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Energyevaluation of a windgeneratortoweror vortex tower

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ABSTRACT
In view of the energy issues coupled with the environmental problems posed by the energy production sector, renewable energies are the answer. Several renewable energy technologies have already been developed and others are currently being studied, notably the wind turbine tower or vortex tower with a turbojet engine for production. It uses a combination of several physical and thermal principles such as the Coriolis Effect, the venturi effect and the greenhouse effect. In this work, we have translated the physical and thermal phenomena into an equation that provides a better understanding of the phenomena that take place in the tower. We were able to notice that the power that can be developed by the turbines is all the higher as the temperature at the base is also higher. In the same way this power increases with the height of the tower. Thanks to a fluid simulation tool (CFD) on behalf of SolidWorks we were able to confirm this. In the majority of African countries, wind turbine towers can operate autonomously, using only renewable energy sources, or with industrial cooling water discharges, producing large amounts of electricity and reducing their thermal impact on the environment and the energy deficit.
KEYWORDS: wind turbine, vortex, venture effect, Coriolis, Greenhouse

I. INTRODUCTION

For more than a century, the world has been experiencing significant economic development. Industrial development and the multiplication of domestic equipment have caused a significant growth in energy demand. Unfortunately, most of this growth in demand has been met by the use of fossil fuels, motivated by economic considerations. Other factors such as CO2 emissions, limited fossil fuel reserves, and global energy independence have not been taken into account. In 1970, [1972 - 2012 the Odyssey of Sustainable Development][1] greenhouse gas (GHG) emissions on earth were equivalent to 28.7 billion tons of CO2 each year.

Access to energy is a central preoccupation in the issue of development. Today, a very large number of people still do not have access to "modern" forms of energy such as electricity or renewable energies. Currently, according to the CNRS, nearly two billion human beings have access only to "traditional" forms of energy and nearly 85% of energy needs are now covered by fossil fuels (coal, oil, gas) which, in addition to being very inefficient, pose serious health and air pollution problems.

Unfortunately, although these solutions help to address the energy deficit in the region, they remain ineffective in some areas. Indeed, the supply of fuel in this region is not at all easy - it is a real Chinese headache. In addition, the winds in the region are so strong that the networks are generally out of order. Controlling the production and consumption of energy and the conditions under which it is conveyed to consumer's poses two major problems that humanity must address (one being economic and the other environmental). Renewable energies are already in action around the world to address these issues.

There is a panoply of technologies using renewable energies, the best known of which are: solar panels, wind turbines, tidal power, geothermal energy, hydroelectricity, etc. New technologies are constantly emerging and deserve special attention. Among them we note the project of the wind turbine tower or vortex tower with intrinsic safety which could be an energy solution of the future.

Wind turbine towers are an innovative solution for the mass production of clean energy and can be less expensive. As such, they should be studied in depth to better understand the mechanism of the thermodynamic reactions that take place in them. Its operating principle is very simple; it uses the air flow at its base, which it heats thanks to a greenhouse. The flow of hot air rises up according to the hot air principle as it moves through the tower. Thanks to its geometry, this air flow will be accelerated and will transmit its energy to a turbine train system located at the top of the tower. The latter is set in rotation and by induction (coil/magnet) there is production of electrical energy.

The objective of our work is to evaluate the producibility of an aerogenerating tower and the interaction between the different physical parameters and the geometrical characteristics.

I.1. Solar Tower

The solar chimney is a means of producing electrical energy from solar energy. It is based on the idea of exploiting the kinetic energy of the natural convection movements of the air heated by the sun. A huge greenhouse called a "collector" contains the air heated by solar radiation and guides it to a chimney. This warm air, naturally sucked up by this chimney, is continuously renewed by the air located at the periphery of the greenhouse. The solar chimney is equipped with black tubes containing water which absorb the heat all day long and release it during the night, a regular wind is then set up. The kinetic energy of the air is then taken up by a system of wind turbines driving electricity generators. This simplicity confers major advantages in terms of construction costs, maintenance, robustness and lifetime [4].

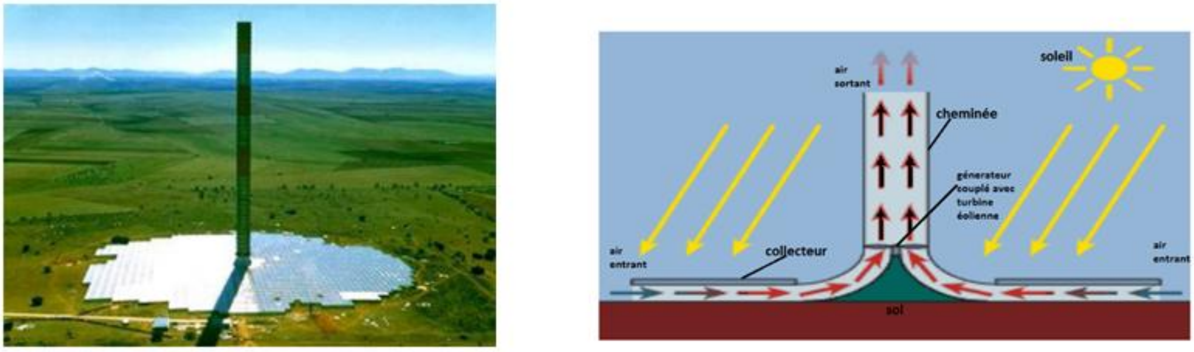

Figure I 11: The Manzanares solar chimney (Spain) and Principle of operation [4].

I.2. Aerogeneratortower

Wind turbine towers (or vortex towers) belong to the family of solar towers whose first project was developed about forty years ago by the French engineer Egard Henri Nazare, a pioneer in the field. Compared to the Nazare project and all those that succeeded him, the wind turbine towers bring however considerable novelties, both by the number of forces and natural effects used, by the diversity of the sources of calories envisaged, by the numerous structural details, by the characteristics of the peripheral greenhouses and the calorie storage system, and finally by the much higher efficiency than can be expected from competing projects. These towers have been patented in about thirty countries by their two designers: the university researcher Alain Coustou [7], a specialist in energy, climate and sustainable development, and the computer scientist Paul Alary [7].

Here we present the general principles, the description, the functioning and a number of the multiple advantages.

I.2.1. General principles

Use of a hollow structure in the form of a tower flared at the base and optimized to combine four or even five natural forces and effects for the massive and permanent production of electrical energy at low cost, without pollution, without consumption of limited natural resources and without being penalized by the irregularity of the wind regime as in the case of wind turbines. The natural forces and effects used are:

- The chimney effect;
- The greenhouse effect;
- The Coriolis "force";
- The Venturi effect.

In addition, wind can provide a supplement, without ever being necessary for the operation of the tower, and it is possible to increase the efficiency and profitability of the installation by using low-temperature calories from industry, nuclear power plants, incinerators or geothermal energy, otherwise largely unnecessarily lost.

I.2.2. DESCRIPTION OF THE STRUCTURE

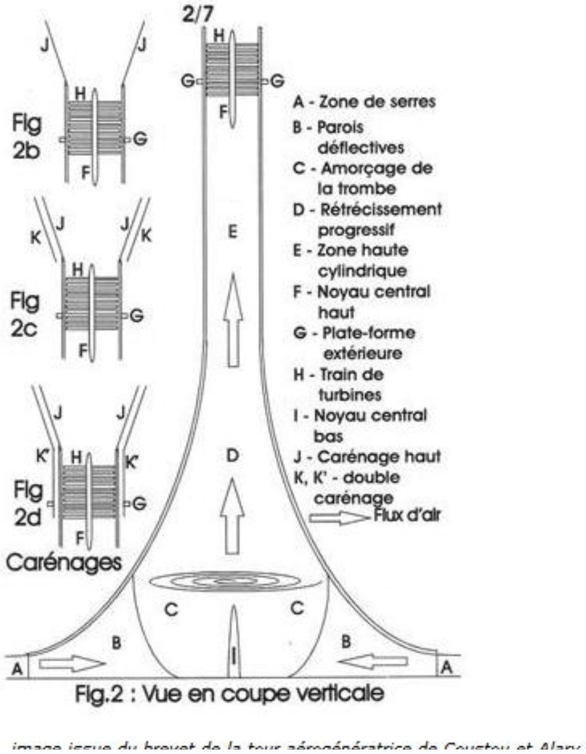

*Figure **Error! No text of specified style in document.**-1:vertical section view of the vortex tower**[7]***

II. MATERIALS AND METHODS

SolidWorks is a Computer Aided Design software created in 1993 and was purchased in 1997 by DassaultSystèmes. SolidWorks includes several simulation modules. We can quote among others SolidWorks Flow Xpress, SolidWorks Flow simulation, SolidWorks Simulation.

For this study we will use the SolidWorks Flow simulation module. This module is based on numerical flow simulation software based on the finite volume method and gives an overview of how a fluid will flow through the model. The flow simulation focuses on a single internal cavity with one inlet and one outlet, the openings must be plugged.

1) The greenhouse effect

The air around the base of the tower, naturally warmer than that at the top, has risen in temperature thanks to the greenhouse effect provided by the glazed surfaces and the calorie reserves stored during the day. [7]

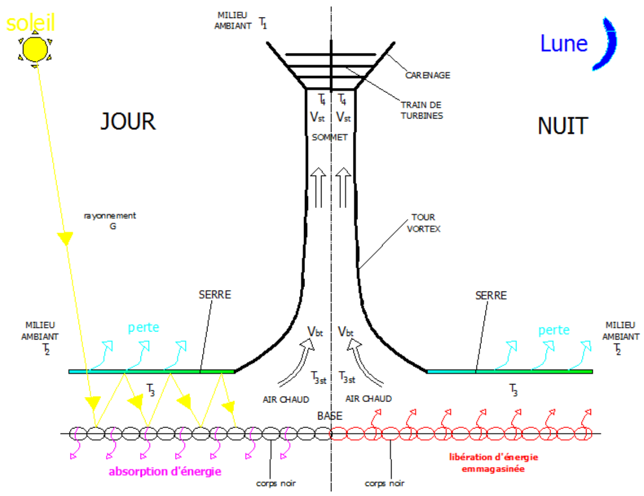

Figure** Error! No text of specified style in document.**-2 :** principle of transmisiion of energy to the vortex tower by the sun**[2]

2) Operation of the greenhouse by solar radiation

The greenhouse transforms the light rays incident on the glass surface into heat that is transferred to the air. If we refer to E: the solar irradiance; Q: the amount of heat transferred to the air; and A_ser: the surface of the greenhouse, it is possible to estimate and express the efficiency of the greenhouse (collector) by the following ratio:

$$\eta_{ser} = \frac{Q}{A_{ser}.E} \; or \; Q = \dot{m}_{bt}.C_p \Delta T_{23} \quad \textbf{(1)}$$

$$\Rightarrow \Delta T_{23} = \frac{A_{ser}.E.\eta_{ser}}{\dot{m}_{bt}.C_p} \quad \textbf{(2)}$$

Avec $\dot{m}_{bt} = \rho_{ser}.V_{bt}.A_{bt}$;

3) Thermodynamic cycle of the vortex tower

The operation of the wind turbine tower requires the presence of air, which transports the heat obtained by the greenhouse effect to all the devices capable of exploiting this thermal energy, transforming it into kinetic energy. The air comes out of the chimney, allowing the fresh air to be introduced at the base of the tower to undergo the next cycle. Therefore the air can be considered here as a working fluid of a cycle of a thermodynamic machine. The analysis of the cycle of the operating fluid of the solar chimney is made under the following assumptions:

- The point **1** represents the point of the atmosphere located at the top of the tower;
- The point **2** represents the point of the atmosphere located at the base of the tower;
- Point **3** represents the greenhouse;
- The point **3st** represents the base of the tower;
- Point **04** represents the top of the tower;
- Point **4** represents the turbine train;
- The operating fluid is dry air and it is considered to be a perfect diatomic gas;
- The heat flow in the system is the net gain through the air;
- The atmospheric conditions at the inlet and outlet are constant;
- The pressure difference ΔP23 in the greenhouse is zero (it is negligible compared to the pressure difference between the inlet and the outlet of the chimney);

The different transformations of the theoretical cycle of the vortex tower (see figure below) are:

- **1-2: Isentropic compression in the** atmosphere (Pressure and temperature increase in the atmosphere downwards);
- **2-3: Isobaric heating** in the greenhouse at the base of the tower by solar radiation;
- **3-3st: Isentropicexpansion** at the base of the tower;
- **3st-4: Isentropic expansion** at the top of the tower.

The actual cycle shows the losses generated in the different organs of the vortex tower. This cycle is used to determine the efficiencies of these organs and then determine the electrical power that the tower can produce. The diagram above illustrates the different processes of the actual vortex tower cycle.

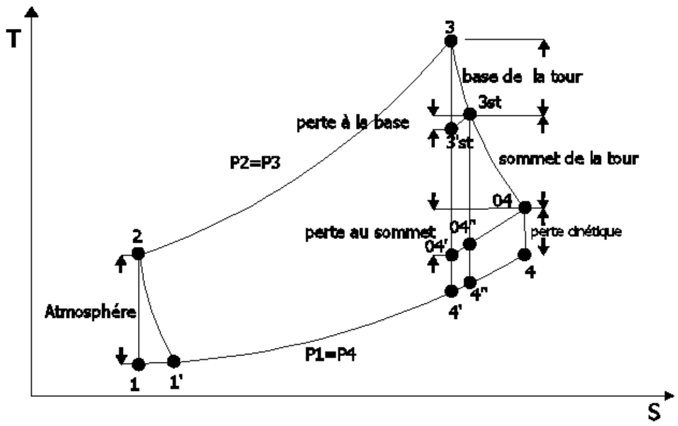

Figure** Error! No text of specified style in document.-**3 :** Thermodynamic cycle of the vortextower**[5]

The actual cycle shows the losses generated in the different organs of the vortex tower. This cycle is used to determine the efficiencies of these organs and then determine the electrical power that the vortex tower can produce.

The solar heat can be summarized by the following relationship:

$$Q = P_{solar} = \dot{m}.C_p(T_3 - T_2) = \dot{m}.C_p.\Delta T_{23} \quad \textbf{(3)}$$

The power developed between points 3 and 4 called P_(3-4) is not exploited in its entirety, there is an amount that is consumed between points 3st and 4 for the convection noted P_(3st-4) necessary to raise the air to the top of the tower.

$$P_{3-4} = \dot{m}c_p(T_3 - T_4)\ et\ P_{3st-4} = \dot{m}c_p(T_{3st} - T_4) = \dot{m}.\Delta h \quad \textbf{(4)}$$

The energy conservation equationis: $\Delta h = \partial w + \partial Q - g\Delta z$

For the transformation from (3st to 4) we have as a condition at the limit$\partial w = 0\ et\ \partial Q = 0$

$$\Delta h = -g\Delta z \leftrightarrow C_p.\Delta T = -g\Delta z \quad \textbf{(5)}$$

The enthalpy drop between points **3st** and **4** is the same as that between points **1** and **2.**

$$\Delta h = g.\Delta z = C_p.(T_2 - T_1) \quad \textbf{(6)}$$

$$P = \dot{m}.C_p(T_2 - T_1) = \dot{m}.C_p.(T_{3st} - T_4) = \dot{m}.\Delta h$$

The available potential convective energy (EPCD) of the air can be given by the following relation:

$$EPCD = \dot{m}.C_p(T_3 - T_4) - \dot{m}.C_p(T_{3st} - T_4) = \dot{m}.C_p(T_3 - T_4) - \dot{m}.C_p(T_2 - T_1) \quad \textbf{(7)}$$

Let the proportion $\mathbf{c} = \frac{\mathbf{T_2}}{\mathbf{T_1}} = \frac{\mathbf{T_3}}{\mathbf{T_4}}$replacing it in equations **(IV-2)** and **(IV-5)** we can define the efficiency η_c of the chimney between points 3 and 4 by the following relation:

$$\boldsymbol{\eta_c} = \frac{\boldsymbol{EPCD}}{\boldsymbol{Q}} = \mathbf{1} - \frac{\mathbf{1}}{\boldsymbol{c}}$$

Thus equation (IV-5) can be written as follows:

$$\Delta h = g.\Delta z = C_p.(T_2 - T_1) = C_p.T_2\left(1 - \frac{1}{c}\right) \Rightarrow 1 - \frac{1}{c} = \frac{g.\Delta z}{C_p.T_2}\boldsymbol{\eta_c} = \frac{\boldsymbol{g.\Delta z}}{\boldsymbol{C_p.T_2}} \quad \textbf{(8)}$$

If we consider that the available potential convective energy (PCE) is totally kinetic, then we have

$$EPCD = \frac{1}{2}\dot{m}V^2\ or\ \eta_c = \frac{EPCD}{Q} \Rightarrow \frac{1}{2}\dot{m}V^2 = \eta_c.Q = \eta_c.C_P\Delta T_{23}$$

This allows us to obtain the theoretical speedV_{bt} with which the hot air starts its ascent at the base of the tower:

$$\boldsymbol{V_{bt}} = \sqrt{\mathbf{2}.\boldsymbol{g}.\boldsymbol{\Delta z}.\frac{\boldsymbol{\Delta T_{23}}}{\boldsymbol{T_2}}} \quad \textbf{(9)}$$

4) VenturiEffect[3]

The "vortex" shape of the tower gives it the power and ability to create a significant depression in the tower. Indeed, under the following conditions:

The fluid in the pipe is incompressible;

The flow is in permanent and laminar regime;

Points A and B represent respectively the base of the tower and the top of the tower.

Then the law of fluid continuity SV=cte leads to the law of conservation of the air flow in the pipe.

:$Q_1 = Q_2 \Rightarrow S_AV_A = S_BV_B$

With$S_A = A_{bt}\ et\ S_B = A_{st}$:Respectively the sections of the base and the top of the tower

$V_A = V_{bt}\ et\ V_B = V_{st}$:Respectively the speeds at the base and at the top of the tower

Knowing the input speed at the base of the tower, previously expressed as theoretical ascending speed $\boldsymbol{V_{bt}}$; the section at the base of the tower and the section at the top of the tower we can therefore estimate the air speed at the turbine at the top of the tower by the following relation:

$$\boldsymbol{V_B} = \frac{\boldsymbol{S_AV_A}}{\boldsymbol{S_B}} \Rightarrow \boldsymbol{V_B} = \frac{\boldsymbol{D_A^2}}{\boldsymbol{D_B^2}}\sqrt{\mathbf{2}.\boldsymbol{g}.\boldsymbol{\Delta z}.\frac{\boldsymbol{\Delta T_{23}}}{\boldsymbol{T_2}}} \quad \textbf{(10)}$$

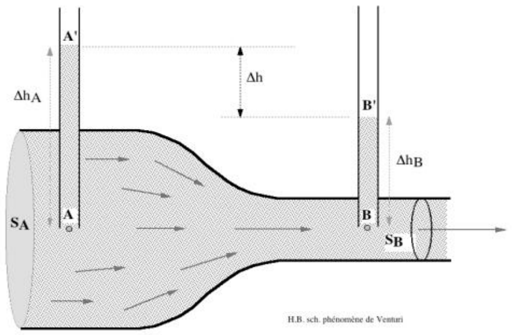

Figure Error! No text of specified style in document.**-4 :** Flow of a fluid in a variable section pipeline**[3]**

DEPRESSION INDUICED IN THE VORTEX TOWER

To establish the expression of depression we will rely on Bernoulli's relation based on the principle of flow conservation relative to the law of continuity of a perfect incompressible fluid.

According to the kinetic energy theorem, the variation of kinetic energy (ΔE_{cin}) is equal to the work of the external forces (W (fext)) applied to the system. [3]

$$\Delta E_{cin} = \frac{1}{2}\Delta m(V_B^2 - V_A^2) = W(f_{ext}) = W_{poids} + W_{f,pressi\,on}$$

$$\Rightarrow \frac{1}{2}\Delta m V_A^2 + \Delta m g h_A + P_A \Delta V = \frac{1}{2}\Delta m V_B^2 + \Delta m g h_B + P_B \Delta V$$

$$\Rightarrow \Delta P = P_A - P_B = \frac{1}{2}\rho(V_B^2 - V_A^2) + \rho g(h_B - h_A)$$

Using the results obtained in (IV-9) we can then write

$$\Rightarrow \Delta P = \rho g \Delta z.\frac{\Delta T_{23}}{T_2}\left(\frac{D_A^2}{D_B^2} - 1\right) - \rho g \Delta z \quad (11)$$

5) Coriolis strength

It is a force that deflects the trajectory of any moving object on the surface of a rotating object. It is a law of kinematics whose statement is relatively: *"any particle in motion in the northern hemisphere is deflected to the right and to the left in the southern hemisphere"*. The right is defined when looking forward of the displacement. It applies in particular to moving air and water masses by acting in particular on the direction of rotation of the wind in depressions (counterclockwise in the southern hemisphere) and in anticyclones (clockwise in the northern hemisphere). It is maximum at the poles and almost zero at the equator.

6) Conversion of kineticenergyintoelectricalenergiy

The turbine converts the kinetic energy of the air flow into mechanical energy, and the generator driven by the turbine converts the mechanical energy into electrical energy.

The mechanical energy developed at the turbine at the top of the tower is defined by

$$\Rightarrow P_{tur} = \frac{2}{3}.V_B.S_B.\Delta P \quad (12)$$

Either η_{tur} the efficiency of the turbine, we can then estimate the electrical power as follows:

$$P_{elec} = \eta_{tur} * P_{tur}$$

$$\Rightarrow P_{elec} = \frac{1}{6}.\pi D_A^2.\rho g \Delta z.\sqrt{2.g.\Delta z.\frac{\Delta T_{23}}{T_2}}.\left[\frac{\Delta T_{23}}{T_2}\left(\frac{D_A^2}{D_B^2} - 1\right) - 1\right]\eta_{tur} \quad (13)$$

III. NUMERICALSIMULATION

We are going to do dynamic simulations of the air in the tower using SolidWorks software. It will then be necessary to explain the mathematical equations that govern the fluid mechanics more particularly the equations used in the SolidWorks software. Then thanks to the latter we will study the energy behavior of several tower models in order to know its behavior with respect to its geometric characteristics (Height, base diameter, diameter at the top ...).

1) Fluidmecanics in*SolidWorks*

Before starting the numerical simulation of the air flow in the tower partially using a numerical simulation code, it is useful to specify what can be expected from such a method. The choice of using such a numerical method will depend essentially on the type and complexity of the problem to be solved: the nature of the fluid, the thermodynamic behavior, the modeling of the environment and the stationary or in-stationary problem. Numerical flow simulation codes, or CFD codes, solve the equations governing the motion of a fluid. These equations translate:

- The conservation of mass;
- The conservation of the quantity of motion of the fluid (Navier-Stokes equations);
- Conservation of energy.

2) Continuityequation (conservation of mass) [6]

This is the equation that expresses the law of conservation of mass for a control volume. The physical principle states that (except for nuclear reactions) the mass of matter is conserved. Therefore, a fixed volume V in space can accumulate matter or exchange matter with the outside, but cannot create or destroy it. Wethen have :

$$\frac{dM}{dt} = \frac{d}{dt}\iiint_V \rho dV = -\iint_S \rho v.ndS \quad (14)$$

The incompressible fluid density ρ=cste if we consider S_e and $S_s$respectively inlet and outlet section of the fluid the continuity equation can also be written as follows in the form of a volume balance :

$$\iint_{S_s} \rho v.ndS = -\iint_{S_e} \rho v.ndS \quad (15)$$

c

$$div\,v = 0 \Rightarrow \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \quad (16)$$

3) Equation of conservation of amount of movement

The principle of conservation of the quantity of movement makes it possible to establish the relations between the characteristics of the fluid and its movement and the causes that produce it. Where it can be indicated that the rate of change of momentum contained in the control volume is equal to the sum of all external forces (pressure force, weight, viscous forces) applied to it.

$$\frac{dP}{dt} = \frac{d}{dt}\iiint_V \rho \mathbf{v} dV = -\iint_S \rho \mathbf{v}.\mathbf{n} dS + \sum F_{ext} \qquad \textbf{(17)}$$

Avec $\sum F_{ext} = -\iint_S p\mathbf{n}dS + \iiint_V \rho \mathbf{g} dV + -\iint_S \overline{\overline{\sigma_v}}.\mathbf{n}dS$

$\overline{\overline{\sigma_v}}$. Is the stress tensor at the viscosity of air.

It is possible to derive partial differential equations, called local, linking the flow quantities at each point from the previous volume equations. Let us consider the velocity v (u,v,w) in the Cartesian coordinate system, we then have :

$$\begin{cases} u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}) \\ u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \nu(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}) \\ u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} + \nu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) + g\beta(T - T_o) \end{cases} \qquad \textbf{(18)}$$

4) Equation of Energy

The energy conservation equation is obtained from the first principle of thermodynamics. This principle relates the different forms of energy. It states that for a closed system:

$$\Delta(U + K) = W + Q \qquad \textbf{(19)}$$

Where U internal energy, K kinetic energy, W work of the external forces and Q the amount of heat exchanged. All these quantities are expressed in joules. This relationship should now be adapted to the open system. To do so, we just have to add the convective flow terms in the equation, we then obtain:

$$\frac{d}{dt}(U + K) = div\, \rho\bar{v}\phi + \dot{W} + \dot{Q} \qquad \textbf{(20)}$$

5) Equation of motion of a fluid

This equation is given in the context of real fluids in general by the Navier-Stokes equation which is written locally as follows:

$$\rho\left(\frac{\partial v}{\partial t} + (v\nabla)v\right) = -gradp + \rho g + \eta\nabla^2 v \qquad \textbf{(21)}$$

6) Boundary condition

- At the base of the tower the boundary conditions are those of Dirichlet: $\mathbf{u} = \mathbf{0}; \mathbf{v} = \mathbf{0}; \mathbf{w} = \mathbf{0}; \mathbf{T} = \mathbf{T_o}\ et\ P = P_o$;
- On the walls of the tower the conditions are : $\mathbf{u} = \mathbf{0}; \mathbf{v} = \mathbf{0}; \mathbf{w} = \mathbf{0}; \frac{\partial T}{\partial x} = \mathbf{0}\ ; \frac{\partial T}{\partial y} = \mathbf{0}$;

7) Finite volume method

Generally speaking, the finite volume method aims to define within the computational domain a network of points called nodes. Each node is surrounded by an elementary volume on which the partial differential equations previously established will be integrated. For two neighboring points, the respective control volumes must have a common side called interface. It follows that the combination of all the control volumes forms the computational domain. This is the calculationmethodused by SolidWorks.

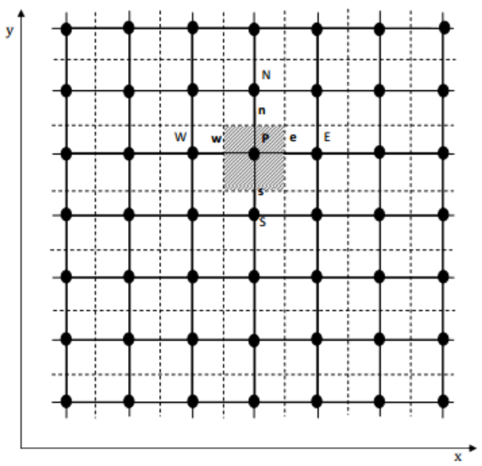

Figure IV 1: Calculation domain for a set of elementary control volumes

IV. RESULTS

We have a tower 300m high, a base diameter of 200m and a top diameter of 25m. We are here to observe the behavior of the air in the tower. The initial conditions are:

- The temperature at the base of the tower is Tb = 50°C;
- The pressure at the top of the tower is given by the ambient air pressure at the altitude Z=300m, i.e. P_{st} =101318,13 Pa;
- The pressure at the base of the tower is given by the relation of the perfect gases at the temperature T = 50°C or P_{bt} ==111699,57 Pa
- The reaction that occurs in the tower is adiabatic ;
- The density varies linearly with the temperature gradient T according to Boussinesq's approximation

$\boldsymbol{\rho = \rho_o(1 - \beta(T - T_o))}$

We will study the behavior of the air in the tower using CFD software called SolidWorks.

With all the parameters being recorded we can start the calculations. SolidWorks software will solve a system of partial derivative equations previously established. Weconsider :

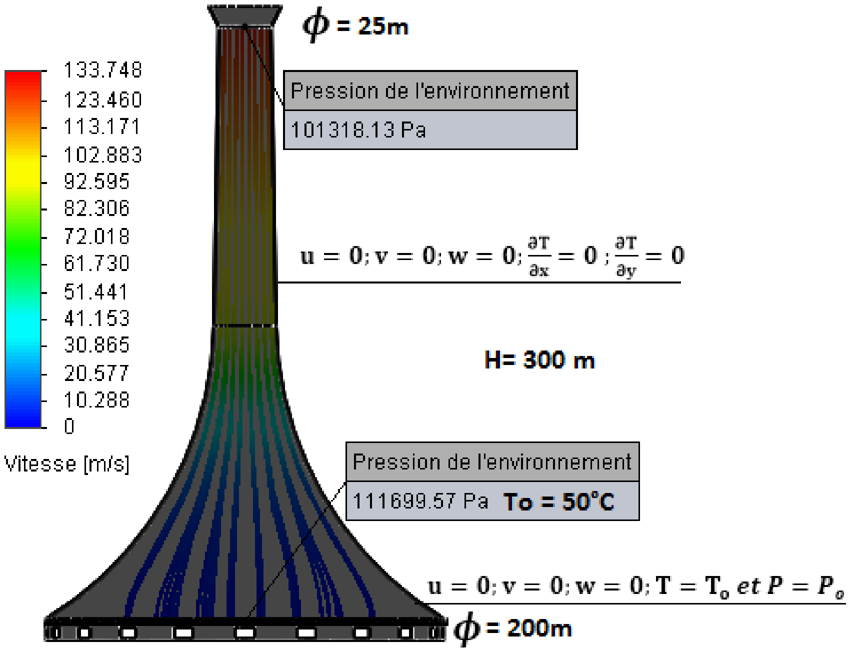

Figure IV 2: Current lines described by the air in the tower (temperature at the base of the tower 50°C)

We carried out several simulations by varying the temperature at the base of the tower. The results are summarized in the following table:

Tableau 1 : *Summary of thermodynamic parameters*

Tbase (°C)	25	30	35	40	45	50	55
Pbase (Pa)	103054,10	104783,19	106512,29	108241,38	109970,48	111699,57	113428,67
Pst (Pa)	101318,1372	101318,1372	101318,1372	101318,1372	101318,1372	101318,1372	101318,1372
Vmax(m/s)	53,877	76,352	93,763	108,578	121,745	133,748	144,845
Pelect (W)	2,4E+07	6,9E+07	1,3E+08	2,0E+08	2,8E+08	3,6E+08	4,6E+08

Tbase (°C)	60	65	70	75	80	85	90	
Pbase (Pa)	115157,76	116886,86	118615,96	120345,05	122074,15	123803,24	125532,34	
Pst (Pa)	101318,1372	101318,1372	101318,1372	101318,1372	101318,1372	101318,1372	101318,1372	
□P(Pa)	13839,627	15568,723	17297,818	19026,914	20756,010	22485,105	24214,201	
Vmax(m/s)	155,308	165,156	174,551	183,543	192,184	200,54	208,625	
Pelect (W)	5,6E+08	6,7E+08	7,9E+08	9,1E+08	1,0E+09	1,2E+09	1,3E+09	

We can then establish the evolution of the air speed at the top of the tower as well as the evolution of the available power as a function of the temperature at the base.
It should be noted that the power observed is the one that can be developed by the turbines at the top of the tower.

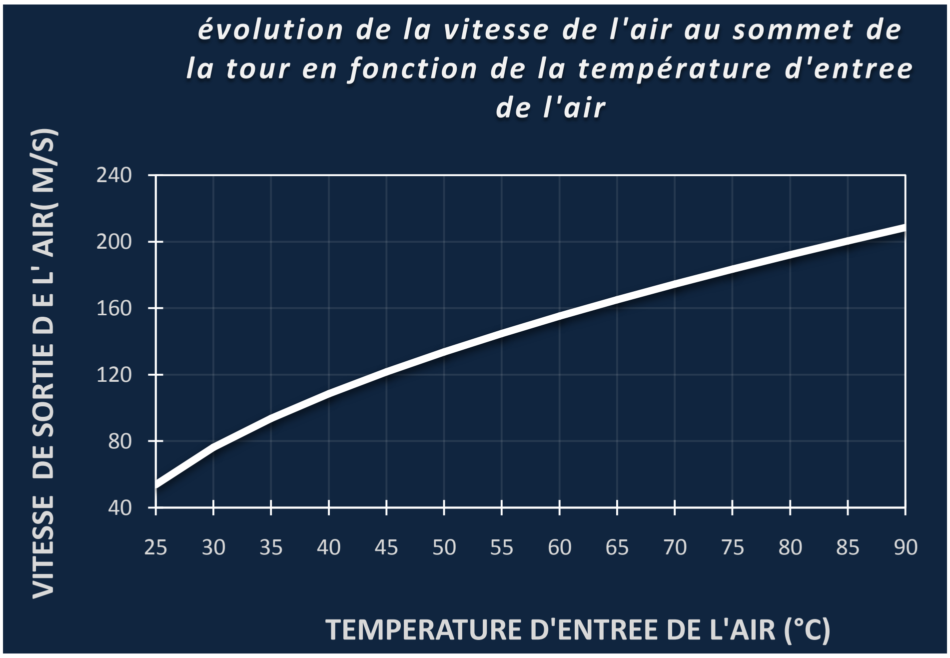

Figure IV 3: Evolution of air outlet velocity as a function of air inlet temperature

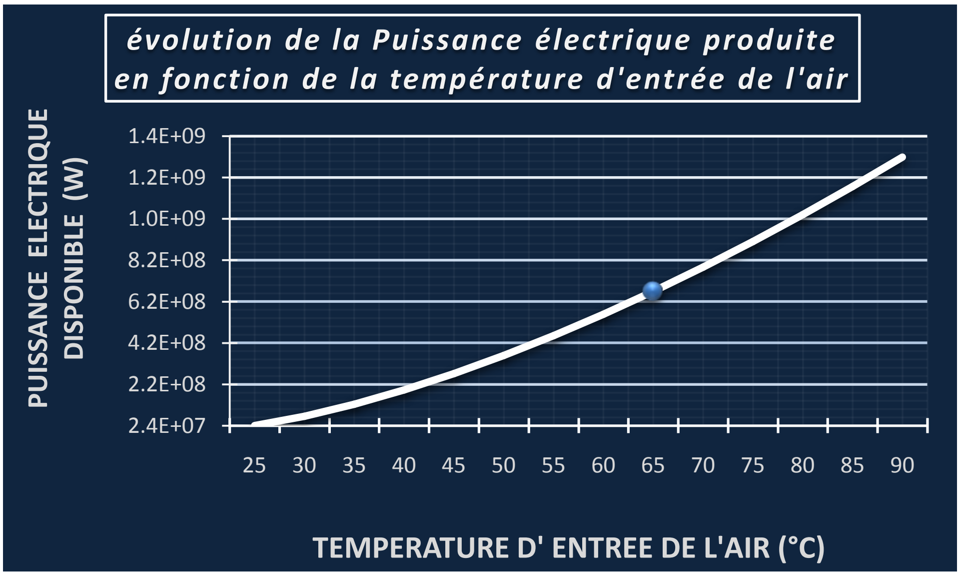

Figure IV 4: Evolution of the electrical power produced as a function of the air inlet temperature

Table 2: Thermodynamic parameter of the evolution of the power as a function of height

h(m)	200	300	350	375	400	450	500	550
T(°C)	25	25	25	25	25	25	25	25
Pbase(pa)	103054	103054	103054	103054	103054	103054	103054	103054
Psortie(pa)	101320,4	101318,1	101317,0	101316,4	101315,8	101314,7	101313,6	101312,4
Pmec(w)	3,058E+07	3,064E+07	3,068E+07	3,069E+07	3,070E+07	3,075E+07	3,087E+07	3,089E+07
Pelec (w)	2,447E+07	2,451E+07	2,454E+07	2,456E+07	2,456E+07	2,460E+07	2,469E+07	2,471E+07

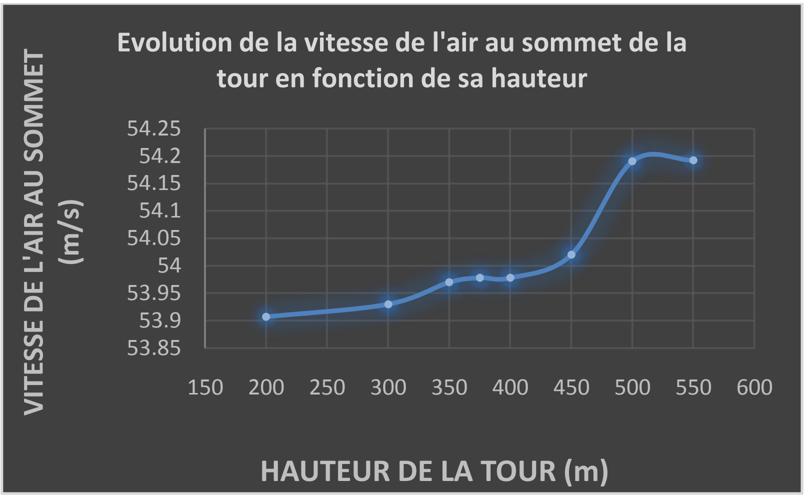

Figure IV 5: Evolution of air velocity at the top of the tower as a function of its height

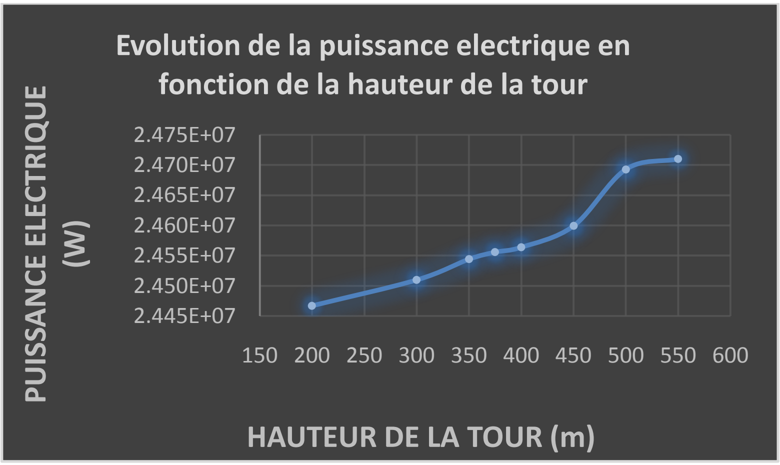

***Figure** Error! No text of specified style in document.-**5 :** Evolution of the power available by the turbines as function of the height*

<u>Interpretation</u>

In view of the observed results we can say that the air speed at the top of the tower and the developable electric power increase considerably with the temperature at the base of the tower.
As far as the height is concerned, the power increases very little with the height.

V. CONCLUSION

In short, this study aimed to make an energy assessment of a vortex tower by means of simulation in order to better study the evolution of the energy produced according to the geometric characteristics of the tower. To achieve this, we translated the physical and thermal phenomena that occur in a tower. Then we used for the simulations a CAD tool with fluid simulation modules (CFD). This simulation uses the laws of conservation of the quantity of movement, conservation of energy, Navier-Stockes laws etc... To predict the behavior of the air in the tower. From the results obtained by this simulation, we can say that hot and Sahelian areas such as desserts are good places for wind turbine towers to flourish since the developable power increases with the temperature at the base of the tower. It has also been noticed that the power of the tower varies very little with the evolution of the height when the other parameters remain fixed. While the variation of the base diameter has a very considerable impact on the producible power.

The construction of very high towers is no longer a myth. In fact, building materials are constantly being improved, and with the performance of today's computers it is possible to predict how a megastructure will behave under the stresses it has to withstand. Nevertheless, with the fact that the tower has a turbine placed at the top, it should be avoided that the vibration frequency of the turbine and the natural frequency of the tower do not coincide because this will make the tower resonate and cause its ruin.

The captive tornado cannot escape from it, as it gives most of its energy to the turbines, hence the name intrinsically safe vortex tower. Moreover, the device does not emit any gas, thus limiting environmental damage to a minimum. All reasons that should lead to a quick decision in favor of the development of wind turbine towers.

NOMENCLATURE

Symbole	Définitions	unités
η_{coll}	Collector (greenhouse) efficiency	/
η_c	Solar Chimneyefficiency	/
Q	Amount of Heat	(J)
A_{coll}	Collector area	(m^2)
G	Solar Radiation	(w/m^2)
E	Solar Illumination	(w/m^2)
ρ	Air Density	(kg/m^3)
ρ_{ser}	Air density in the Greenhouse	(kg/m^3)
$\dot{m}$	Mass air flow	(kg/s)
$\dot{m}_{bt}$	Mass air flow at the base of the tower	(kg/s)
V	Air Speed	(m/s)
A_c	Chimney Area	(m^2)
A_{bt}	transverse surface of the base of the tower.	(m^2)
T_2	ambient air temperature at the top of the tower	$(°C)$
T_3 (Tbase)	ambient air temperature at the base of the tower	$(°C)$
ΔT_{23}	Temperature gradient between the atmosphere and the greenhouse	$(°C)$
C_p	specificheatcapacity of air	$(J/Kg.°T)$
Δh	Enthalpydifference	(J/Kg)
P	calorific power	(J)
g	gravityaccelerator	(m/s^2)
D_A	insidediameter of the base of the tower	(m)
D_B	Inside diameter at the top of the tower	(m)
ΔZ	Tower height	(m)
P_A	air pressure at the base of the tower	(Pa)
P_B	Air pressure at the top of the tower	(Pa)
V_A ou V_{bt}	air speed at the base of the chimney (air inlet speed)	(m/s)
V_B ou V_{max}	air speed at the top of the chimney (air outlet speed)	(m/s)

V_{th}	Theoretical speed of air rise due to convection	$(\mathbf{m/s})$
EPCD	Potential convection energyavailable	(J)
Ec	kineticenergy of air	(J)
P_{Elec}	Electric power developable by turbines	$(\mathbf{w})$
P_{tur}	Turbine power	$(\mathbf{w})$
∂**Q**	The amount of heatexchangedduringprocessing;	
∂**w**	The workproducedduringprocessing	

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