

# A Review on Energy Generation Using Draught of Wind Induced By Solar Chimney

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**ABSTRACT:** In the recent years there has been a very wide gap is felt between energy production and against energy demand. By principle, energy creation is not possible but it is interchangeable. For meeting the power demand many power plants were installed and operated by using various types of energy resources. The power plants using nuclear energy poses problems relating to hazardous handling of working medium and complexity in converting the energy in usable form. An increasing proportion of the future energy demand will have to be met in the form of electricity. Renewable energies can satisfy more than the half of the global primary demand by the middle of next century. In long term view and to realize the full potential of natural forms of energy, it is essential to invent the techniques of tapping them and making the components of the system eco friendly, more efficient, easily adaptable.

In this paper an attempt has been made to introduce solar power generation system for generating electricity by using renewable energy resources. We introduce a solar chimney power generation system for house hold uses by installing it on the roof of our houses. The concept is creating the temperature difference in the medium (Air) and allowing it to pass through the nozzle converting the pressure energy into kinetic energy leading to the rotation of the wind turbine on its way.

Due considerations are given to the following parameters as they are influencing the operating conditions of the system:

Area under sun, availability of sun lighting, costing, technology. The overall behaviour shall also depend on the velocity of wind, sun exposure, population and economy as commercial factors.

**KEYWORDS:** Energy need, wind energy, solar energy, renewable power generation, IR-Incident Radiation, SCPP-Solar Chimney Power Plant.

## I. INTRODUCTION

Ever increase in fuel shortage and prices promoted the interest in the adoption of alternative fuel. Many researchers experimented with wide range alternate fuels [6], [7-16] and technologies [4] and invented successfully. Many researches improved the performance of the system and implemented the technologies in mobility applications [5]. Use of solar energy get high popularity in all kind of applications like heating water, agricultural applications and wind mill generated power for pumping water etc. Man learns to make active use of solar energy at a very early stage like geo thermal energy. Factors used in the tapping of solar energy and carried out energy related activities in olden times are essentially combined in the solar chimney power plant. Conventional glass roof collector, chimney and wind turbine that forms a solar chimney power generation unit. These kinds of units will be very much useful during energy crisis periods.

The concept of solar chimney power plant resembles to room cooling of house through natural air circulation. The principle of SCPP is based on of thermo-syphon effect caused by solar heating of air within a glass roof collector. Thus, the basic components of SCPP are glass roof collector, chimney & wind turbines. It has got a tall chimney at the center of circular glass cover. Sun rays heat the air inside chimney & outside cold air. It creates an air circulation through the system. The kinetic energy of air is thus utilized to drive wind turbines & generates electricity. The entire process can be subdivided into heat input to air, up draughts & power output. During night hours, the plant can be operated with the stored energy from the solar source. The heat energy collected during the day time, stored & supplied through suitable heat transfer systems ensures night time operation of SCPP. It is evident that system is very simple & has no moving parts expect the turbines & water pumps for night time operation. If the pressure take-off at the turbine is increased, the air mass through flow reduces and the temperature in the collector rises. This results in an increase in the surface temperature of the collector cover and resultant thermal losses due to IR emissions and convection losses. Pressure take-off at the turbine and temperature determine plant output to varying degrees. Thus for each power output there is an optimum pressure take off.

The thermal analysis and design of solar chimney plant needs optimization of combined day time and night time operation of the solar chimney power generation systems. The following sections deal with the plant analysis for day time and night time operation separately and the discussions on the plant optimization for round the clock operation.

**Parts of Solar Chimney Power Generation System:**

**1) The solar collector:-**

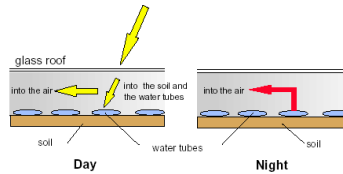


Fig. 1: principle of heat storage underneath the roof using water filled black tubes

The collector is a simple air heater enclosing the air between the glass cover and ground. The incident radiation passes through the cover and heats the air as well as ground. The ground acts as heat storage medium and dissipates energy over a long period thus utilizing both direct and diffuse radiation for the purpose. The hot air moves radially inward to the base of the chimney where wind turbines are placed circumferentially. Cover material and areas of the collector plays vital role in determining the efficiency and economical working of the plant.

The first comprehensive experimental studies on a commercially exploitable solar chimney power generation system were carried out during the period from 1981 to 1989 in Manzanares (Spain) (1995).

Correlation factor for efficiency of collector for various collector materials has been formulated.

S. NO.	TYPE OF COLLECTOR	COLLECTOR EFFICIENCY
1.	White glass Double Glazing	$0.66 - (R_{col} - 400) / (440 * 100)$
2.	Green Glass Double Glazing	$0.633 - (R_{col} - 400)(0.633 - .585) / 2200$
3.	Green glass Partial Glazing	$0.585 - (R_{col} - 400)(0.585 - 0.53) / 2200$
4.	White glass Partial Glazing	$0.505 - (R_{col} - 400)(0.505 - 0.539) / 2200$

**Chimney:**

Chimney creates the necessary draught for air circulation. It is the difference of weight of air inside & outside of chimney for the same column of height that produces the pressure difference for circulation.

$$\text{Efficiency of chimney} = g * H_{ch} / (C_{pa} * T_{amb})$$

Chimney efficiency depends only on the height of chimney & ambient temp. Berger Mann (1997) has predicted height of chimney for various power output of the plant. The chimney profile is considered as tapered in order to reduce the losses.

**Wind Turbine:**

Wind turbine converts the kinetic energy of air and pressure difference across the turbine into useful mechanical work, which then converts to electrical energy by generators. The turbine is basically of propeller type arranged circularly at the base of the chimney. The dimensions are fixed hence limits the minimum radius at which the turbines are kept horizontal and a radial space of about one diameter of chimney is provided for accommodating gear boxes, generator, etc.

Turbine power o/p,

$$p = \text{Efficiency of generator} * \text{Efficiency of turbine} * \text{Difference of pressure} * \text{Volume of turbine} * \text{Area of turbine.}$$

**Pressure loss:**

The major losses in chimney are identified as entry loss, exit loss, chimney friction loss and collector friction loss and bend loss.

$$\Delta p_{loss} = \text{collector friction loss} + \text{chimney friction loss} + \text{bend loss} + \text{exit loss} + \text{entry loss}$$

$$= \Delta p_{col} + \Delta p_{ch} + \Delta p_{bend} + \Delta p_{exit} + \Delta p_{entry}.$$

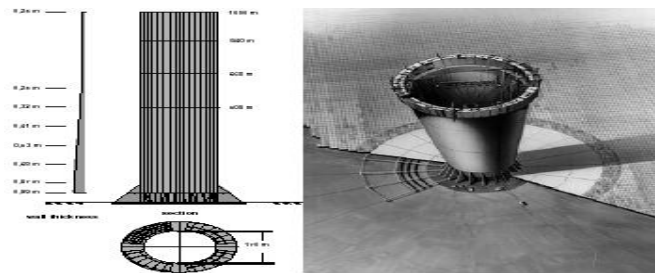


Fig.2: Wall thickness of a chimney tubes

Thermal Design of the Plant (Day Time Operation):

The design is to find the radius of the collector so that an output of 220 MW is obtained.

Table for technical and meteorological input data.

S.NO.	PARTICULARS	DATA
1	Average global solar radiations( $W/m^2$ )	689
2	Average ambient air temperature ( $^{\circ}C$ ) day	26.5
3	Average ambient air temperature ( $^{\circ}C$ ) night	23.5
4	Chimney height (m)	1000m
5	Turbine type	Propeller
6	Turbine diameter	25m
7	No. of turbines	36
8	Location of turbines	$2 D_{ch}$
9	Mechanical efficiency (%)	80
10	Generator efficiency (%)	96
11	Collector height at turbine position(m)	25.5
12	Collector height at outer periphery(m)	7.5

Optimization of Plant (Day Time Operation):

An appropriate software program has been developed to obtain radius of collector and simultaneously optimizing various parameters of the plant in order to reduce the losses.

$P$  (actual power produced) = 220 MW

With optimized computer model of solar chimney power plant, effect of other parameters namely –collector outer height, chimney diverging angle, ambient temp and chimney height on the radius of collector and losses are simulated.

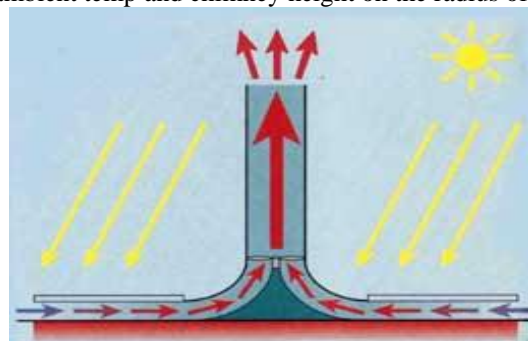


Fig.3: Day time operation of the solar chimney power generation system

**Results and Discussion (Day time operation):**

A preliminary thermal design with straight chimney and using solar and climatologically data of the selected site suggests that about 17 % of the total draught produced wasted through various losses. The overall efficiency of the plant was about 1.24 %. Some of the parameters that effects the design and its performance significantly are chimney diverging angle, air temperature rise , height of chimney, ambient temp, collector height and chimney diameter.

**Effect of change in diverging angle of chimney:**

With increase in diverging angle, there is reduction in radius of collector but the rate of reduction is negligible after 10 degree, because of constructional difficulty, the diverging angle is restricted to 6 degree.

- Reduces exit loss by 85 %

- Reduces bend loss by 20 %
- Reduces chimney friction loss by 85 % and
- Reduces collector friction loss by 20 %

**Effect of change in air temperature rise:**

With increase in temp rise, radius of collector reduces at a greater rate initially. An increase of temperature rise from 25<sup>o</sup> c to 35<sup>o</sup> c leads to

- Exit loss reduction of 67.2 %
- Entry loss reduction of 60 %
- Bend loss reduction of 67.2 %
- Chimney friction loss reduction of 65 %, collector friction loss reduction of 67 %.

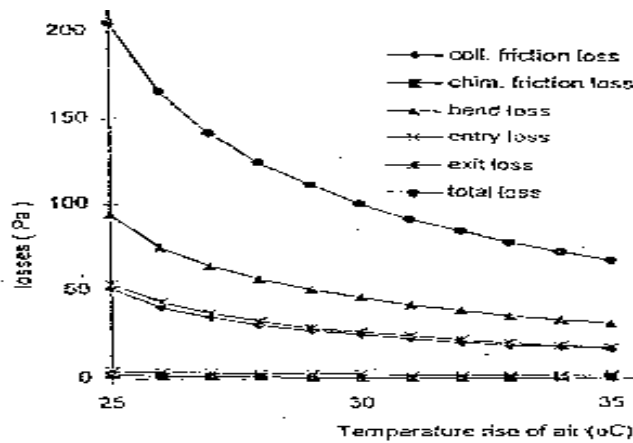


Fig.4: Reduction in losses with temperature rise of air

**Effect of Ambient Temperature:**

With the ambient temperature rise, average air velocity in the collector increases leading to a linear rise in the total pressure loss. However there may be reduction in convective heat loss from the collector to the environment. The air draught generation descends because of lesser density differences between the column of hot air inside and outside of chimney. This adversely affects the power o/p of the plant.

Proportion of	Solar chimney Pf/kWh	Coal Pf/kWh	
Investment	11.32	3.89	2.12
Fuel	0.00	3.87	6.57
Personal	0.10	0.78	0.31
Repair	0.52	0.92	0.83
Insurance	0.01	0.27	0.12
Other running costs	0.00	1.16	0.03
Tax	2.10	0.69	0.37
Total	14.05	11.58	10.35
Commissioning in 2001 Power : 400 MW Running hours : 3445 h/s Yearly energy : 2979 kWh		Own investment 1/3 at 13.5% External investment 2/3 at 8% Total interest rate 1D, 67% Tax Rate : 30%	

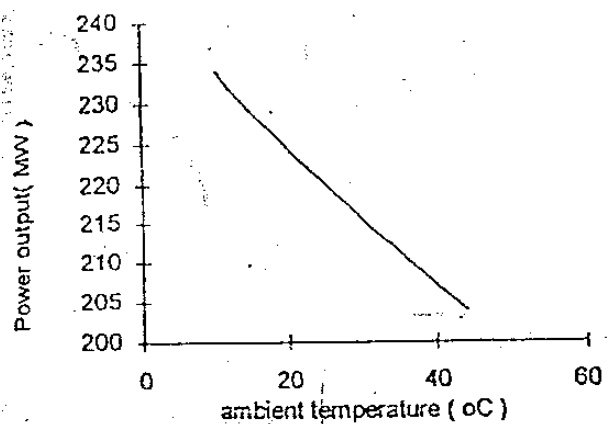


Fig .5: Reduction in power output with rise in ambient temperature

**Effect of Increase in Chimney Diameter:**

Increase in chimney diameter, reduces the radius of collector .however the reduction is marginal after 24.2 meter of chimney diameter with the assumption of 6<sup>o</sup> diverging angle and 1000 meters height of chimney. A change of chimney diameter from 15.5 meter to 24.2 meter reduces the collector area by 2.7 %.

And also,

- collector friction loss =22 %
- exit loss=75 %
- chimney friction loss=84 %
- bend loss =61.2 %
- entry loss =1.835

**Effect of Increase in Collector Outer Height:**

1. An increase in outer height of the collector from 7.5 to 9.5 m reduces radius of 10m.
2. Among the losses ,entry and collector friction losses are influenced more because of reduction in the inlet air velocity

**Effect of Increase in Chimney Height:**

Efficiency of the plant increases; chimney diameter and collector requirement reduces constantly considered at day time. Two solar chimneys with 200 MW each and 400 MW coal and combined cycle power plants according to the present business managerial calculations.

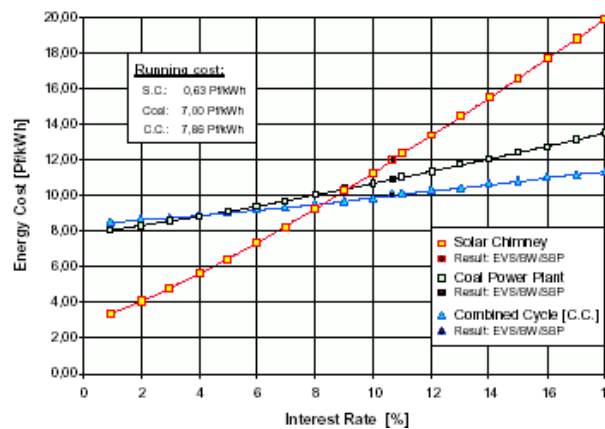


Fig.9: Energy production costs from coal, combined cycle, power plants and solar chimneys depending on the interest rate.

**Thermal System for Night Operation:**

Operating the plant for round the clock will improve its use factor and reduce generation cost. However, night time operation will require heating of air through some extended means. Tijare and Majumdar carried out detailed studies on few solar assisted heat exchanges that can be incorporated in solar chimney power plant. Garg suggested the use of hot water to heat air by spraying during night time. One of the novel ways is to store solar heated water and circulate in suitable heat exchangers provided in the collector to heat air during night time.

**Heat Exchangers:**

For night operation, air is heated using solar heated water. The heat exchanger proposed is of remunerator, counter – flow and single through type. Heat exchangers are arranged inside the glass roof collector such that it provides minimum obstruction to air flow. The unit heat exchangers are arranged in series radially outward .below table gives the technical data for design of heat exchanger.

**Flat Plate Collector (FPC):**

FPC is the main device of collecting the solar energy through water medium which will be used for the night time operation. It has to heat water sufficiently to include all losses and energy required for heating the air in the chimney collector during night time which is bare corrugated type.

**Results and Discussion (Night Time Operations):**

Optimization a single component does not guarantee overall optimization of the plant. However, it is essential to visualize the effect of the parameters on individual component’s performance and delineate parameters in terms of influence. Due importance is given to the pipe length as it restricts the optimization of individual component. Greater length is associated with greater time to transfer to water across the water tanks through the components.

## II. CONCLUSION

With its large covered ground area, the solar chimney power plant possesses theoretically a natural energy store, which costs virtually nothing. The radiation power incident on to the collector is converted into a rise in temperature at the ground surface.

SCPP is more suitable to take base load. At day time, the supply energy cannot be controlled based on the load. Hence the plant continuously produces the rated output.

Though the plant has been designed to take regular transient condition, any unpredictable demand and climatic conditions may lead to variation in the output as well as frequency of electrical output. Small stand by plant take care of such situation. It is a long term project and can be installed in otherwise non-productive barren lands.

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