 m / s), however, the evacuated HCTSC system gets more heated because of the increased forced convection generated by the cross wind. The higher the cross wind speed, the greater the heat dissipation capacity.

Okoye et.al [2017] The purpose of this paper was to raise awareness that Stacked Solar Power Plants (SCPPs) are a viable and sustainable alternative in rural communities with limited or no access to the grid. The study considered site-

specific hourly meteorological data to assess the feasibility of SCPP in seven selected areas of Nigeria. A theoretical model has been developed for the power output, the electricity cost paid (LCOE) and the avoided CO2 emissions forecasts. In addition, the effects of seasonality on solar radiation, ambient temperature and energy were investigated. The outcomes revealed that the SCPP with a collector diameter of 600 m and a stack height of 150 m on a typical day under Nigerian conditions would yield an average power of 154 to 181 kW. Over a lifetime of 40 years, the cost of electricity is between € 0.216 and € 0.254 / kWh, compared to € 0.563 / kWh for widely used diesel generators, and the annualized decline in CO2 emissions is between 162 and 191 tonnes.

Vieira et.al [2017] This research project aimed to examine the influence of geometrical parameters on the available power of stacked solar power plants (SCPPs) by design. The influence of different soil temperatures (mimicking the effect of different solar influences on the collector device) on the optimal shapes is also appraised. The geometry is subject to three limitations: sensor zones, turbines and chimneys. In addition, three degrees of freedom are taken into account: R / H (ratio between the bend radius and its entry height), R1 / H2 (ratio between the radius and the height of the chimney) and H1 / H (ratio between collector base height and sensor entry height) constant (H1 / H 10.0). The time averaged conservation of mass, momentum and energy equations (RANS) was solved numerically with the finite volume method (FVM). For turbulence modelling, the standard model k e-ε was used.

Cao et.al [2017] in this study, a new solar double chimney power plant (SDCPP) was proposed and analysed so as to improve the safety and effectiveness of the solar chimney power plant (SCPP). It was found that, for an SDCPP with 5MW configuration size, the average temperature rises of the horizontal and tilted solar collectors are 5.64K and 7.87K respectively. The highest wind speeds in the inner chimney and in the interlayer of the inner and outer chimney were 15.28m/s and 19.41m/s respectively. The average annual energy productivity and energy efficiency of the SDCPP was 4.72 MW and 1.2%. The energy productivity of the SDCPP was 1.59 times higher in contrast to the CSCPP and 2.77 times higher in contrast to the SSCPP. By comparing with the CSCPP literature, the SDCPP can increase its energy productivity by 21% to 55%. SDCPP is a auspicious means for generating solar thermal without concentration.

Ghalamchi et.al [2016] In this work, a pilot plant was built to study the temperature fields and obtain new experimental data. The sensor roof was made of 4 mm soda-lime glass and black aluminum foils were applied to the sensor absorber. In this work the temperature and velocity distribution in different pilot sizes and collector materials was described and compared. Lastly, the best condition was achieved and the maximum velocity of the fluid at the inlet of the chimney was 1.7 m / s and the best data with respect to the temperature of the absorber and the fluid were each 353.78 and 329.01 K. It has been noticed that reducing the size of the inlet has a positive effect on the performance of the solar fireplace, but this reduction has an optimum range and this optimum number is 6 cm for this configuration. The diameter of the chimney is the most influential geometric parameter in the performance of the solar chimney.

Hanna et.al [2016] In this research study, they had constructed a experimental setup for ten run days in Aswan, Egypt to appraise the operation of the turbine inside the lantern factory. It has been perceived those ambient temperatures, however, play a vital part in the effect on the production of electricity for solar energy. Most importantly, the efficiency of the solar cooker is proportional to the temperature of the air from solar collectors, especially in the range of 1:00 to 3:00. Based on the result, it can be judged that the rotational speed of the fan can be chosen at 1650 rpm, with the average fan efficiency of 57%. The conclusion is that this digital model is a valid basis for the system to generate solar thermal output and the simulation model can easily be employed to predict the efficiency of any solar exhaust system. The results and results of the test results are good. Finally, the maximum effectiveness of the solar chimney power plant in this study is specified as the high value than it is in previous work according to the site that the study was performing in Aswan, Egypt.

Ohya et.al [2016] In this research, laboratory experiments and numerical analyses (CFD) for a solar tower were performed. The home-model experiments of buildings with a 2-meter-high sun height were used as examples of the reference used. In order to define the finest configuration of the building, they were examining the impact of the open half-hour exposure of the tower and tower towers, at the speed of the written push system. After changing the height of towers and openings with openings, the difference between the temperature between the air and the collection tools, different media has been tested by laboratory and digital analysis. As a result, it has been perceived that the diffuser building with a half-degree openness of 4 ° is the best shape, producing the highest speed in differing temperature, both in laboratory experiments and in analytical calculations.

Mustafa et.al [2015] In this study mathematical and experimental models for circular solar collectors were implemented. The modelling methodology using the conservation equations of continuity, momentum and energy was presented and the solution of the model is obtained using a code developed in the MATLAB program. An experimental model of concentric circles of 8.8 m and

1.0 outside and inside diameters was designed and manufactured to allow the measurement of thermal processes and flow processes in the system. The roof was inclined at 8.5 °. The results perceived that with the same solar radiation the temperature of the air stream, the screen and the ground increases by decreasing the radius. As the inclination of the cap increases, the temperature of the airflow decreases and the temperature of the cap increases for constant solar radiation.

Amirkhani et.al [2015] In this paper, use of artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS) in SCPP modelling had been discussed and the experimental data of the built pilot in Zanjan had been applied. The input parameters of this model were time, ambient temperature and solar radiation, while the only output is the air velocity inside chimney. In order to assess the performance of ANN and ANFIS models, 20% of the experimental data was utilized for model testing. The evaluation of the ANN and ANFIS models indicated the good predictive capabilities of ANFIS model. The most important advantage of the models based on soft computing techniques in comparison with numerical methods was the drastic reduction of the computational cost.

3. CONCLUSION

The experimental and numerical investigation conducted on solar chimney enabled to determine the effect of various design parameters on performance of solar chimney power plant. The performance of solar chimney can be significantly improved by optimizing design of solar collectors, chimney diameter, bend radius and entry height. The power generated by chimney is significantly affected by air velocity inside chimney.

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