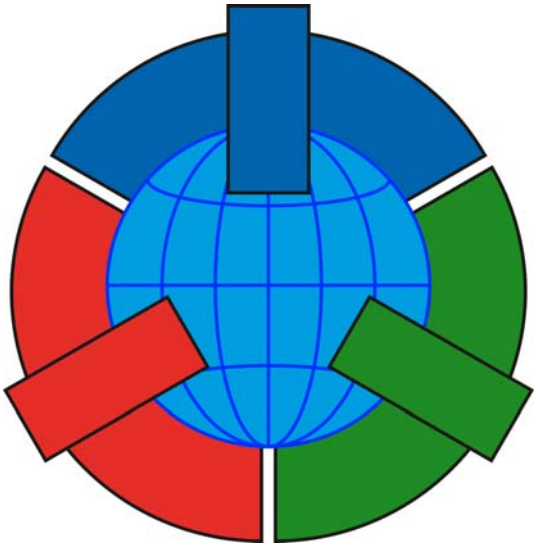

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Sokobanja, Serbia, October 20–23, 2015

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Contents

Architectural strategies of wind turbine implementation in buildings and the urban environment

Sanja Spasić Đorđević[a], Hristina Krstić[b]

[a] *Faculty of Civil Engineering and Architecture, Nis, Serbia, sanjaspasic@ymail.com*

[b] *Faculty of Civil Engineering and Architecture, Nis, Serbia, hristinaa@hotmail.com*

Abstract: Exploitation of wind power in urban areas is a new idea in which, in the last few years, architects are very interested in. The growing need to improve the environmental performance of buildings and life environment in general, leads to increased need of architects for the projects which rely on the use of renewable energy. In addition to the use of solar energy in urban areas, a new idea is the implementation of wind turbines in architectural projects. This idea needs to meet in the first place ecological, but also technical and aesthetic characteristics in order to become applicable in practice. The paper deals with different strategies of implementation of these solutions and also with analyse of examples in practice.

key words: *wind, turbins, architecture, energy, buildings*

Corresponding author: Sanja Spasić Đorđević, sanjaspasic@ymail.com

1.0. Introduction

Energy efficiency is a wide range of activities that aims to reduce consumption of all kinds of energy, with increasing use of renewable energy sources. Most often when we talk about renewable energy we think of solar energy, however, it includes also wind energy, biomass and geothermal energy. In recent years, an increasing number of studies is dedicated to wind energy and its exploitation.

The electricity we use today is harmful due to emissions of gases that have a negative impact on the environment and human health. In the fight against climate change and improving the life environment, a growing number of architects and engineers got into the studies about how to reduce the percentage of electricity use in urban areas. Of course, depending on the intensity of the wind, this strategy is not applicable everywhere. However, the development and improvement of the performance of wind turbines makes implementation possible in windy environments. During the implementation of wind turbines, three important steps must be taken into account:[1]

- Wind flow in a constructed area must be estimated
- Optimal way of installation of wind turbines must be chosen
- The third important step is research on the impact of solution on the environment, research of economic viability and feasibility study which must be done.

[1]Abohela I, Hamza N, Dudek S: Urban wind turbines integration in the built form and environment, FORUM Ejournal 10 ,June 2011

Following these steps architect comes up with the answer is the implementation desirable in the present case.

This reasoning raises a number of questions: Does this kind of savings can impair the living space of man and other living beings? Does the implementation is losing the aesthetic factor in the design of buildings? Is the implementation only possible with the newly designed solution or it can be adapted to the existing condition? In this paper we will try to answer on all of these questions. Also through analyses of the examples that have already been built in the world, we will observe how the implementations are done but also whether this form of energy use can lead to cost savings. The aim is to highlight the positive and negative aspects of the use of wind turbines in urban areas.

2.0. Application of wind turbines in architecture

Wind energy has always attracted the attention of researchers who wanted to make it useful and therefore helpful. First, the conversion of wind energy into mechanical work was used for sailing and later for windmills. In the last decades of the twentieth century that wind is proved as an important resource for generation of electricity. "Wind farms" became popular in recent years. A large number of wind turbines to each other, in areas of strong winds is an efficient way of distributing electricity. With advances in technology and new tendencies towards the preservation of the environment, an increasing number of architects is involved in researches about the most efficient way to implement wind turbines in buildings and urban areas. Implementation would reduce the need for use of electricity and would enable energy production to be carried out on the spot (ie. on the parcel). This would be leading to a reduced need for expensive transmission systems - infrastructure. This also reduces the losses in transmission, and the amount of material required (cables, poles, etc.). As another advantage of this approach in the design concept of the architecture of an object must be mentioned clearly and visually expressed the view that the owner of the building is dedicated to the preservation of resources and planet for itself.

Figure 1. Landscaping stand-alone wind turbines in urban locations, http://www.alternativeconsumer.com

Figure 2. Retro-fitting wind turbines onto existing buildings, http://www.pljgroup.com

Figure 3. Full integration, http://inhabitat.com

This case we do not have with the solar panels because they often cannot be visible from the street while generating electricity. In some cases, in addition to the benefits that we get from the use of wind turbines, by installing wind generators the facilities can get more original and aesthetic impact. If the project meets the technical, aesthetic and environmental factors we can consider it as a success.

Three main strategies for the implementation of wind turbines on buildings in urban areas are:[2]

- Landscaping stand-alone wind turbines in urban locations (Sl.1)
- Retro-fitting wind turbines onto existing buildings
- Full integration, such that the wind turbines drive the architectural form

The first strategy is possible in areas that have high levels of population, while the second strategy is for high buildings due to better wind flow. In the third case, the integration is done by placing wind generators on the tops of the buildings, on the sides of the facades but also at the voids which are projected within the building.

When it comes to systems of large buildings that should receive high gusts of wind, the implementation have to be carried out at the earliest stage of the project. Besides from technical characteristics: size of the turbine and RPM, which are subjects for research from the side of engineers, architects approach the solution by analyzing the position of the building at the location, its shape and orientation of the object. For smaller systems best for use are horizontal and vertical axis turbines, which can be installed in a later phase of the project too.

However, the use of wind energy in urban areas is faced with major problems that need to be thoroughly analysed and solved during implementation.

2.1 Difficulties with implementation of wind turbines

Every innovation as itself brings with it some risk and problems. The biggest obstacle that arises in integrating architectural facilities and wind energy is low profitability. While large independent turbines provide the cheapest electrical energy, small wind turbines are less profitable, and therefore are not always alluring choice to users as opposed to solar panels. With the use of wind energy in urban areas it is necessary particular attention to be paid to the following problems:

- Noise and vibration of wind turbines are the most common obstacles to their integration in architectural and urban planning projects. The problem of noise generated by the rotor blades can be reduced by changing their design, while the noise from the electrical generator can be minimized with good sound insulation within the turbine head. The vibrations are more intensified when the turbine is raised to a pillar standing on the roof of the building. In this case, there can be a harmonious resonance in the house. To prevent noise and vibration it is necessary to take into account the materials from which the facility is built. Less noise is generated by wind turbines with a vertical axis.

- Air flow problem is more pronounced in urban areas then at free-fields, that are reserved for "wind farms" normally. In such environments the existence of wind is linear and all flows going in one direction. In urban areas, the flow of wind encounters various obstacles (other buildings, green), which leads to the stream breaks and it operates in several different directions. This separation creates turbulence that affect the efficiency of wind turbines. During the implementation of wind turbines in the architectural structures it is necessary to examine the environment and depending on the height of surrounding buildings to assess the best position for placing turbines.

- Safety for the environment is another of the problems that occur during installation. There is a risk that some of the blades, under the strong gusts of wind, a flight of birds in the turbine or under the influence

[2] N. Campbell, S. Stankovic, M. Graham, P. Parkin, M. van Duijvendijk, T. de Gruiter, S. Behling, J. Hieber, M. Blanch, ”Wind Energy for the Built Environment (Project WEB)”, European Wind Energy Conference & Exhibition, Copenhagen, 2-6 July 2001.

of another element, detach and fall. With "wind farms" such a risk also exists, but because they are located in unpopulated areas, the fear that people would be injured is minimal. This is one reason why the majority of investors do not opt for this type of deployment.

3.0. Applied strategies for implementation of wind turbines in architectural projects

There are many examples of the implementation of wind turbines in architectural objects in the world. The paper contents analysis of several examples which had undergone the full implementation. Such examples have a great impact on architectural projects because setting up of wind turbines requires additional analysis of the location, form and materials from which the facility is built. In Serbia, these examples are still lacking.

3.1. Bahrain World Trade Center

World Trade Center in Bahrain (Figure 4,5) is one of the largest facilities of an independent renewable energy sources. It is characterized by three wind turbines, solar collectors covering more than half of the facades of both multi-storey buildings, as well as energy-saving materials used in construction.

Figure 4. Bahrain World Trade Center, wind turbines, http://inhabitat.com

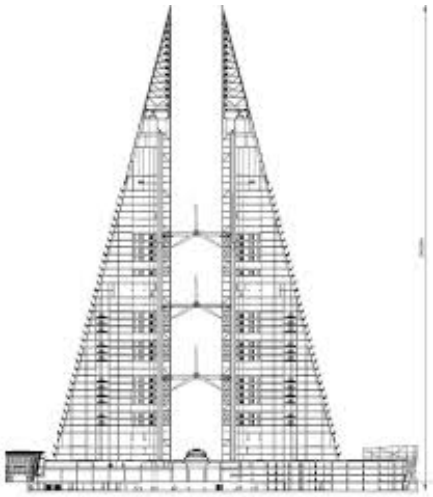

Figure 5. Bahrain World Trade Center, http://www.atkinsglobal.com/

The most impressive innovation in this project is the implementation of wind turbines. Wind turbines are mounted on the walkway between the two multi-storey tower whose height reaches 787 meters. The towers are connected with three gangways and on each of them has one wind turbine diameter of 39 meters, which is designed to convert mechanical energy into electricity. The capacity of each turbine is 225kVA. These wind turbines operate roughly 50% of the time and provide 11% - 15% of the entire structures total power consumption (1.1-1.3 MWh / year). Weather in Bahrain are variable, abundant periodic droughts and dust storms occur, and the design of turbines adapted to such conditions. The turbines are designed to automatically adapt to the weather, in order to avoid any damage due to unstable wind power.

Wind turbines are set between objects, whose rounded form reduces contributing to air flow. As the wind speed varies with increasing altitude, the architects have developed a strategy which is designed conical shape of the object which satisfies the relationship building height and wind speed. In this way, implementation is influenced building in aesthetic terms, but did not alter his appearance. As a downside of

this implementation the negative impact on the environment (birds) can be pointed out, but also the possibility of falling of the blades which endangers the safety of passers-by.

3.2. The Pearl River Tower

The Pearl River Tower (Figure 6.) was built in 2012 in China. As with the previous one, in this example, the form of the building is designed to direct the flow of wind to places turbines are installed. Unlike the previous example, it was used.

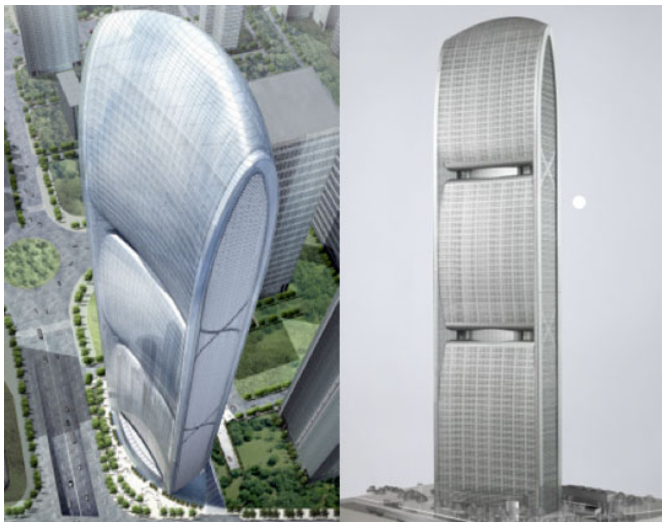

Figure 6. The Pearl River Tower, http://inhabitat.com

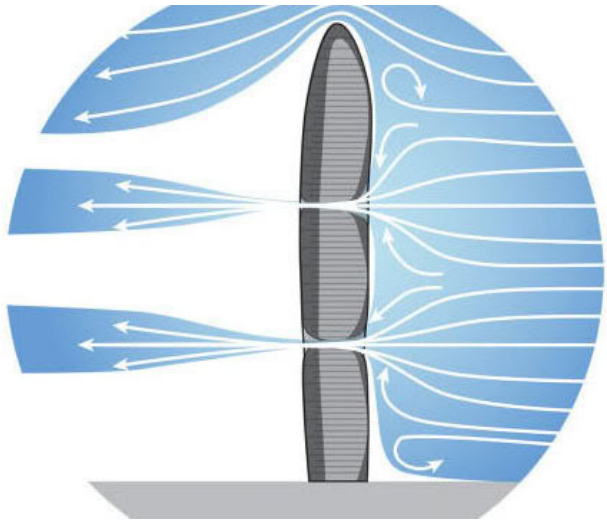

Figure 7. The Pearl River Tower, "wind tunnel" http://inhabitat.com

In Bahrain World Trade Center building is set with narrow side toward the flow of the wind in order to reduce the exposed surface. It is not the case with Pearl River Tower. Skyscraper is projected to have a rectangular shape with a curved front facade. There are four slots that penetrate the building structure and make the "wind tunnel" (Figure7.). Four wind generators are placed in these tunnels and having a vertical axis (propeller in horizontal position). Wind turbines are located on two floors. When it comes to the wind strike, the air strikes in the building and running the facade to find its way and to avoid the obstacle. This attack, causes turbulence that is softened when the air reaches the edges of the object. Part of air that hits the object is brought to the tunnel, accelerates as it passes through the reduced space of the tunnel, it starts wind turbines and comes from the other side of the building with full its strength. The negative side in this example is that it relies on the fact that the wind effect on the object always come from the same direction, so that energy production is reduced when there is a side impact. However, unlike the previous example in Bahrain, negative impact on the environment in the Pearl River Tower is reduced. This is because the wind turbines are placed in the tunnel.

3.3. An incomplete objects

In this chapter will be presented projects where wind turbines are planned to be implemented, but they are not implemented yet. Different implementation strategies have been applied that influenced on object shape as well as on environmental characteristics.

- Taiwan Tower (Figure 8.): This building was conceived as a skyscraper with cover around it in which are housed wind turbines. Unlike the previous two examples where the setting up of wind turbines influenced on the orientation of the objects, in this model this is not the case. Wind turbines are placed on all sides of the building and there are 600 of them. They are supposed to produce 6 megawatts of electricity. In this way a great effect will be gained, as well as noise reduction caused by use of small wind turbines, and the facility comes to the form that still has not been seen in architecture.

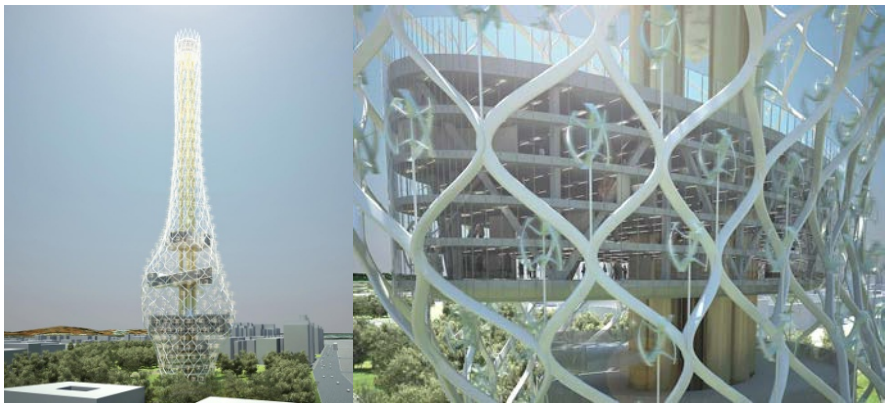

Figure 8. Taiwan Tower, http://www.designboom.com

Figure 9. Miami COR Tower, http://www.archdaily.com/

- Miami COR Tower (Figure 9.) is yet another example of a skyscraper in which wind turbines are applied. The method used is similar to the principle of integration as in the previous example. It is based on using of cover of building made with openings in it where wind turbine is placed. However, the main difference is that it is applied to a much smaller number of wind turbines and they are located only in the upper parts of the building. This allows a clear view from the windows of the building and the strongest wind strikes are more likely to be used because wind turbine is located at a high altitude where winds are much stronger. This is yet another object in which the implementation of wind turbines is planned to satisfy all aesthetic and technical characteristics.

- The Gate Residence (Figure 10, 11): Unlike all previous examples, this object is not a skyscraper but the entire eco-village in which wind turbines are implemented. Wind turbines are implemented in environment around buildings as well as in buildings as them self.. They are placed on the roof of the buildings and also all along the streets that follow the objects. According to technical calculations this system with additional solar panels can produce sufficient electricity for the entire settlement. As in example of Taiwan Tower, vertical axis wind turbines were applied also here.

The turbines are designed in the way that smaller ones are placed on rooftops in order to reduce noise in the houses, while along the streets wind turbines of larger capacity are placed and lifted off the ground on several pillars in order to avoid obstacles that can slow down and degrade wind and reduce efficiency. If this project was implemented, this facility would become the most complicated architectural structure with wind generators.

Figure 10. The Gate Residence, http://inhabitat.com

Figure 11. The Gate Residence, http://inhabitat.com

4.0. Conclusion

The continuing architects need to improve living environment and environmental performances of buildings leads to increased exploring of the use of renewable energy sources. The paper presents the basic principles by which are the architects guided when the implementation of wind turbines in architectural projects is in question. It also pointed to the problems that can arise during implementation, but also analyzed examples that have already been built in the world.

From presented examples we can conclude that in the examples which are already built, wind turbines were used cautiously, while in the unbuilt examples we can notice new unseen methods which are not enough researched yet. When it comes to the use of wind energy in urban areas, certain amount of hesitation still exists. As we noted in the paper, the main reason for this are certainly problems that occur during this procedure, the second reason, perhaps more important, is that this is still an expensive investment. Investing in something complex like this is always a risk. By the losses could occur if the wind force is not constant, or even if the wind changes direction. Architects have found a variety of solutions in order to prevent such cases, however, it is still not enough of them to make use of wind generators in urban areas started to implement regularly.

Implementation of wind turbines in urban areas requires the involvement of different professionals such as mechanical engineers, urban planners, architects, and all those who are directly involved in the building where is implementation in process. When it comes to the implementation at the already built facility, that includes the city government to give the green light that such a facility cag wind n be implemented, but also the people who will live in this house. On the aesthetic side implementation of already constructed facility often spoils the appearance of the object and the initial idea of architects. In urban projects for the main town nucleus we have rarely met with the strategies of application of wind turbines. Important condition for implementation of wind turbines is great height for placing wind turbines. If you lift the wind turbine at a great height, it further requires a large area of the grounds for doing so and in this way usable area is making smaller. Therefore, this method of implementation of wind turbines in urban areas is least developed.

Most often when we speak about the full implementation, high towers are planned from the start and at the tops of buildings places are reserved for wind turbines. This principle we could have noticed in in the analyzed examples in this paper. Also, full implementation is rarely about implementation of just one type of renewable energy. The most often used methods are implementation of solar panels, green roofs, integration of the architectural principles of saving, such as the impact on the shape of the object, the materials, the position and orientation of the object.

Finally, we can conclude that these are only initial steps, developing of new systems for checking the security of these solutions can lead to an increasing use of wind turbines in architecture. Based on the examples we have to conclude that wind turbines can be implemented in facilities in the way to meet the aesthetic and functional characteristics.

5.0. Literature

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