Power Generation from a Man Made Tornado inside a Solar Thermal Tower

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***Abstract*— Everywhere we see, due to increased environmental concerns, people are moving on to natural, renewable, eco-friendly, non-conventional resources for power generation. But there is a huge amount of untapped energy in disastrous natural phenomena such as typhoons, cyclones, hurricanes, and tornadoes. The novelty of the idea lies in mankind's power to generate energy not just from Mother Nature's boons but also from her banes. This paper builds upon the idea of a Solar Thermal Power Tower Plant and describes how a tornado could be regenerated inside it, and its ferocious wind power be used to generate electricity. This paper traces the developments that have been taking place in power tower technology and introduce what we think would improve the efficiency. An innovative idea modifies the original solar chimney concept by adding spiral guides to initiate a tornado-like wheeling motion. Due to conservation of momentum, angular velocity of air increases as is approaches the centre of the chimney. Power is extracted from rotational wind energy through turbine generators.**

***Index Terms*— Tornado, Solar Energy**

I. INTRODUCTION

A controlled tornado can be generated by channeling the air currents in a spiral manner and wind power thus created can be used to generate electricity. The non-uniform distribution of sun's radiation creates pockets of warm air that tend to rise up due to buoyancy and create low-pressure zones. These low-pressure zones are filled in by nearby cooler air. But the motion of the fluids is rotational due to the earth's west to east rotation as dictated by the Coriolis force. Hence, in the northern hemisphere the air currents gyrate anticlockwise, and in the southern hemisphere – clockwise, creating circular patterns.

Moving objects are deflected slightly due to the rotation of the earth when viewed from the rotational frame of reference. Gaspard-Gustave Coriolis described this effect in 1835 with tidal waves using the mathematical equations of Pierre-Simon Laplace. Meteorologists use this concept to predict the formations of hurricanes and cyclones. Basically, air flows from high pressure to low pressure, but the earth's rotation causes the wind to curve. Coriolis force is zero at the equator. Hence, a man made tornado cannot be generated at the equator.

From the principle of rotational motion we know that as the mass of a gyrating object concentrates itself inward towards the axis of rotation, the angular velocity of the object increases. This principle can also be applied to the weather phenomenon that causes a tornado's power to increase exponentially. Due to the pressure difference, air (which may or may not contain moisture) spirals its way inward, towards the centre of the axis of rotation and this in turn increases the rotational speed of the air current. As a result, the updraft pulls in more air from the edges, which further increases the velocity. Thus this cycle ends up creating a gargantuan tornado with turbulent force from what was once a small innocuous spiralling rustle caused by the wind. This tornado causes soil erosion and it has enough power to uproot anything that may come its way. It would be quite innovative to regenerate such a natural phenomenon under a controlled setting and generate electricity from its wind power. This concept of generating power from a regenerated tornado can best be accomplished inside a Solar Thermal Tower (also called Solar Chimney).

A Solar Thermal Tower works on the principle of the greenhouse effect wherein heat from sunlight is trapped underneath a vast expanse of a translucent collector material, which forms the base of the Solar Thermal Tower. The centre of this collector leads to the solar chimney from where the hot air rises up due to buoyancy and the induced up draught draws in the cooler air from the outer periphery of the collector. This process of natural ventilation is called Stack Effect. It is mainly due to difference in indoor and outdoor air temperature and moisture, which facilitates the required updraft in the tower and hence increases the efficiency of the tower. The turbines located at the base of the tower convert both wind and rotational energy of the artificial tornado to mechanical energy, and the alternators they are coupled to, convert mechanical energy to electrical energy.

This innovation calls for spiral air channels to be built like walls underneath a Solar Thermal Tower's collector instead of the proposed radial ones. Newly christened, the Solar Powered Tornado Tower would rely on the Coriolis force to make the air currents gyrate collectively with the axis of symmetry of the tower as the axis of rotation of the tornado. As the hot air moves up due to buoyancy and draws in cooler air from the edge of the base, the air will travel through the built-in spiral channels towards the centre. As the volume of each spiral channel will decrease and converge to one turbine per channel, air pressure will increase, as will its velocity. The powerful wind will then go through the guide blades and turn the reaction turbines at the base of the tower. After each channel ends at the base of the tower, air from all the channels spiral in together and rise up the chimney. An additional impulse turbine could be set up at the centre of the base with its axis of rotation coinciding with that of the tornado's, where the energy from the spiralling air currents is transferred to the turbine coupled to an underground alternator.

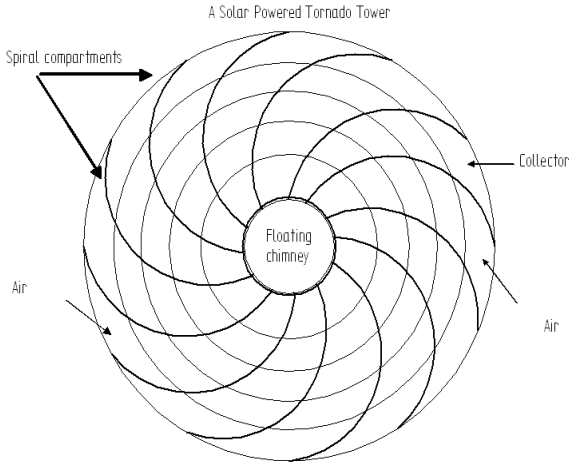

Fig. 1. Top View: Spiral walls built under the collector

II. Application

A Solar Thermal tower based on the greenhouse effect was initially proposed by Professor Jörg Schlaich, founder of Schlaich Bergermann and Partners. According to his proposal, the 7 km diameter collector roof gradually slopes towards the 1 km tall 400 ft wide tower from a height of 3 ft at the periphery to 25 ft at the base of the tower. Heating the air under the collector 95°F above ambient air temperature outside, wind velocity is approximated at 35mph generating 200MW using 32 turbines at the base. And that is without the tornado effect. Including the tornado effect, air pressure and velocity will be high enough to turn additional turbines connected in series at the very centre of the structure. To ensure space enough for the air currents to spiral inside the tower, all alternators must be placed underground. The shafts of the reaction turbines may be coupled to their respective alternators using either bevel gears or spiral gears.

Prof. Jörg Schlaich's concept was successfully demonstrated by constructing a prototype experimental plant in Manzanares, Spain. The tower stood 200m tall with a collector covering floor space of 46,000 square meters. After connecting it to the grid in 1981, tests were conducted on a second to second basis during the trial version from July 1986 to February 1989. These tests concluded that the solar tower could be built and it could be an efficient source of renewable energy.

This zero emission Solar Thermal tower was initially to be constructed in Australian desert and was estimated to produce about 200MW of power which would provide energy to 200,000 homes. Australian based Enviro Mission has joined hands with Solar Mission to build this tower. Any location within 20° and 40° latitude in the northern or southern hemispheres is suitable for this project as the effect of the Coriolis force can be best controlled in these regions. Enviro Mission has selected the Buronga district (northeast of Mildura town) of Wentworth Shire in New South Wales, Australia as their power plant site. The generation capacity is said to be comparable to a small nuclear power plant. Of course, several towers would compare to a large nuclear power plant. As this project is a major public interest, the Australian federal government has given Solar Mission's project, "Major Project Facilitation Status". Therefore, getting federal approval is not a problem. But this project is supposed to cost A$1 billion. The Australian government needs to invest A$48 billion towards electrical infrastructure development. That is what is keeping the project on hold.

An improvement to the existing Solar Thermal Tower has been proposed by Prof. Christos Papageorgiou. His idea is to make the chimney lightweight. In fact, he claims that if it is made lighter than air, for a 1km tall tower with clear plastic as the collector material, construction costs come down to 11.5 million €. The tower can be constructed using very strong fabric reinforced with composite fibres like the ones used in balloon technology supported by aluminium rings along the length of the tower, making sure the fabric is air tight. This design will make the tower floating in the air but strongly connected and flexible at the base. The flexibility is achieved by using accordion like structure so that the tower may tilt but not break under strong winds and seismic activities. This structure can be given additional strength to stay up in the air by tying it with strong ropes made of Aramid yarn.

This clean Solar Powered Tornado Plant can reliably serve as a base load power plant working at full load 24 hours a day and even on cloudy days. This is because the flooring is made of black tarmac or asphalt, which will absorb the sun's heat energy during the day. As the construction materials are extremely cheap and are available everywhere, this plant can be easily set up in less industrialized countries as well. This plant is eco-friendly as it does not chug exhaust gases (which usually contain greenhouse gases that cause global warming) into the atmosphere, nor does it throw any other toxic matter. It decreases the amount of greenhouse gas emissions by 700,000 metric tonnes, unlike coal or oil powered plants. By the time the hot air reaches the top of the tower, the air temperature decreases. Hence it does not cause global warming as much as other plants even though it uses the concept of greenhouse effect down at the collector level. Therefore, it is probably the cleanest chimney ever. In fact, last year, Time Magazine voted this project among the "Best Inventions of the Year". According to Ben Kage's opinion put up on the web, the power output increases with the size of the structure. Keeping size constant, one may also say that the cost of construction decreases for the same power output. Not only that, another great advantage with such a plant is that it does not require any coolant. So, it can be easily built in arid regions.

According to Prof. Christos Papageorgiou, the cost of construction for a 100 MW tower (producing no less than 300 GWh/year) should be between 30 to 60 million €. He estimates the operation and maintenance cost to be around 1.7 million € per annum. In case of damage to any of the floating parts, the structure can be lowered by partially deflating some of the lifting tubes. The lifting

gas (usually He or NH_3) should be stored in appropriate vessels and later refilled into the tubes. Combining Prof. Christos Papageorgiou's design with the idea of using spiral walls as channels, the tower could be made more energy efficient as well as cost efficient.

III. Conclusion

This project, unlike wind farms, can generate electricity from wind energy without depending on the wind. But before taking on such a large scale Solar Powered Tornado tower project, a prototype similar to the one built in Spain is recommended. Tests must be conducted on the safety of regenerating a manmade tornado inside a tower and the strength of materials used. A few proposals have been made regarding the strength of the greenhouse panes that constitute the collector material. Justin Thomas, the author of "New Roofing Material uses Translucent Aerogel", has proposed the use of Lexan resin, an extremely light translucent aerogel as an alternative roofing material which can handle wind loads of up to 140mph. A tower this tall needs to be sanctioned by Civil Aviation Authorities and warning lights need to be installed to warn aircrafts.

Now that the plant will be more cost efficient due to reduction in installation cost, the government should not delay in giving the approval to commence construction, assuming all safety measures have been taken care of.

In the Indian context, such a power plant setup would be an asset to our economy, as it would take care of the energy crisis prevalent in most of rural India without harming the environment.

References

[1] A.B. Kasaeian, Sh. Molana, K. Rahmani, D. Wen, "A review on solar chimney systems", Renewable and Sustainable Energy Reviews, vol. 67, pp. 954, 2017, ISSN 13640321.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Hussain H. Al-Kayiem, Ogboo Chikere Aja, "Historic and recent progress in solar chimney power plant enhancing technologies", Renewable and Sustainable Energy Reviews, vol. 58, pp. 1269, 2016, ISSN 13640321.

[3] Tingzhen Ming, Renaud de_Richter, Wei Liu, Sylvain Caillol, "Fighting global warming by climate engineering: Is the Earth radiation management and the solar radiation management any option for fighting climate change?", Renewable and Sustainable Energy Reviews, vol. 31, pp. 792, 2014, ISSN 13640321.