Modeling solar chimney for geometry optimization

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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 this work 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 other 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.

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1. Introduction and the review of previous work

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 [1,2]. 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. [John Twidell, [36]].

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 SCPP 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 non-CO2 and greenhouse gases [3]. 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 fresh water generation when it is economically scaled to balance water cost against power generation [4–6,34].

An additional application of SCPP is for food drying. As the airflow inside the collector increases towards the center higher values of velocity and temperature are obtained. The emphasis for combining the food drying process with power generation in the SCPP is on reducing the drying losses. The tests confirmed the feasibility of SC as food dryers for agricultural products [7,8].

The SCPP system is a solar thermal power plant that is simply capable of converting solar energy into thermal energy in the solar collector. In the second stage, the generated thermal energy is converted into kinetic energy in the chimney and ultimately into...