Research Journal of Engineering Technology and Medical Sciences (ISSN: 2582-6212), Volume 05, Issue 01, March-2022
Available at www.rjetm.in/

Solar Chimney Power Plant Designs: An Analytical Review

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Abstract: *Abstract: The use of solar energy today is also necessary and important. Chimney solar power generation technology is one of the solar energy harvesting techniques where direct and diffuse solar radiation is absorbed into the solar chimney power plant. The efficiency of solar chimney has been demonstrated for power generation and is a promising approach for future power generation plans. This article provides a comprehensive scenario of solar technology research and development, as well as the history of solar chimney over the past few decades.*
Keywords: *Renewable energy, Solar chimney, Solar collectors, Energy conversion*

I. Introduction

The energy consumption trend has been very quick and drawing deep attention in the recent years. The trend in developing countries, and especially in Iran, is much higher than the global average. One accepted fact for human societies is that the world's need for energy is growing rapidly, and cheap fossil energy sources are slowly but certainly will be exhausted over the next several decades. To keep these valuable fossil fuel sources for future generations, to prevent environmental damage caused by burning these fuels and to meet the increasing demand of energy, there is no way, except turning toward the use of clean and renewable energies [1]. Renewable energy sources provide approximately 13.3% of the total energy needs of the world. As a result, over the years, many scientists have been working on research and development of this kind of energy. The main reasons of those activities can be explained by factors such as warming up the earth, an increase in the prices of the energy carriers and the decline in fossil fuel reserves. Researchers fnd that pollution resulting from the production and the use of fossil fuels is the primary reason for global warming [2]. Undoubtedly, in the near future, the production of electrical power from renewable energy could be one of the most important and fundamental methods. The solar chimney power plant is a relatively new technology for power generation from solar radiation. Solar chimney power plantsare simple thermal power plants that can convert solar energyto thermal energy in the collector and transform it to mechanical energy in a turbine.

Solar chimney power plant also named solar updraft tower power plant is a natural generator of power using solar radiation process to increase the internal energy of the air flow, which can be transformed into electric power by meansof a suitable turbine. This technology can be used for electricity production on large-scale, at low-cost and withoutcarbon dioxide (CO2) and other greenhouse gas (GHG) emissions. It consists of the collector, the chimney located atthe center of the collector, and the turbo-generator. Thecollector is composed of transparent cover and tubes of waterin heat storage case and the ground beneath the transparent cover. The tubes filled with water are covered a plastic sheet to avoid evaporation. The solar radiation crossing through thecollector roof and striking the ground surface beneath it induce the heating of the lower surface of the collector (waterand ground storage) and the increasing of air temperature inside the collector. The hot air underneath the collector flows through the chimney tower under the buoyancy effects. The kinetic energy of the airflow is then converted into mechanical energy via wind turbines located at the entrance of the chimney by rotating the generator to produce electric power.

Since the fundamentals researches of Schlaich [1] in the solar chimney field, considerable efforts were made in analyzing their performance in order to prove their feasibility and profitability. The important studies [3] on solar chimneys fields are applied to drying process, ventilation or productionof electricity systems, and in these last decades, they are focused mainly on the optimization of the design of these

systems by the maximization of the produced power and the minimization of the cost of the installation. About the theoretical and experimental studies, relating to the performance of solar chimney power plants (SCPP) led theselast years: for the experimental ones, it should be noted that they are practically focused on the Mansanares prototype; for the fundamental studies, carried out by [3], the authors have presented a short discussion on energy balance, criteria of design and cost of the system and energy production analysis. The experimental prototype of a solar chimney power plant was realized and tested in Manzanares, Spain, in the 1980s. [3]

Fig.1. Solar chimney power plant in Manzanares

Since then, several works were performed on solar chimney power plants [4]. The experimental ones are based essentially on the data gotten at Manzanares prototype. During the production of the useful energy system, the energy conservation is among one of the most important goals. This is why the study of the second law of thermodynamics is of great importance. Indeed, minimizing the generation of entropy improves heat transfer and consequently increases the efficiency of energy use [5].

The analysis of the problem presented in this paper is corresponding to energy calculation, for the prediction of the performance, such as the electric power delivered by a solar chimney power plant (SCPP), according to some geometrical and physical parameters, such as the collector radius, the height and the diameter of the chimney tower and the solar radiation. The approach undertaken in this paper is related mainly, to the analysis of a solar chimney power plant with heat storage system to ensure the continuity of electricity production during all the time.

The solar storage system is designed to generate hot air under the roof of the greenhouse sensor. The heated air rises through the buoyancy through a high structure in the middle of the sensor, called the solar chimney. The hot air drives during the ascent an air turbine that is arranged in the chimney to produce electricity. A typical example of the configuration of a solar chimney is shown in the following figure 1.

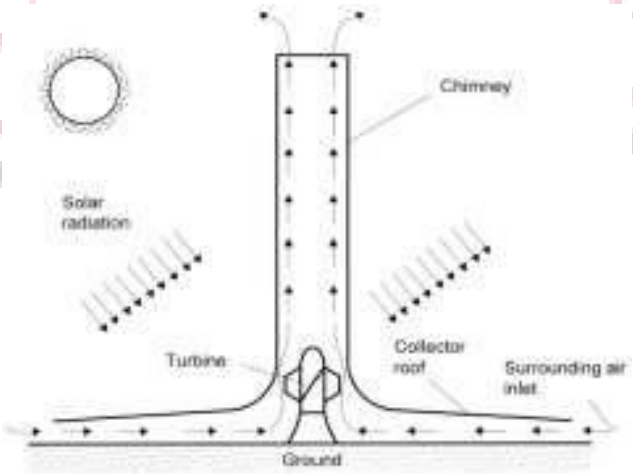

Fig.2. Solar chimney power configuration

II. Related Work

Ehsan Gholamalizadeh et al. [2] presented CFD on a solar collector with a slanted collector roof. A three-dimensional model using RNG (normalization group) -K turbulence closure is simulated. The non-gray discrete ordered radiation pattern is used to implement the radioactive transfer equation. To simulate solar radiation, the solar ray tracking algorithm is used. The results showed that the variations in the pitch of the collector influence the convection model through the collector, causing an increase in the mass flow of the system.

Aakash Hassan, Majid Ali & Adeel Waqas [4] studied CFD analysis of a solar power plant to illustrate the effects of the inclination of the sensor and the cutting angle on the performance of the Manzanares prototype. The numerical models were constructed with solar charge models, DO (discrete ordinate) and RNG k-3 turbulence. First, the CFD simulation results were validated by comparing the experimental data of the Manzanares prototype. Thus, based on the robustness of the numerical methods applied, several numerical simulations have been made with different inclinations of the deflection angles of the collector and of the chimney to improve the performance of the solar chimney.

Ahmed Ayadi al el. (2018) [5] studied and optimized the properties of a solar power plant (SPP) in a numerical and experimental way. The numerical simulation is performed with the commercial code "CFD" "Ansys Fluent 17.0". An experimental SCPP device is being developed at the Sfax National School of Engineering, Sfax University, Tunisia, North Africa. The results confirm that the height of the sensor roof has a great influence on the optimization of SPP. In fact, an increase in the power generated is recorded while the height of the sensor roof is reduced.

Siyang Hu and Dennis Y.C. Leung Focus [6] studied CFD for improvement in the production of SCPP with divergent chimneys. In this work, a mathematical model was created to analyze the hydrodynamic characteristics of a series of divergent chimneys in a cathodic protection layer. The result of the mathematical model was compared to that of the CFD simulation to evaluate the validity and performance of this model. Subsequently, parametric studies were conducted with this mathematical model.

Ehsan Gholamalizadeh & Man-Hoe Kim [7] presented a study of dynamic numerical calculation of fluids on a solar chimney system with inclined roof. A three-dimensional model that uses the turbulence closure R_G (normalization group) k_ε is simulated. In this approach, the height of the roof is adjusted by increasing the height of the outlet manifold, while the height of the intake manifold is adjusted to the height of the Manzanares solar chimney pilot manifold

III. CONCLUSION

According to the studies and the items mentioned in this article, it is obvious that since 30 years many studies have been carried out on the solar chimney power plants; so naturally, there are still some dimensions of the subject that remain unknown. Hence, the present researchers are suggesting to fulfil the research gaps in this field. Further development of studies and reviews on the construction and installation of the solar chimney power plants in the future.

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