Review on Solar chimney performance at different divergence angle

Kuldeep Mishra[1], Shailesh Gupta[2], Rohit Sahu[3]
[1] *Research Scholar, SRIT, Jabalpur (M.P),*
[2] *Professor & Principal, SRIT, Jabalpur (M.P.)*
[3] *Asst. Professor & Head of Department, SRIT, Jabalpur (M.P.)*

Abstract **- The solar chimney power plant system (SCPPS), sometimes called solar updraft tower (SUT), is a renewable energy power plant for generating electricity from solar radiation. The system is composed of four parts: chimney, collector, energy storage layer, and power conversion units (PCU). The main objective of the collector is to collect solar radiation to heat up the air inside. As the air density inside the system is less than that of the environment at the same height, natural convection affected by buoyancy, which acts as the driving force, comes into existence. Due to the existence of the chimney which is erected in the middle of the collector, the cumulative buoyancy results in a large pressure difference between the system and the environment.**

The present review paper considered various previous study to determine the various basic parameters i.e. pressure, temperature, velocity and Turbulent Kinetic Energy to assessment of the SCPPS.

Index Terms **- Solar chimney, Power plant, kinetic energy, etc.**

I.INTRODUCTION

Solar Power Generating Technologies and the Status Quo

The techniques that utilize working fluids or receiving devices to convert solar radiation into electricity eventually by some way are referred to as solar power generation techniques. Currently, there are two main kinds of solar energy generating technologies. The first kind is solar thermal power generation technologies, that is, they convert solar radiation into heat first, and this is followed by a particular power generation process to change thermal energy into electrical energy, such as thermoelectric power generation utilizing semiconductor or metallic materials, thermionic power generation in vacuum devices, alkali metal thermal power generation, and MHD power generation, and so on. The characteristics of these technologies are power generation devices with no moving parts, a relatively small electric generation capacity, and they are still in the primary experimental phase for many technologies. Currently, thermal power generation technologies are issues that are the most interested in, researched most deeply, and the most promising worldwide. Technologies, including solar central power tower technology, parabolic trough solar thermal technology, and dish solar thermal technology use flowing work mediums to convert the solar radiation into thermal energy, and then drive the generator by heat engine to convert the heat energy of the medium into electricity. The basic equipment compositions of these technologies are similar to conventional power generation equipment. Other solar power generating technologies converting solar energy into electrical energy directly are light induction power generation, photochemical power generation, and biological power generation. The photovoltaic power generation technology, which transforms the solar radiant energy into electrical energy through the solar battery, is successfully commercialized. [7]

II-LITERATURE REVIEW

2.1 Background

Despite the continuous increase of the share of the renewable energy sources and their penetration in the global energy distribution, fossil fuels still cover around 66.3% of the total electricity production. In the global market, electricity generation from fossil fuel is expected to continue to play an important role in the international energy mix. However, it has been well established that the existing methods for electricity production from fossil fuels like; coal, oil, or even natural gas are harmful to the environment and bear the limitation that they are bound to diminish as energy sources.

Combining the merits of two renewable energies in one system is a noble and sustainable approach to power generation. Solar chimney power plant SCPP is a system based on this principle. A solar collector heats the air which moves up through a chimney in the middle of the collector. The chimney is provided with a wind turbine that harvests the kinetic energy in the moving air (wind) to produce electricity.

Global installation of a large number of megawatt-size SCP Plants will serve as a major contribution to clean power generation and when combined with innovative new technology such as photocatalyst, it can progressively reduce the concentration of nonCO2 and greenhouse gases. Another implication of this technology is in water recovery and processing. Fresh water generation and sea water desalination are considered. Water can be recovered in a process similar to atmospheric convection as moisture capture in warm air with the help of the extended air-cooling process inside the chimney. Spraying water droplets at the bottom of the chimney has been suggested to enhance the process. Alternatively, in power generating systems most of the water recovery is done by employing high performance condensers. In certain areas, the system can be operated for power and freshwater generation when it is economically scaled to balance water cost against power generation.

2.2 Previous Research

Referring to energy crisis as related to the increasing rate of environmental pollution and limitations of fossil-fuel resources, the use of sustainable energies is inevitable and an absolute necessity for the world. Renewable energies are known for being the best alternative for solving the energy shortage and CO2 emission problems. Among the renewable sources, solar energy plays a significant role due to the accessibility of resources and diversity of energy conversion means. Another significant problem facing the world, besides the energy crisis, is freshwater shortage; this has been the case particularly in the last ten years, and it is expected that the problem will get worse in the next few years. The main reasons for water shortage are weather changes, increasing water consumption, and limited availability of freshwater resources.

Solar chimney (SC) power plants are designed based on converting the solar radiation into kinetic energy and then to electricity. The structure of the solar chimney power plant (SCPP) as denoted by Schlaich for the first time in 1978 consists of a chimney, solar collector, and wind turbine (or turbines). Solar radiation heats up the layer at the base of the collector then the air is heated up by convection from this layer. This convection process causes the air to move inside the chimney due to the density difference between the air inside the collector and the air outside the collector. While the air is moving inside the chimney, it passes through a turbine installed in the chimney base to generate electricity.

Many researchers around the world have introduced various projects or modifications to the conventional solar chimney to enhance its performance, expand its application, or develop or improve simulation models. The thermal efficiency of conventional solar air heaters could be significantly improved by making some design configurations. In this study, (Prakash Parthasarathy, Nugroho Agung Pambudi; 2019) a solar chimney air heater was employed and the effect of glazing, fins and convection (natural/forced) on the thermal efficiency of the heater was investigated. It was found that the incorporation of glazing and fins improved the performance of the heater. Further, the heater showed improved efficiency when operated under forced convection mode. Among the designs, the forced induced glazed solar chimney air heater with fins displayed the highest average thermal efficiency of 16.50 %

Wind energy characteristics include lack of “stability and predictability”. Solar updraft tower, also known as solar chimney SC, is a device in which wind is locally generated by the thermal effects of a solar collector which covers an area surrounding the chimney. In the work carried out by Hardi A. Muhammed, Soorkeu A. Atrooshi; 2019 computational fluid dynamics, is applied to model the heat and transport relations in the collector and chimney area. The geometry, mesh layout and the existing analytical models are verified for consistency against the experimental data of Manzanares plant in Spain. As one of the geometrical parameters such as collector diameter is changed, an optimization process occurs, leading to a decision on the best matching size for the other dimensions.

The process checks the output against the optimized profiles of temperature, velocity and pressure. Based on studying 180 cases in 15 groups for collector size against chimney height and diameter and another 130 cases in 12 groups for collector height, a table and graphs of matching dimensions are obtained. As a consequence of this work, it is possible now to make a more accurate decision on consistent dimensions for a solar chimney plant.

Air motion can be induced in naturally ventilated buildings using passive solar chimneys. The work carried out by Ahmed Abdeen et al; 2019 aimed to optimize solar chimney design to maximize indoor air velocity induced by natural convection, with a particular emphasis on thermal comfort. A three-dimensional, quasi-steady computational fluid dynamics (CFD) model was established for the prediction of buoyant airflow using the renormalization group (RNG) k-εturbulence model.

In order to validate the CFD model, experiments involving an inclined solar chimney attached to a single room were performed. The experimental results agree reasonably well with the CFD calculations, with a 5.14% deviation between the values. Moreover, a Multi-Objective Genetic Algorithm (MOGA) coupled with Design of Experiments (DOEs) and the Response Surface Method (RSM) was employed to derive the optimal solar chimney design for the enhancement of indoor air motion. The optimization results reveal that the maximum indoor air speed in the living zone is achieved using a solar chimney of 1.85 m height, 2.65 m width, 75° inclination angle, and 0.28 m air gap. Sensitivity analyses indicate that solar chimney width is the most influential parameter, followed by inclination angle and then air gap, while the solar chimney height has a negligible effect. The proposed solar chimney is able to passively induce air motion of up to 0.28, 0.47, and 0.52 m/s at mean solar radiation values of 500, 700, and 850 W/m2, respectively. These elevated air velocities are capable of enhancing thermal comfort upper limits by removing sensible and latent heat from the body.

Solar chimneys have the drawback of being unproductive at night. Hussain H. Al-Kayiem; 2018 proposed a hybrid solar chimney integrated with an external heat source to complement solar energy for uninterrupted power generation. Flue-gas channels were utilized to supply air into the collector passage. The hybrid arrangement was investigated experimentally and numerically. An experimental model comprising a 6 m-diameter solar air collector, 6.65 m-height chimney, and four flue thermal channels was designed and fabricated. The hybrid system was further simulated using ANSYS-Fluent. The numerical procedure was validated by comparing with experimental measurements for a conventional solar chimney with mean differences of 8.7% and 7.8% in air flow velocity and air temperature rise, respectively. Results showed that the hybrid approach considerably enhanced the plant performance. The insertion of flue channels, even with no flue-gas flow, enhanced the velocity and temperature by 6.87% and 6.3%, respectively measured at the chimney base. Simulation results with 0.0015 kg/s at 116 °C flue gas in the thermal channels demonstrated that the air-mass flow rate and collector efficiency enhanced by 12.0%, and 64.0%, respectively. This study proved that the proposed technique can resolve the setback of night operation of solar chimney power plants and enable 24/7 power production.

The electric power production using solar chimney power plant is directly related to the velocity value along the chimney. In this work, the effect of the chimney configuration on the solar chimney power plant performance was investigated by Abdallah Bouabidi et al; 2018. A series of numerical simulations were conducted to simulate the turbulent flow. An experimental setup was developed in Tunisia to carry out several measurements. The comparison between the numerical and the experimental results showed a good agreement. The study focused on studying the solar chimney power plants with standard, divergent, convergent and opposing chimney. The velocity fields, the static pressure, the magnitude velocity, and the temperature distribution were presented and discussed. The results revealed that the chimney form affects the air velocity behaviour. The maximum velocity emerges with divergent configuration. However, the other configurations adjust the maximum velocity location, in the chimney centre for the opposing configuration, and in the chimney top for the convergent configuration. This variation is due to the static pressure distribution affected the chimney configuration change.

A new solar chimney power distillation plant (SCPWDP) is proposed and studied in the work carried out by Suhil Kiwan et al; 2018. The plant generates electricity and produces distilled water by direct evaporation of water using the same geometry as the conventional Solar Chimney Power Plant

(SCPP). The novelty of the proposed system is the use of the solar chimney for direct evaporation of water and extracts the energy from the wet air stream. The novelty is achieved by dividing the area of the collector into two sections; in the first section the air is heated, and then it passes over the water that existed in the second section of the collector area carrying with it water vapor.

In this communication, a multi-objective optimization method is implemented using evolutionary algorithm techniques in order to determine optimum configuration of solar chimney power plant (Saeed Dehghani, Amir H. Mohammadi, 2014). The two objective functions which are simultaneously considered in the analysis are power output and capital cost of the plant. Power output of the system is maximized while capital cost of the component is minimized. Design parameters of the considered plant include collector diameter (Dcoll), chimney height (Hch) and chimney diameter (Dch). The results of optimal designs are obtained as a set of multiple optimum solutions, called 'the Pareto frontier'. For some sample points of Pareto, optimal geometric is presented. In addition, effect of changing design variables on both objective functions is performed. This multi-objective optimization approach is very helpful and effective for selecting optimal geometric parameters of solar chimney power plants. The results show that, power output of the plant increases linearly when solar irradiation increases and increase in ambient temperature causes slight decrease in power output of the plant.

The work presented in the study carried out by B. Belfuguais, S. Larbi; 2011 is related to an energy system analysis based on passive cooling system for dwellings. It consists to solar chimney energy performances determination versus geometrical and environmental considerations as the size and inlet width conditions of the chimney. Adrar site located in the southern region of Algeria is chosen for this study according to ambient temperature and solar irradiance technical data availability. Obtained results are related to the glazing temperature distributions, the chimney air flow and internal wall temperatures. The air room change per hour (ACH) parameter, the outlet air velocity and mass air flow rate are also determined. It is shown that the chimney width has a significant effect on energy performances compared to its entry size. A good agreement is observed between these results and those obtained by others from the literature.

III-CONCLUSION

In the present review paper gives a brief study of the solar chimney performance based on previous research papers. The effects of the divergence angle on pressure drop temperature, turbulent kinetic energy and velocity inside the chimney plant of air has been observed. On the basis of previous study.

It is recommended for future work to perform an aero-economical optimization of the solar chimney in order to include the cost of electricity with the power density in optimizing the solar chimney divergence angle.

It is also recommended to investigate and optimize other geometric parameters like the collector shape and chimney radius. An investigation of the effect of the collector geometry on the aerodynamic performance of the turbine is strongly recommended for future work.

REFERENCES

[1] Abdallah Bouabidi, Ahmed Ayadi, Haytham Nasraoui, Zied Driss, Mohamed Salah Abid, Study of solar chimney in Tunisia: Effect of the chimney configurations on the local flow characteristics, Energy & Buildings (2018), doi: 10.1016/j.enbuild.2018.01.049

[2] Ahmed Abdeen, Ahmed A. Serageldin, Mona G.E. Ibrahim, Abbas El-Zafarany, Shinichi Ookawara, Ryo Murata; Solar chimney optimization for enhancing thermal comfort in Egypt: An experimental and numerical study, Solar Energy 180 (2019) 524–536.

[3] Amin Mohamed El-Ghonemy, Solar Chimney Power Plant with Collector, IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)

[4] B. Belfuguais, S. Larbi, Passive Ventilation System Analysis using Solar Chimney in South of Algeria, World Academy of Science, Engineering and Technology International Journal of Mechanical and Mechatronics Engineering Vol:5, No:10, 2011.

[5] Cao F, Liu Q, Yang T, Zhu T, Bai J, Zhao L, Full-year simulation of solar chimney power plants in Northwest China, Renewable Energy (2018), doi: 10.1016/j.renene.2017.12.022.

[6] Hardi A. Muhammed, Soorkeu A. Atrooshi; Modeling solar chimney for geometry optimization, Renewable Energy 138 (2019) 212-223
[7] Hussain H. Al-Kayiem, Mohammed A. Aurybi, Syed I.U. Gilani, Ali A. Ismaeel, Sanan T. Mohammad, Performance Evaluation of Hybrid Solar Chimney for Uninterrupted Power Generation, Energy (2018), doi: 10.1016/j.energy.2018.10.115
[8] P.J. Cottam, P. Duffour, P. Lindstrand, P. Fromme, Solar chimney power plants – Dimension matching for optimum performance, Energy Conversion and Management 194 (2019) 112–123
[9] Seyyed Hossein Fallah, Mohammad Sadegh Valipour, Evaluation of solar chimney power plant performance: The effect of artificial roughness of collector, Solar Energy 188 (2019) 175–184
[10] Shi, Guomin Zhang, Wei Yang, Dongmei Huang, Xudong Cheng, Sujeeva Setunge, Determining the influencing factors on the performance of solar chimney in buildings Long, Renewable and Sustainable Energy Reviews 88 (2018) 223–238.
[11] Omar A. Najm, S. Shaaban; Numerical investigation and optimization of the solar chimney collector performance and power density, Energy Conversion and Management 168 (2018) 150–161
[12] Omer Khalid, Ahmed and Abdullah Sabah Hussein, New design of Solar Chimney (Case study), Case Studies in Thermal Engineering
[13] P. Parthasarathy, N.A. Pambudi, Performance study of a solar chimney air heater, Case Studies in Thermal Engineering (2019), doi: https://doi.org/10.1016/j.csite.2019.100437.
[14] Saeed Dehghani, Amir H. Mohammadi; Optimum dimension of geometric parameters of solar chimney power plants – A multi-objective optimization approach, Solar Energy 105 (2014) 603–612
[15] Suhil Kiwan, Moh'd Al-Nimr, Qamar I. Abdel Salam, Solar chimney power-water distillation plant (SCPWDP), Desalination 445 (2018) 105–114
[16] Toghraie D, Karami A, Afrand M, Karimipour A, Effects of geometric parameters on the performance of solar chimney power plants, Energy (2018), doi: 10.1016/j.energy. 2018.08. 086.
[17] Vargas-López R, Xamán J, Hernández-Pérez I, Arce J, Zavala-Guillén I, Jiménez MJ, Heras MR, Mathematical models of solar chimneys with a phase change material for ventilation of buildings: A review using global energy balance, Energy (2019)
[18] Fluri TP, Pretorius JP, Dyk CV, von Backström TW, Kröger DG, van Zijl GPAG. Cost analysis of solar chimney power plants. Solar Energy 2009; 83:246–56.
[19] Bernardes MA dos S. Technische, ökonomische und ökologische Analyse von Aufwind-kraftwerken PhD Thesis Universität Stuttgart; 2004 Schlaich J, Bergermann R, Schiel W, Weinrebe G. Sustainable electricity generation with solar updraft towers. Struct Eng Int 2004;14: pp. 225–9.