CHIMNEY AND POWER

POSSIBILITY OF ELECTRICITY GENERATION FROM INDUSTRIAL CHIMNEYS

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Abstract

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.

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 industrial chimney, a component of total pressure drop (static pressure drop) will be used up for rotating the turbine. 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.

Introduction

The root of the idea for generation of electricity from industrial chimneys lies in the solar updraft towers commonly called 'solar chimneys'.

Solar chimneys work on the basic principle that when air is heated it moves up. A tall tower is used as a passage for the hot gases from the large solar collector. As the heated air moves away from the system through the tower, suction is created at the base of the tower which helps to draw more air from the surrounding atmosphere and thus ensures continuous supply of air into the system.

As the heated air moves up from the tower, it imparts some of its energy to the turbine present at the tower base which converts the mechanical energy into electrical energy.

How does energy generation take place in the solar updraft tower?

To understand how energy generation actually happens in the solar chimney let us first see various components of a solar tower and their importance.

- *Collector:* This is a huge arrangement of flat glass plates over the earth surface, which heats the air inside them through greenhouse effect. Glass is transparent to shorter wavelengths of light radiations coming from the sun, but the earth's surface reflects the radiations with longer wavelengths to which glass is not transparent and hence, the air present in between earth's surface and glass surface gets heated. Normally the temperature rise is to the tune of 30-35 degree C.
- *Tower or Chimney:* 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.
- *Turbines:* 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.

Turbines in this case are more related to hydro electric turbines which convert static pressure drop of the water from a certain height into electricity as in this case also the mechanical energy generated is proportional to the height of the tower through which the heated air has to be up-drafted.

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.

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

ηTower = $g{\cdot}H/(c_p{\cdot}T_0)$ 1

where g is gravitational acceletation, H is height and cp is specific heat at contant pressure.

Net power output from the system:

P=Q ηTower ηTurbine ηCollector. .. 2

Q is the rate of heat input to the system = M c_p ΔT where M = mass flow rate of air into the system, and ΔT is the temperature rise between ambient and collector outlet (= tower inflow)

Similarities between solar updraft towers 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.

The equations used for calculation of power in case of solar updraft tower hold good here also.

Efficiency of tower is the same as that of equation 1 given earlier for solar updraft tower.

Power output from the system is given as:

P = Q ηTower ηTurbine 3

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.

How to fit in 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 of a generator.

Conclusion

Chimneys in any industries are used for two purposes:

1. To flush off the flue gases away from the surroundings so that they get diluted and spread in the atmosphere.
2. To provide necessary draught such that necessary air (O_2) is driven into the combustion chamber.

Points given below summarise the above discussion:

- Solar updraft tower uses a simple concept that hot air rises up.
- The energy associated with rising air is used to generate energy.
- Chimneys on the other hand use the same principle but to serve a different purpose - of driving the flue gases away from the combustion chamber.

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 cost analysis.

Also, 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; and
- Effect on draught produced by using a turbine in the chimney.

References

Details on solar updraft tower from prototype of solar updraft tower constructed in Manzanares (about 150 km south of Madrid) in 1981/82.

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