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FLOATING SOLAR CHIMNEY AND POSSIBILITY OF ELECTRIC GENERATION FROM INDUSTRIAL CHIMNEYS

Amit Dodke[1], Prachi Lingarwar[2]
[1](*Elecctrical Engineering, Sureshrao Deshmukh College of engineering, Selukate, Wardha/ R.T.M. Nagpur University, India)*
[2](*Elecctrical Engineering, Sureshrao Deshmukh College of engineering, Selukate, Wardha/ R.T.M. Nagpur University, India)*

ABSTRACT:*During next century the global pattern of energy consumption will see a shift towards creation of new renewable energy capacities in the growing economics of the developing world. 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 order to take the long term view and to realize the full potential of renewable, it is necessary to formulate comprehensive renewable energy policies, which will encompass govt., industry, research institute, local communities and users. We plan to introduce solar power generation system for generating electricity in adequate for effective and rapid development of RE sector. Solar updraft tower is one such source of renewable energy which works on the basic principle that hot air moves up. The tower acts as a giant chimney and generates necessary pressure drop to rotate a turbine at the entrance of the tower which is further converted to electrical energy.In this case we use new technology floating solar chimney.Turbines in case of solar updraft tower generally run not using the kinetic energy of gases as in the case of wind turbines. Therefore, with the presence of a turbine in an solar chimney, a component of total pressure drop (static pressure drop) will be used up for rotating the turbine.*
A floating solar chimney power station has three major components:
• A circular solar collector (the greenhouse)
• A solar chimney on the center of the collector
• A set of air turbines geared to electric generators.
Similar to solar chimney we can also produce electricity from industrial chimney. In industries lots of flue gasses waste. This flue gasses use to produce electricity.
A study is needed to explore the effect of using this principle of energy production in industrial chimneys in terms of loss of pressure drop, increase in frictional losses, and impact on the draught.

Keywords:– *Generation, Floating Solar Chimney, Industrial chimney.*

I. INTRODUCTION

In this paper a new type of solar chimney that which I called Floating Solar Chimney (FSC) is described .The main characteristic of the floating solar chimney is that, since it can self-float in the air, it can be constructed in any dimensional combination (diameter to height), while it can give a higher efficiency to its respective solar power station, which is occupied with this type of solar chimney.

The inventor of the basic idea concerning the solar power stations with solar chimneys is Professor Jorge Schaech. The solar chimney is constructed by reinforced concrete. The theoretical foundation of the thermodynamic operation of the solar power stations with solar chimneys has been done by Von Barckstrom and Gannon in a series of articles. In these articles they proved that the thermodynamic cycle, and thus the principle of operation of such a power station is similar to the operation principle of a gas turbine. For these power stations the “fuel” is the solar energy, which is collected by the inside the solar collector (the greenhouse effect). The warm air tends to escape through the solar chimney to upper layers of atmosphere. This stream of warm air, passing through a system of turbo-generators, generates finally electric power.

For this reason I called them Solar Turbine Power Station (STPS). I believe that STPSs if properly designed and constructed using floating solar chimney (FSC) can achieve lower construction cost per produced KWh of power compared with modern wind power farms.

In addition we should take into consideration the fact that:

• The sun is more stable and available compared to wind.

• The operation of the STPSs with FSCs is smoother following the diurnal and annual solar irradiance.
• The STPSs can operate 24 hours per day for 365 days per year due to thermal storage of the solar collector's ground.
Similar to solar chimney we can also produce electricity from industrial chimney. In industries lots of flue gasses waste .This flue gasses use to produce electricity. here I explain comparison between solar and industrial chimney and possibility of electricity generation from industrial chimney.In introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. FUNCTIONAL PRINCIPLE

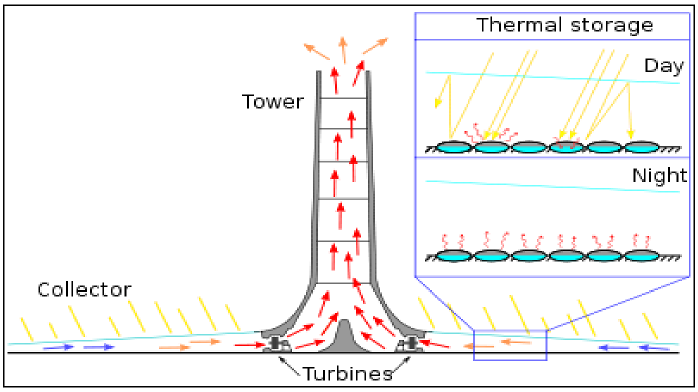

Fig: 1 Constructional diagram

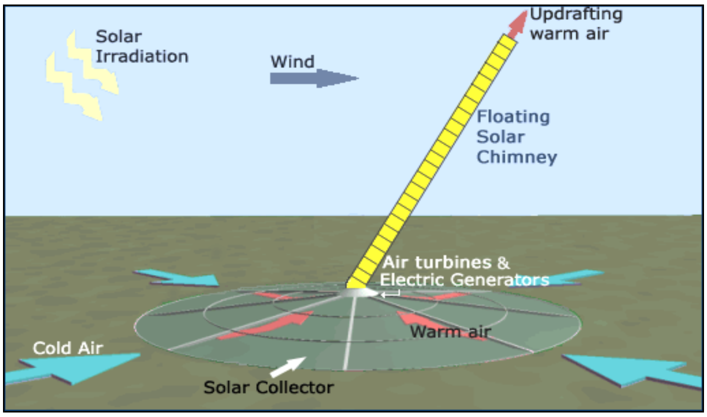

Fig: 2 Overall view of FSC plant

The principle is shown in fig (1) Air is heated by solar radiation under a low circular translucent roof open at the periphery; the natural ground below it form an air collector. In the middle of the roof and the natural ground below it form an air collector .In the middle of the roof is a vertical tower with large air inlets at its base. The joint between the roof and the tower base is airtight. As hot air is lighter than cold air it rises up the tower. Suction from the tower then draws in more hot air from the collector, and cold air comes in from the outer

perimeter. Continuous 24 hours-operation can be achieved by placing tight water filled tubes or bags under the roof. The water heats up during day time and releases its heat at night. These tubes are filled only at once, no further water is needed. Thus solar radiation causes a constant updraft in the tower. The energy contained in the updraft is converted into mechanical energy by pressure-staged turbines at the base of the tower, and into electrical energy by conventional generator.

III. COMPONENTS OF SOLAR FLOATING CHIMNEY POWER STATION

- Circular solar collector (the greenhouse)
- A solar chimney on the center of the collector
- A set of air turbines geared to electric generators near the bottom of the chimney

3.1 Collector: [1,4]

The FSCPS power output is proportional to collector area and tower height, i.e. proportional to the cylinder in fig-3

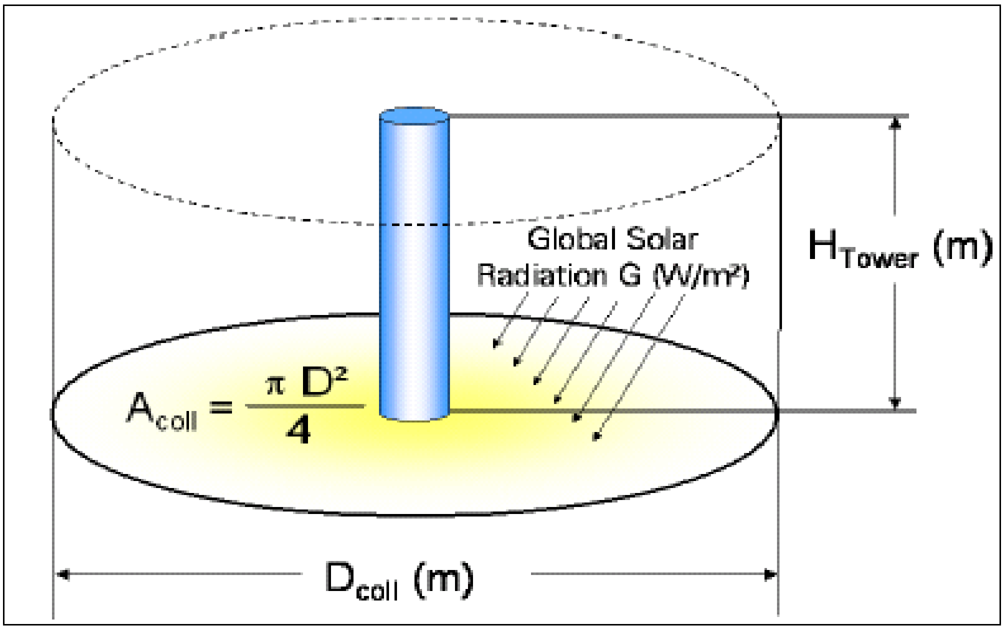

Fig:3 Diameter of collector

Hot air from the solar tower is produced by the green house effect in a simple air collector consisting of a glass or plastic film glazing stretched horizontally two to six meters above the ground. The height of the glazing increases adjacent to the tower base, so that the air is diverted to vertical movement with minimum friction loss. This glazing admits the solar radiation component and retains long-wave re-radiation from the heated ground. Thus the ground under the roof heats up and transfers its heat to the air flowing radially above it from the outside to the tower

Fig :4 The area under the roof is used for agricultural purpose

The area under the roof is used for agricultural purpose, so that large area invested for FSCPS is not gated wasted.

3.1.1 Storage:

If additional thermal storage capacity is desire, water filled black tubes are laid down side by side on the radiation absorbing soil under the collector. The tubes are filled with water once and remain closed thereafter, so that no evaporation can take place. Since even at low water velocities from natural convection in the tubes the heat transfer between ground surface and the soil layer underneath, and since the heat capacity of water (4.2 kJ/kg) is much higher than that of soil (0.75-0.85 kJ/kg) the water insides the tubes stores a part of the solar heat and releases it during the night, when the air in the collector cools down. This enables the plant to run for 24^{th} per day on pure solar energy.

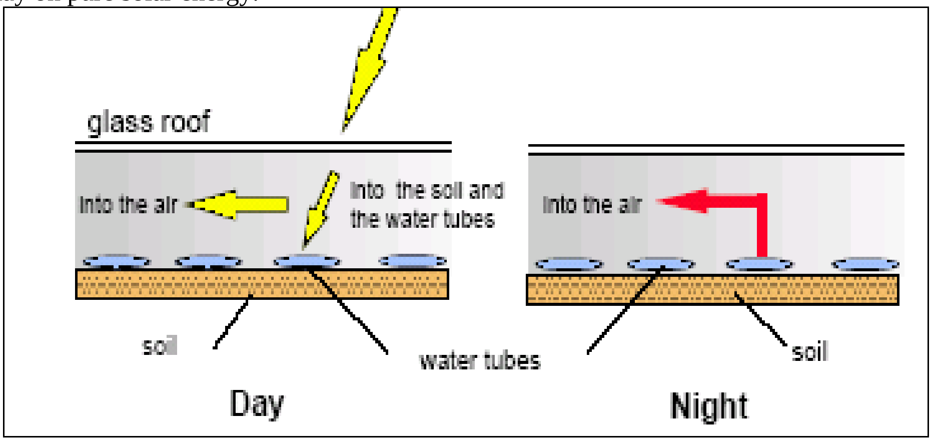

Fig: 5 principle of heat storage underneath the roof using water filled black tubes

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).

Table:1.1 Correlation of collector efficiency for various collector materials had been Formulated.

S. N.	**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	$0.505-(R_{col} – 400)(0.505-0.539)/2200$

Table:1.2 for optical parameter of various glass roof materials

	Green	White	IR Reflex
Glass thickness(mm)	4	4	4
Long-wave absorption	0.918	0.918	0.15
Long-wave Transmission	0.000018	0.000018	0.000018
Short-wave absorption	0.05	0.01	0.07
Short-wave Transmission	0.887	0.97	0.81
Refractive index	1.50	1.50	1.50
Specific heat capacity	481	481	481
Density (kg / m^3)	2580	2580	2580
Thermal conductivity(w/m.k)	0.9	0.9	0.9

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3.2 Floating solar chimney: [2]

This acts as a thermal engine of the solar updraft tower transforming the heat energy into mechanical energy. As the air gets heated up in the collector it rises up and is released into higher layers of atmosphere through a Chimney present at the centre of the collector. Now, as the air moves up through the tower, it creates pressure difference between surrounding atmosphere and the tower base which are connected through the collector and hence sucks in more air from surroundings. So here we use solar floating chimney.

In the present paper a new idea of constructing solar chimneys is presented. The proposed solar chimney is a lighter than air structure, made by double wall consisting of light enduring layered fabric, used in balloon and airship industry, filled with light gas (He, NH_3), that is giving to the chimney the self-floating property. This solar chimney is named Floating Solar Chimney (FSC).

In these invention have also proposed a construction that will allow the chimney to cope successfully with the forces that are exercised on it.

The above-mentioned forces are basically two:

- The forces which are resulted from the pressure difference between the warm stream of air inside the FSC and the air on its exterior.
- The forces from the external winds, which are appeared at the places where the FSC is installed.

The FSC construction is made by a series of balloon-rings from light enduring (airship) fabric (see fig. 6), connected successively in such a way that they form the main cylinder of the solar chimney. The internal and external ring diameters define the internal and external FSC's diameters. The ring height (h) multiplied by the number of lifting balloon rings determine approximately the height of the chimney.

To encounter the sub-pressure we can use, if necessary, special supporting rings place between the balloon rings (see fig. 7). These rings have negligible thickness and diameters smaller or equal than the diameters of the lifting have negligible thickness and diameters smaller or equal than the diameters.

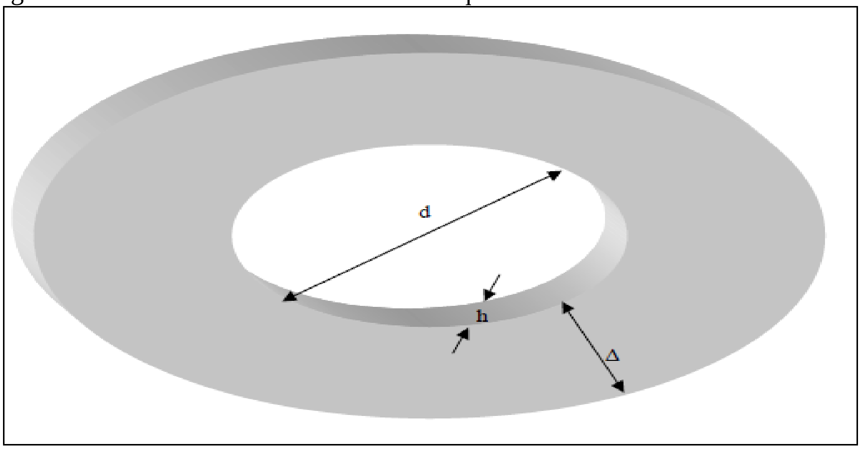

Fig.6 Balloon ring

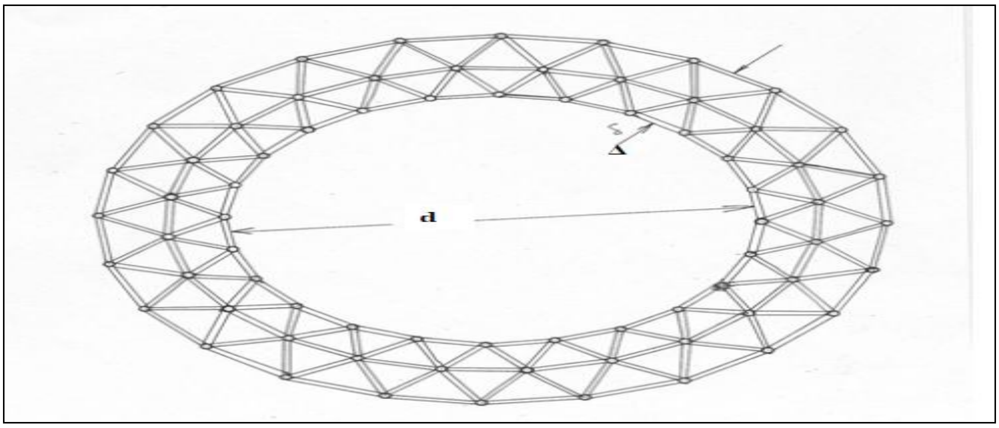

Fig.7 internal structure of balloon ring

To encounter external wind's forces is a rather more complicated issue. To do so the supporting rings are not sufficient, although they do help in this respect. The external winds' problem is encountered by the FSC's deflecting ability.

Thus when external winds appear the FSC is deflecting, reaching its angle of balance (fig. 8). In this way, in its balance position, the FSC encounters vertically only the drag forces from the velocity's normal components, which are counter-balanced from the opposite FSC's buoyancy components. These normal forces to the FSC's cylinder are encountered locally with the assistance of the supporting rings. Wind velocity's tangent component creates a friction force parallel to the FSC's cylinder without deforming its shape. As already stated in order to encounter the winds' action on the FSC, it should have a deflecting ability. For this purpose two more elements are necessary:

• A system that will keep the FSC at its position and which will receive the parallel and tangent forces from the external winds. This system is a two-part heavy base, which can incline on the FSC's seat without parting from it. (Fig. 8)

• A flexible (accordion type) folding part of its base which will be unfolded partly as a result of the deflection, preventing the warm air to escape by the bottom of the structure .

The above-mentioned system is sufficient with regard to constant speed winds, independently of the chimney's altitude. However, additional measures should be taken to encounter the differential forces on the chimney due to any possible variation of the wind's velocity with altitude. This wind's velocity variation creates differential forces along the chimney's cylinder.

To encounter these differential forces the chimney's cylinder is separated in parts. These parts are constructed by a fixed number of tube balloon-rings. The parts are separated by isolation tubes filled with environment's air, which can easily get in and out of them. These relief tube isolate dynamically the consecutive parts of FSC from each other, allowing each part to reach its own deflecting angle, depending on the average wind velocity on the altitude where it is located.

Since the external wind forces are increasing with the square of their velocity, it is recommended that in the places of installation of the STPSs, the annual average of wind velocity (υ_{av}) not to exceed a certain limit, (for example 3 m/sec). The seismic activity of the place of installation does not affect the FSCs, although it does so in the case of the reinforced solar concrete chimney.

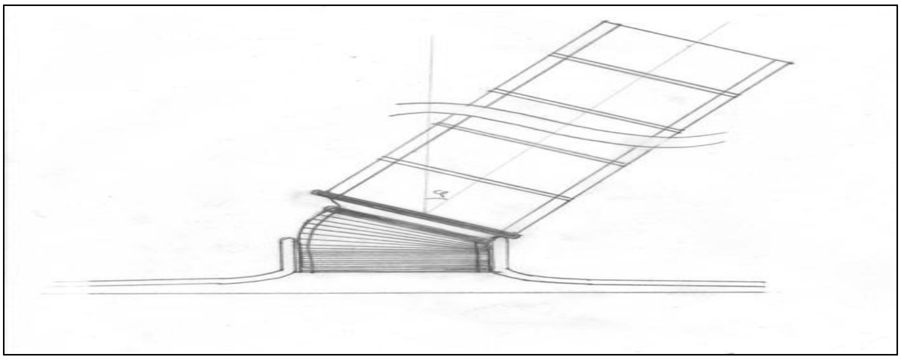

Fig.8 : Indicative diagram of the FSC under external wind

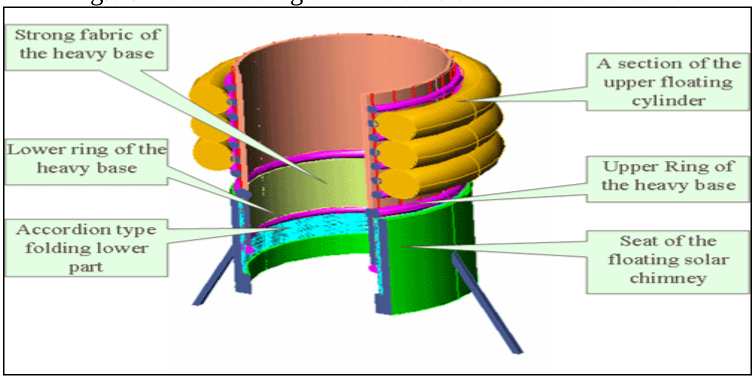

Fig.9 The seat, the heavy base and a small part of the FSC

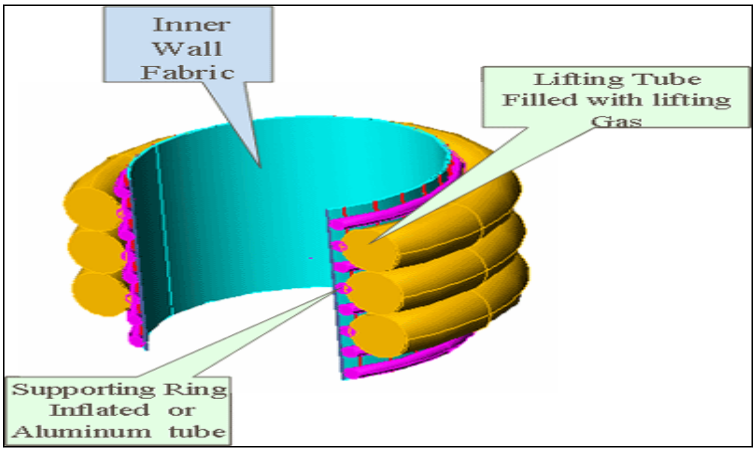

Fig.10 A small part of the main body of the Floating Solar Chimney

3.3 Turbines And Generator: [2]

Turbine is generally housed at the centre of collector below the chimney. As the heated air moves up from the collector to atmosphere through the chimney it imparts some of it's up-drafting energy to the turbine which is converted to mechanical energy, which is later converted into electrical energy.

The basic unit that transforms the dynamic energy of moving air into electric energy is the axial air turbine. In large power STPS there will be one or several air turbines always ducted.

These air turbines transform the dynamic energy of moving air with constant speed, using the pressure drop, in rotating mechanical energy and finally through a gear box and an electric generator of the same power, into electric energy.

The electric generator can be synchronous or induction depending on the use of the output electric power. However for a straightforward production of H_2, with an

Electrolysis method, an appropriate generator should be designed. The air turbines of STPS, as already mentioned are of constant speed and stepped pressure. The usual wind turbines on the contrary are of constant pressure and stepped air speed. The wind turbines are designed and constructed to operate under severe external conditions and their power output is limited by the bets limit. Hence for the same diameter with a stepped pressure air turbine they produce much less power and are more expensive. The choice of the position, the number and the dimensions of the air turbo generators it is an important decision procedure .but it cannot be examined in depth in the present paper. When the hot air moves up at the turbines, it imparts a part of total pressure drop called static pressure drop to turbines which is converted into mechanical energy. Usually with no turbine in between, total pressure drop generated would be converted into kinetic energy, but in this case with a turbine in between a part of total pressure drop would be used up by the turbine to convert it into mechanical energy.

IV. EXTERNAL WIND EFFECTS[2]

The effect of external winds on the FSC can be encountered by the deflection of the FSC. The local wind pressure on the FSC's walls related to this deflection is limited in comparison to the operational sub pressure acting on the FSC walls.

However the deflection of the FSC due to external winds is decreasing the operating height of the FSC. Hence in favorite places for STPSs' installation the average annual speeds of local winds should not exceed for example 3m/sec and the waybill constant of the local winds is better to exceed 1.5. For such locations for STPS the operating height of the FSC is not more than 5% smaller, compared to initial height of 3000m.

The intermediate, open to the environmental air, balloon rings can help the FSC to encounter the dynamic effects between the successive parts of the FSC, due to the differential forces by the variation of wind speed with altitude.

V. EFFICIENCY OF TOWER AND OVERALL PLANT OUTPUT [2]

Net efficiency of tower is given by the Back Storm's work as:

Tower $=\frac{g\times H}{(Cp\times T)}$ 1

where

g = gravitational acceleration

H = height and cp is specific heat at Constant pressure.

Net power output from the system:

P= Q × ɳ Tower × ɳ Turbine × ɳ Collector……….. 2

Q is the rate of heat input to the system

Q= M× cp ×T

Where

M = mass flow rate of air into the system

T =temperature rise between ambient and collector outlet (= tower inflow)

VI. MATERIAL AND COST FOR THE FSC CONSTRUCTION [2]

The basic materials for the FSC construction are

- Reinforced layered fabric (similar to the fabric used in balloon or airship industry for the balloon tube rings. It is estimated that the fabric has a weight of $90gr/m^2$ and tear force strength above 2500 Nt/m.
- Aluminum tubes with appropriate dimensions for the supporting rings.
- NH_3 or He as lifting gas.

To present preliminary results of such a construction with ordinary low cost materials.

The existing experience and the state of the art for design and construction of plastic, composite materials and Al, used in airplane, airship and balloon industry and several other sectors, must be used in order to design and construct FSCs with the appropriate properties and dimensions for the corresponding STPSs.

The material quantities are approximately proportional to the product $\Delta P_{max}(d+\Delta)^2$

For the FSC of 3000m height (filled with NH_3) and 100m internal base diameter, of the STPS of 200MW a detailed study showed that the dimensions Δ and h for the balloon rings are

Δ_{MAX} for the bottom balloon rings equals to 9m.

Δ_{MIN} for the top balloon rings equals to 3m.

h can be chosen equal to 4m.

The quantities of basic material for the whole FSC are approximately:

2150 tons Al, 475 tons Fabric, 390 tons NH_3

The cost of this FSC is estimated to 30mUSD.

The cost of the solar collector of 5.95sqKm surface area will not exceed the 75mUSD, while the turbo generators cost including power electronics, is estimated to 50mUSD. Adding 10mUSD for the auxiliary construction the overall cost for the STPS of 200MW is equal to 175mUSD.

If Helium (He) is chosen as lifting gas the FSC cost and thus the STPS cost, will increase by 7.5mUSD.

VII. ADAVANTAGES OF FSC PLANT OVER CONCRETE CHIMNEY PLANT [2]

- The concrete Solar Chimney is a huge and difficult construction and thus very expensive. The sole function of it is to updraft the warm air of the greenhouse to the upper layers of the atmosphere.
- The same function can be executed with the Floating Solar Chimney that is a simple lighter than air construction, much cheaper than the respective concrete chimney.
- The concrete chimney has a construction height limit (about 1000m) related with the weight and strength of concrete and steel. This height defines the efficiency of its solar power station to less than 1%. The Floating Solar Chimney has no such limit. up drafting the warm air with a proportional to this height force to the upper layers of the atmosphere, and thus giving to its solar power station efficiencies from 4,5% to 7%.
- For the same output power its solar collector area is 4,5 to 7 times smaller, thus the overall cost Thus can become 3 – 4,5 km high, of its respective power station is less than 850 $/KW (see ref.[6]) while the equivalent concrete Solar Chimney power station has a cost of 3.500 $/KW, producing annually the same electric energy (approximately 3000 KWh per rated KW).

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VIII. SIMILARITIES BETWEEN SOLAR CHIMNEY AND INDUSTRIAL CHIMNEYS

- Industrial chimneys are used to flush out the waste hot flue gases from combustion into outside atmosphere.
- Here, combustion chamber takes the place of collector as in solar updraft tower which performs the task of heating the input gases to the tower/chimney.
- Usually the temperature of the hot flue gases is higher than what is attained from the air in the collector. So, with a turbine employed at the entrance of tower/chimney a part of total pressure drop between tower base and ambient air will be converted into energy as in case of a solar updraft tower.

IX. ANALYSIS OF INDUSTRIAL CHIMNEY: [3]

Fig.11 Industrial chimney

X. WORKING OF INDUSTRIAL CHIMNEY

Working of industrial chimney power plant is similar to the solar chimney power plant. On similar principal industrial chimney power plant can be operated. Instead of floating chimney we use here concrete chimney. In solar chimney power plant solar collector is used to heat the air inside it and provide hot air to the chimney base but here whatever flue gasses is produce in combustion chamber is use to produce electricity. Turbines in solar tower do not work with staged velocity like free-running wind turbo generator, in which, similarly to hydroelectric power station, static pressure is converted to rotational energy using a cased turbine. On similar way turbine can operate in industrial chimney power plant. Normally in furnace 1200 degree C. is produce and till reaches to the chimney it temperature is 120-135 degree C. This temperature is sufficient to produce electricity.

10.1 Chimney and Power:

Power output from the system is given as:

$P = Q \times \eta\,\text{Chimney} \times \eta\,\text{Turbine}$

Where

$Q = M \times Cp \times T$

M= mass flow rate of flue gases

T= temperature rise in combustion chamber.

$\eta\,\text{Tower} = \frac{g \times H}{(Cp \times T)}$

Where

g = gravitational acceleration

H = height of chimney

Cp = specific heat at Constant pressure.

Efficiency of collector term is not needed here assuming that flue gases are at combustion temperature. So, from the above equations, we can surmise that power output from this kind of system depends on height of chimney, mass flow rate of flue gases and temperature rise in collector/combustion chamber.

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XI. ADVANTAGES AND DISADVANTAGES

Advantages of industrial chimney are:

- Wastage flue gasses is used to generate electricity
- This plant helps to provide electricity for increasing demand in future.

Disadvantages of industrial chimney are:

- Flue gasses affect the turbine blades.
- Cost analysis of amount of energy produced in a given time frame Vs. actual cost of installation and maintenance will be high.
- Finally, with installation of a turbine in a chimney there will be a loss of total up-drafting energy of flue gases which would further affect the draught produced by the chimney.

So, further study would be needed to assess the effect on the entire system and do the necessary constant analysis.

11.1 How to fit a turbine in Chimney? Is it really possible?

These questions need an answer as we should also consider how to install a turbine such that it would not impact the present design of the chimney and also need to take into account the amount needed for this. A considerable amount of research has to be devoted in this direction. As stated earlier, the turbines in this system are not similar to one's used in the wind power generation which rotate using the kinetic energy of incoming air. These use the static pressure drop at the turbine blades to generate electricity. Hence are more similar to the hydroelectric turbines which also use the same principle. Also, for present case of generation of electricity from an already existing industrial chimney, use of horizontal axis turbine might prove more effective by taking into consideration few design modifications to the existing Chimney. This rotational energy can then be converted into electrical energy outside the chimney system which is not the case with solar updraft tower with large amount of space available beneath the chimney for installation

XII. CONCLUSION

The purpose of this paper is to give initial information for the technological feasibility construction of the FSC, and to present preliminary results of such a construction with ordinary low cost materials.

The existing materials plastic and Al etc used to made FCS.

Using such materials and design techniques, the FSCs can be constructed with a bigger height and much lower cost compared to a solar chimney by reinforced concrete. The FSCs' construction techniques with any appropriate diameter and height, for the STPSs of given power output, could accelerate the use of solar chimney power stations.

It is worthwhile to mention that special studies of experts could be proved important especially in the following subjects:

- Study of solar collector in order to maximize its efficiency around the point of maximum power output.
- Study of supporting ring structure, for achieving the maximum strength under given sub pressure. This can be achieved using a combination of special or composite material, and appropriate design.
- Study of dynamical behavior of the FSC under external winds of variable speed with altitude.
- Study and design of an appropriate type of stepped-pressure ducted air turbine.

also in case of industrial chimney some of the important points to be considered are:

- Effect of particulate matter in flue gases on the turbine blades;
- Cost analysis of amount of energy produced in a given time frame vs. actual cost of installation and maintenance;
- Effect on draught produced by using a turbine in the chimney.

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