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# Study of Influence of Size parameters on power output in Chimney Operated Solar Power Plant

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**Abstract:** *Solar chimney power plant can be a major source of power generation. It consist of three simple parts: chimney, collector and turbine. The power output of this power plant depends on size of chimney and collector. The main objective of this study is to verify that how much power can be produced if the size of chimney and collector increase from minimum to maximum theoretically. A small prototype model of solar chimney power plant is fabricated to verify this. Power output is calculated by considering the specific size of this prototype and accordingly the calculations are done for the larger size. The result indicates that larger the collector diameter and chimney height higher the power output of the chimney power plant.*

***Keywords:*** *Chimney, Collector, Turbine, Power output, Prototype,*

## I. Introduction

The conventional energy sources like coal and petroleum products are depleting day by day. There is also restriction to use this sources in a larger extent because of their effect on environment and on our health. Use of nonconventional energy sources like solar and biomass is a need of this era. Solar energy is a source of energy which is available in large extent but not explored much. There is a requirement to use these sources in the area like power generation to generate electricity in very chipper rate. Solar chimney power plant is one of the old source of electricity generation from solar energy with the use of simple parts like chimney, Turbine and collector. The first experimental power plant was setup in Manzanrus Spain in 1981 with the collaboration with German ministry of research and technology. The tower height was 194.6 m and collector radius was 122 m. The plant run for nearly four years and given power output of 50 kw [1].

Many researchers had done the study on solar chimney power plant with Manzanrus power plant as reference. W. Haaf et el. [2] done the fundamental invitations into solar chimney power plant. He presented the principle of this plant in the form of simple estimates. He concluded that economical power generation is possible with large scale plants up to the power capacity of 400MW.He also provided many design features of Manzanrus pilot plant. W Haaf [3] communicates preliminary test results from the Manzanares pilot plant. He presented various values of energy balances, collector efficiency, pressure losses due to friction and losses in the turbine section by maintaining 24-hour records of each parameter. The findings of Haaf agree with model calculations. L.B. Mullett [4] has done the analysis of solar chimney for its overall efficiency, design and performance. He concluded that overall efficiency is directly related to the height of chimney. He also state that there is not efficient scale for small units of solar power plants .N. Pasumarthi et el.[5],[6] performed the study of solar chimney power plant theoretically and experimentally. A mathematical model was developed to study the effect of various parameters such as air temperature, air velocity and power output. He also predicted that the power output of a solar chimney is directly proportional to the product of temperature differential attained in the collector and the mass flow rate of air. He also state that The temperature inside the collector can be increase by increasing collector area, The mass flow rate can be increase by increasing the height of chimney. Tahar Tayebi et el.[7] conducted detail numerical analysis of collector of solar chimney. A mathematical model based on Navier-Sokes, Continuity and energy equations was developed for determining solar chimney collector mechanism. The iterative method was used to solve basic equations. The results were compared with Manzanares prototype there was a good agreement between two .Hussain H. Al-Kayiem et el. [8] predicted the behavior of roof top solar chimney during the day time for proper designing and sizing. He simulated the fluid flow and thermal energy processes mathematically using mass balance and energy. He converted the model to a mat lab computer program and solved it by iteration method. The analysis was carried out at various chimney height and collector areas. P.J.Cottam et el. [9] presented a steady state analytical model for describing the thermodynamics of the solar collector. He predicted that height of the canopy has significant effect on the plant performance and that the canopy must be sufficiently high at the junction with the chimney to ensure maximum kinetic energy in the flow at the chimney inlet can be reached. For ease of construction and reduction of cost the canopy was built in stepped annular flat sections and there was minute loss in the performance of solar chimney .Atit Koonsrisuk et el.[10]In this paper provided the modeling of solar chimney, collector and turbine collectively. He validated the results by comparing with the actual physical plant. He predicted that the plant size, the pressure drop at turbine and solar heat flux as important parameters for enhancing the performance of solar chimney. He also predicted a simple method to evaluate the turbine power output. Kai Chen et el.[11] done the thermodynamic analysis of low temperature waste heat recovery system based on the concept of solar chimney. Here waste heat is used to heat air to produce an air draft in chimney. The heat source temperature, ambient temperate and area of heat transfer are evaluated. The velocity of air provides more stability than mass flow rate. Mehran Ghalamchi et el. [12] performed the experimental study of geometrical and climate effects on the performance of a small solar chimney. He designed a solar chimney pilot power plant with 3 m collector diameter and 2 m chimney height in Iran. He found the maximum air velocity of 1.3 m/s and collector air velocity nearly zero.Y.J.Dai et el.[13] performed case study of solar chimney power plant in China. He analyzes the parameters such as chimney height, ambient temperature, and solar irradiance on the power generation. Saeed Dehghani et el.[14]communicates multi objective optimization method using algorithm techniques for determining optimum configuration of solar chimney power plant. This optimization approach is very helpful for the selection of optimal dimension parameters of solar chimney power plant. The result shows that with the increase of solar irradiation, power output of the plant increases and it slightly decreases with increase in ambient temperature. Fei Cao et el.[15] provides heat transfer model which is used to compare the performance of solar chimney power plant. He also analyzed the power generation from solar chimney at different latitude in China. He also predicts that the main parameters responsible for the performance of solar chimney are chimney height and thermo physical characteristics of flowing air.

## II. System description and working principle

A solar chimney power plant is heat conversion system consist of green house type solar collector made of glass or plastic material. It size is large in the range of 100 to 500 m diameter or more than that. It is supported on metal or Iron support and sloped at some specific angle to create heated air draft. Chimney is supported exactly at the center of the collector. It is larger in height which varies from 500 to 1000 m. Chimney can be made from metal or concrete as per requirement. At the base of the chimney and inside the collector there is a location of generator. Generator can be located with its axis parallel or perpendicular to the axis of chimney. If its axis to be parallel to the axis of chimney then it is located axially. If it is required that its axis are perpendicular then it is located in more than one quantity along the periphery of the collector.

When the heated radiation incident on the surface of collector they are get absorbed by the collector because of their high heat intensity. The air inside the collector gets heated. This heated air rises up due to density difference of inside and outside air of collector. A buoyancy effect get created and chimney direct this heated air from its inlet to out let creating high air draft .Because of this high air draft the collector get activated and rotate its blade and the generator coupled to it generates electricity.

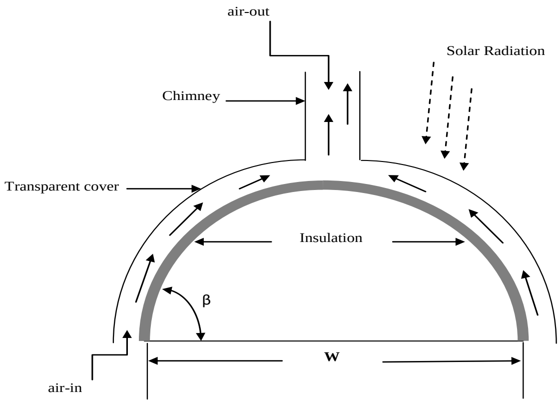


Fig. 1 Working Principle of Solar Chimney

The performance of solar chimney power plant depends upon many factors. The material used for making of collector, chimney materials, height and diameter of chimney, diameter of collector and generator use for converting rational energy into electric energy. The theoretical modeling is performed by using correlations which connects various parameters of chimney collector and turbine. The factors such as power, pressure drop and efficiency are calculated using various imperial relations.

**Solar Chimney**:

Solar chimney is works as a thermal engine of chimney power plant. Because of high surface to volume ratio there is less friction loss from inlet to out let. The efficiency of the chimney practically

independent of the increase of air temperature inside the collector. The efficiency is find by the ambient temperature at bottom surface of chimney and total height of chimney.
The efficiency of chimney is given by

$$\eta\ chimney= (g\ H_C)/(C_{PA}T_{AB}) \quad (1)$$

g- Gravitational force
$H_c$ - Chimney Height
$C_{PA}$ - Specific Heat
$T_{AB}$ - Ambient Temperature

**Solar Collector**:

The solar collector acts as a heat storage of power plant. It is a device which create temperature difference at inlet and outlet. The amount of heat generated is depends on the solar radiation incident on the collector. The heat generated inside the collector is given by

$$\eta\ coll = \alpha - U\Delta T/G \quad (2)$$

α - Coefficient of thermal expansion
U - Overall heat transfer coefficient
G - Global radiation Incident on the collector at specific region
ΔT - Temperature difference at inlet and outlet

The mass flow rate inside the collector is given by

$$M= \rho_C\ A_C V_{CI} \quad (3)$$

$\rho_C$ - Density of Collector
$A_C$ - Area of Collector
$V_{CI}$- In let air Velocity

The pressure difference between chimney base and surrounding is given by

$$\Delta\ Pt = (\rho_C*g*Hc*\Delta T)/T_{AB} \quad (4)$$

$\rho_C$ - Density of Collector

g- Gravitational Force
$H_c$ - Chimney Height

**Turbine**:

Turbines are the devices which are placed inside the collector and bellow the chimney. Air updraft which is generated due temperature difference and density difference when pass over the blades of turbine, it rotates the blades of turbine. as the turbine works as cased pressure staged wind Turbo generator , the static pressure is converted to rotational energy of the blade. The maximum power generated by the turbine is given by

$$Pwt_{max} =( 2* \eta\ chimney* \eta\ coll*A_{COLL}*G)/3 \quad (5)$$

The maximum inlet velocity generated inside the turbine is given by

$$Vc_{\ max} = ((2*g*H_c*\Delta T)/T_{AB}))½ \quad (6)$$

If this power is multiplied by the efficiency of the turbine then it generates electrical power from chimney to the generator.[1],[2],[3],[13].

## III. Various size parameters considered AND POWER OUT PUT

For determining the effect of various size parameters on the efficiency of Turbine The size parameters like chimney height and Turbine are considered and using the equations from (1) to (6) The values of Power output of Turbine is determined. Some values like global radiation, specific heat, Ambient temperature, Coefficient of thermal expansion, Overall heat transfer coefficient are considered for the specific location where the experimental setup of solar chimney power plant is to be made. The values determined shown in table.1

TABLE-1

| S.N | Chimney Height(m) | Collector Diameter(m) | Power output(w) |
|---|---|---|---|
| 1 | 2 | 4 | 0.08235 |
| 2 | 5 | 6 | 0.4633 |
| 3 | 10 | 8 | 1.6473 |
| 4 | 15 | 10 | 3.86109 |
| 5 | 25 | 14 | 12.6122 |
| 6 | 50 | 24 | 74.133 |
| 7 | 100 | 44 | 498.338 |
| 8 | 200 | 84 | 3632.521 |
| 9 | 500 | 204 | 53561.167 |
| 10 | 1000 | 404 | 420128.777 |

## IV. RESULTS AND DISCUSSION

For determining the effect size parameters on the power output of the turbine ,the graphs are drawn which are given below.

1) Chimney Height Vs Power out put

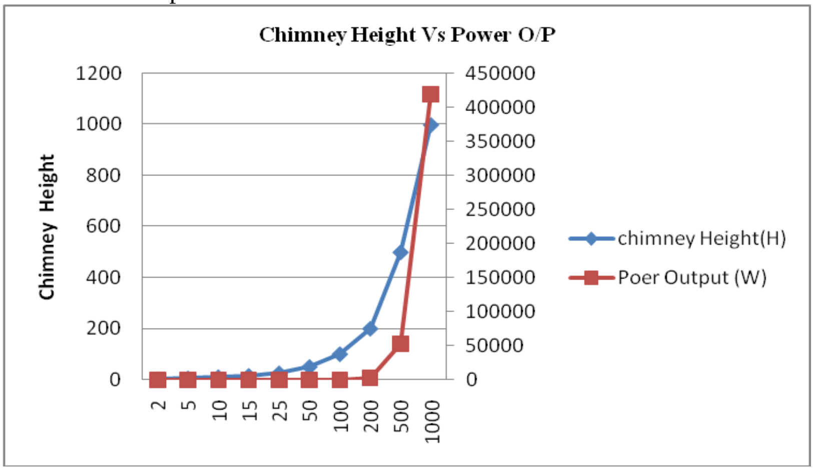


Fig. 2 Chimney Height and Power output

Fig.2 Indicates the variation of out put power output along with the power generated by the turbine.

2) Collector Diameter Vs Power Output.

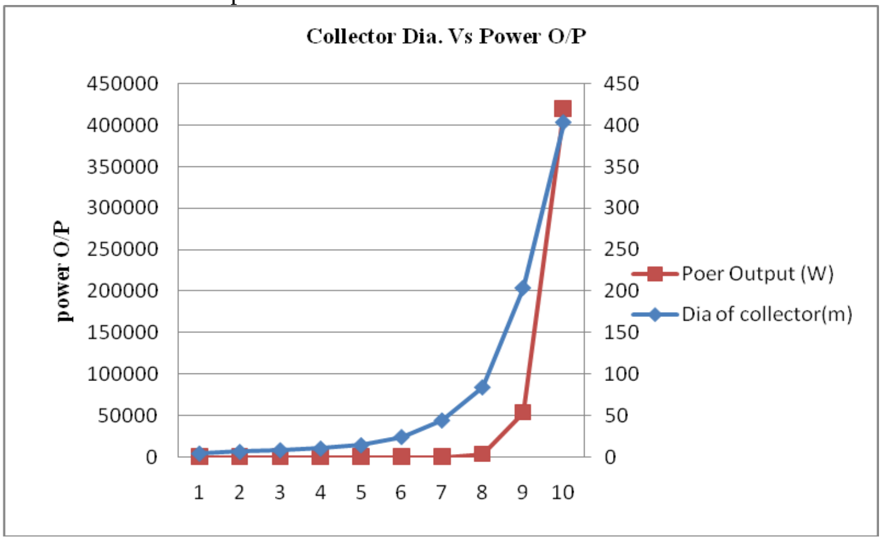


Fig.3 Collector Diameter and Power out

Fig. 3 Indicates the variation of power output with diameter of the collector which calculated from the mathematical modeling discussed in section III.

## V. CONCLUSION

For simulating the power output to be generated by the turbine The mathematical modeling of chimney, Turbine and collector is considered some basic sizes of chimney and turbine are considered as per the size considered in the pilot plant of Manzanrus Spain as a reference plant. The values of various power output are calculated and graphs are plotted. Following conclusions are drawn from the plotted graphs.

1) Chimney diameter and Collector diameter are responsible for increasing the Power output of the turbine.
2) The efficiency of Turbine can be Increase by increasing Chimney Height and Collector Diameter.
3) Power output and chimney efficiency are closely related with each other. By multiplying Turbine efficiency with efficiency of turbine electrical power can be transferred from grid to the turbine.

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