BÁNKI KÖZLEMÉNYEK
1. ÉVFOLYAM 2. SZÁM

CFD Simulation of an urban environment for placing wind turbines

Városi környezet CFD szimulációja szélturbinák elhelyezéséhez

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Besides solar energy, wind energy is also a major factor in the aspect of "green energy" utilization that should be taken advantage of. In urban circumstances the flow of the wind is more predictable therefore it is worth to be utilized paying attention to various components such as impact on humans. Under the given conditions the goal is to obtain more benefit from this fluid energy. During the preliminary CFD (Computing Fluid Dynamics) simulations it have been concluded that the multi-rotor configuration is more effective than the single-rotor construction. Further measurements and simulations are based on the multiple impeller is situated in a given infrastructure.

Keywords: *wind turbines, CFD, urban environment, multiple impeller, energy, efficiency.*

A napenergia mellett, a szélenergia is egy meghatározó tényező a „zöld energia" hasznosítás szempontjából, amit használnunk kellene. Városi körülmények között a szél áramlása kiszámíthatóbb, ezért megéri kihasználni azt, figyelembe véve különböző körülményeket, mint az emberekre gyakorolt hatást. Az adott feltételek mellett a cél, hogy minél többet lehessen hasznosítani ebből a fluid energiából. Az előzetes CFD (Computing Fluid Dynamics) szimulációk során a több-rotoros kialakítás hatékonyabbnak bizonyult, mint a szimpla-rotoros, változat. A további mérések és szimulációk a több impelleres konfiguráción alapulnak, egy adott infrastruktúra elemre helyezve.

Kulcsszavak: *széltúrbina, CFD, városi környezet, több járókerék, energia, hatékonyság.*

1 INTRODUCTION

Nowadays, if we meet the phrase: green energy or renewable energy, may think about the solar panels that utilizes the power of the Sun. But beside solar panels wind turbines are also taking a major part of utilizing green energy. If wind turbines are mentioned, people may think about the huge ones that are far away from inhabited area.

These huge turbines, which blades are 20-60 m long, ale to generate approximately 5 megawatts power. This is sufficient to supply energy to a larger office building. There are examples for big size urban wind turbines like in Toronto, a 30 floor-high lakeshore wind turbine is able to supply 250 houses with energy.

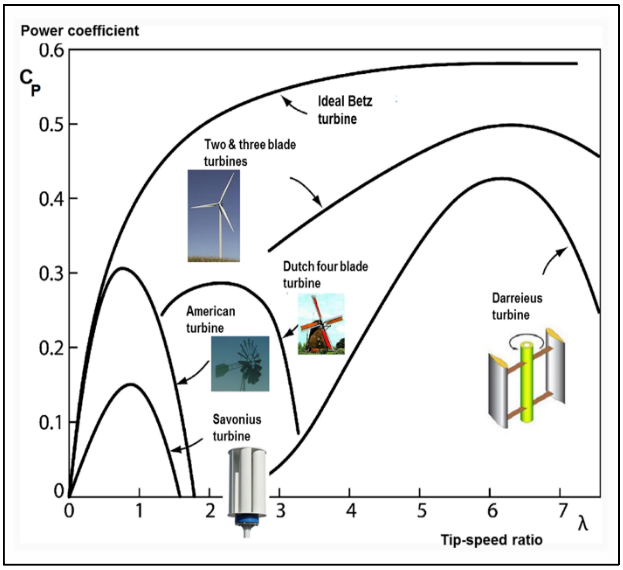
The project WEB (Wind Energy in Built Environment – „Szélenergia az épített környezetben"), funded by the European Commission, suggests that it is acceptable and economical to design or supply a building with wind turbines if at least 20 % of the electricity need of the building are covered by the wind utilization. Of course, square buildings, for example, reduce efficiency due to flow breaks and turbulence. With the aid of edgeless, rounded surfaces or flow passages, the flow of wind must be directed towards the rotors. [6]

1. Figure: Different type of wind turbines are on different infrastructure elements. [4], [8]

My goal is to bring these turbines in the cities in a smaller form and taking advantage offered by the streets. This topic is very complex, one of the stages is the simulation of the flow of the wind turbines.

In order for a wind turbine to work in an urban environment, must meet a wide variety of requirements. First of all, it must not to induce bigger noise than the wind. The interfering effect and its spread are also influenced by the frequency of the noise. Another important thing is the sight. In densely populated areas, many people my feel anxious as a result of the not suitable sight. Therefore, they will do the utmost to prevent this development. Many people are afraid of wildlife, birds from its effects.

Most of the world's energy consumption is spent on energy-supplying buildings (40%). The average annual consumption of an average family house is approx. 4000 kWh, the heating, cooking and heating of water demand is approx. 10000 kWh, this is a total of 14MWh a year. The average wind speed in Hungary is 4-5 m/s and the windy days are 70-80 days a year. All this can be said to be modest but 1500-2000 kWh energy per year can be produced for a family house. [2,5]



2. Figure: Dependence of the power coefficient and tip-speed ratio.

2 UBAN WIND TURBINES

The importance of renewable energy sources is unquestionable. The wind energy is one that has potential opportunities. Many types of wind turbines are known and their appearance in cities is no longer surprising (1. Figure).

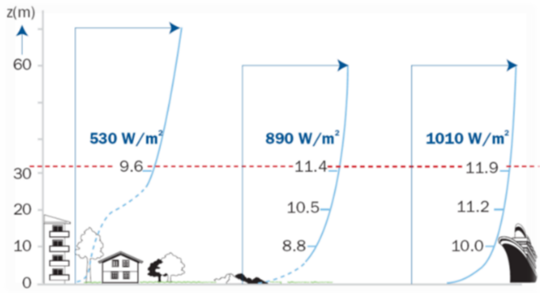
There exist many concepts of how these turbines should look and be situated in the best case scenario. Over the years of using different kind of renewable energy utilizing devices (solar panel, solar water heating systems and wind turbines) community energy consumption was established. The main idea is to share the energy utilizers among associated families and/or neighbours resulting decreased individual costs of the material, installation and others but the benefit is higher. Wind turbines that are able to be placed within an inhabited area, could be an alternative choice to these communities.

2.1 *Principle*

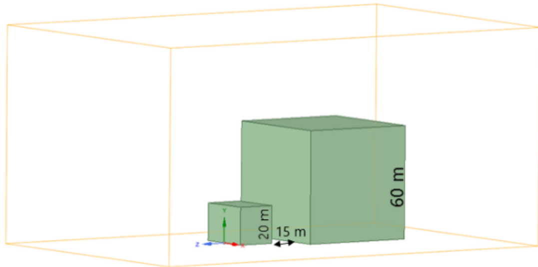
Many type of wind turbines are existing and these are differentiated by their dependence of the power coefficient and tip-speed ratio (2. Figure). The power coefficient is the ratio of the extracted and the wind power. The tip-speed ratio is the ratio of the speed of the rotor circumference and the speed of the wind. According to the Betz-theory [9], in ideal case the maximum extractable power is less than 60% but in real cases the loss is even higher.

Other influencing factor is the environment where wind turbines are being placed. In usual case these are located far away from inhabited areas, in the middle of a meadow or are installed in the sea near to the seashore. The purpose is to minimize the barriers against the wind flow helping to evolve as high velocity of the wind as possible, sufficient and safety, to increase the amount of the extracted power.

In urban circumstances the flow development (compared meadows) is blocked by different obstacles and buildings therefore a lower average wind speed can be achieved at the same height. However, the case can be advantageous: the wind direction could be easier to predict so a smaller wind utilizer can be placed but in a more efficient way. (3. Figure)



2. Figure: Wind speed profile in different environments



3. Figure: Prepared model for CFD simulation

3 SIMULATION

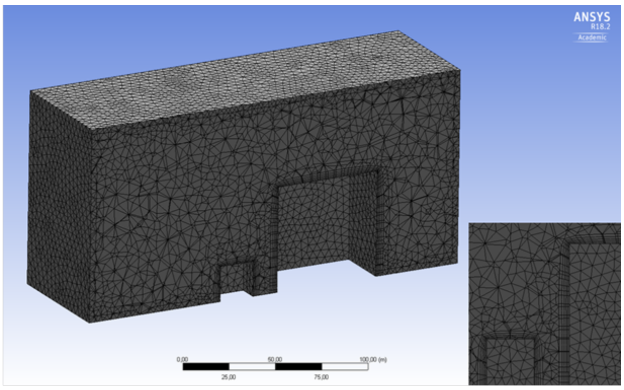
To investigate on the concept, ANSYS CFD simulation software was used. Computation Fluid Dynamics is based on the finite volume method, means that the 3D model is discretized and computation is made for each element.

3.1 *Simulated environment*

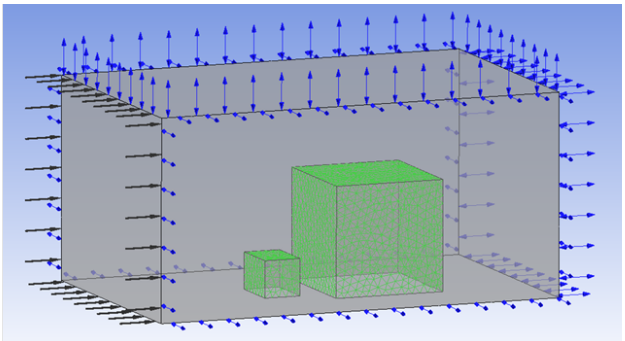
By creating a computer simulation, examine the flow conditions in the surroundings of buildings. This phenomenon was placed in a virtual environment. In the present case, the selected building geometries are a multi-storey 60 m high office building, with a 20 m tall lower building in front of it. The distance between the two buildings is 15 m. The created model for the simulation is shown in 4. Figure.

3.2 *Meshing*

For the software to execute the simulation, need to break down into smaller parts therefore a proper mesh has to be created. There are several options for grid making. In this case, the mesh was made from tetrahedron elements. At the end of the task, it is possible to evaluate quality if necessary to change to make more proper. In order to make the calculated value more accurate along the walls of the buildings, inflation has been made. (5. Figure)



5. Figure: Meshed geometry with inflation



6. Figure: Definied boundary conditions

3.3 Boundary Conditions

It is known from the literature, that the wind produces excessive pressure on some surfaces of the attacked building, and on other surfaces. Wind speed is largely determined by local factors, depends on the terrain, the surface coverage and other obstacles in the given environment (trees, buildings, bushes, etc.)

In the first case, wind direction is assumed to be perpendicular with constant speed of 3 m/s as an average wind speed in dense cities. Other surfaces are defined as walls and openings. (6. Figure) In the future, second case wind profile power law relationship will be given as an initial condition (1), where:

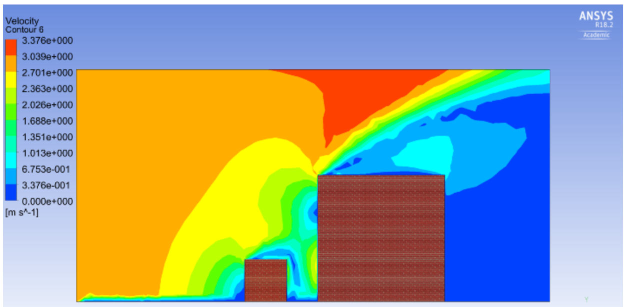
$$\frac{v}{v_r} = \left(\frac{h}{h_r}\right)^{\lambda} \tag{1}$$

$\boldsymbol{v}$ is the wind speed *[m/s]* at the height of $\boldsymbol{h}$ *[m]*, $\boldsymbol{v_r}$ is the known wind speed at a reference height $\boldsymbol{h_r}$ and $\boldsymbol{\lambda}$ is a coefficient that depends on the surface structure and the equilibrium position of the atmosphere. [3]

If the different fluctuations and irregularities are taken into account, this turbulent flow is described by Navier-Stokes equations and the continuity equation. The turbulence model is used by the SST, which combination of *k-ε* and *k-ω* models, so that, away from the boundary layer turbulent viscosity is calculated from the *k-ε* model while near the wall *k-ω* is used.

3.4 Results

At the end of the simulation, the results were evaluated. A complex turbulent flow develops around the buildings. The nature of the flow is greatly influenced by the separation of the boundary layer, which can be occurred when the pressure increases in the direction of the flow along the solid wall. From the result of the simulation, it is clearly visible that there is a separation bubble above the building. Above the separation bubble there is a flow zone where the wind speeds up (red area). If the wind turbines are placed in this zone it is expected that the rotor will reach the wind at a higher entry speed than in any other zone, even in the undisturbed zone. (7. Figure)

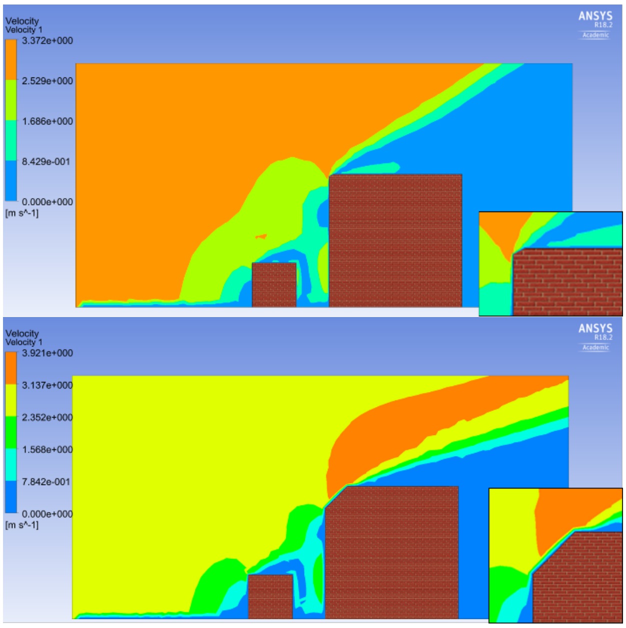


7. Figure: Velocity change of the wind flow in the simulated environment.

3.4.1 Further experiments

By modifying the geometry, possibly, the accelerated flow zone moves to a more advantageous position in the perspective of placing the turbines.

Therefore, by chamfering the top-face edge in different ways, two cases were created. First is a small, asymmetrical chamfering by 1-2 m, the second is a bigger, symmetrical by 5 m. It is shown in the 8. Figure, this approach could be a beneficial way in view of placing and utilizing wind turbines. Not least, safe and simple placement of the turbines is also an important viewpoint. In future examinations this modified geometry will be used with the wind speed exponential function (1).



8. Figure: Modified building geometry: asymmetric (upper), symmetric (below)

4 Conclusion

Computer simulation, as a tool, was carried out to investigate the flow around buildings. The aim was to underline the fact that, in certain circumstances, consideration should be taken into to utilize wind conditions at the top of buildings, for this, placing wind turbines in the region of interest, may offer a positive result. The future goal is to investigate the effectiveness of wind turbines in this environment and, last but not least, the impact on human health and comfort.

There are, of course, many kind of strategies that cities can use in the future. Utilizing the benefits of wind power, developing ‘clean’ transport technologies, expanding public transportation and increasing energy efficiency in buildings are solutions that cities can continue to explore. Depending on settlements, climates, existing infrastructures and available resources, different cities are likely to use different approaches to handle their energy needs and reduce their carbon footprint.

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