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Wind Turbine Concepts for Energy Efficiency in Buildings

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Abstract

This paper presents the various wind turbine technologies for energy management in buildings. Zero energy buildings are the buildings in which the total energy consumed by the whole building will be equal to the total energy that is produced or generated by those buildings using renewable sources of energy. The structure of building includes the wind turbines in its structure only so that the wind that is passing in the environment of the building can be used for energy generation purpose also for the building. This paper is emphasis on the zero energy buildings for development of the nation. Further, Building augmented wind turbines installed between two buildings are also discussed briefly in the manuscript.

Introduction

Conventional or non-renewable sources of energy are used since very long time as the sources of electricity. These Sources are not clean in nature. This means the sources emit carbon monoxide and create pollution to the environment. Along with this the non-renewable sources are limited. Due to these limitations of non-renewable energy sources, the focus of people is shifting from non-renewable or conventional energy sources to renewable or non-conventional sources of energy. People are moving towards renewable sources to save the conventional one for future use and save the environment from the impacts of non-renewable sources. Techniques and designs regarding the renewable sources are being developed. Renewable sources are those sources which are not conventional and are not being used before the time. Renewable sources include sun, wind, water, geothermal energy etc [1].

Using these sources as major sources of energy has become the need of time. To establish these sources are major sources for overall energy supply, various researches and developments are required. By using renewable sources, we are saving the environment from the pollution and also we can save the energy. So, energy conservation can also be one motivation for using renewable sources to produce energy.

Wind as a source of energy has become very popular and is continuously growing since last decade. The technologies and research work regarding wind turbines and wind energy generation are getting developed in fast rate. Many programs are started which promote the use of wind energy for energy generation. Incentives are provided for that. By this the energy market of wind has also increased levels. Apart from other sources the utility side generates electrical energy using wind energy and supply this electrical energy to other utilities or consumers. But the level and popularity of wind energy has risen so much that the wind energy is used by consumer side also for power generation. Small scale wind turbine technologies[2]-[8] are used for electricity generation at small level. Consumers can install wind turbine based plants on the rooftop of their buildings, homes or in front of the homes, buildings in open area etc. Simply, this can be said that the contribution of wind energy to the overall energy supply is very significant.

A lot of energy can be saved if the users install wind turbine based power plant on or in their buildings, homes etc. Energy conservation plans also promote the use of small wind turbines technologies. This initiative can take us towards zero energy building. Zero energy buildings are the buildings in which the total energy consumed by the whole building will be equal to the total energy that is produced or generated by those buildings using renewable sources of energy. So, putting up solar panels on the rooftops of the building, solar water heaters or putting small wind turbines on or in the buildings, can lead us to the creation of zero energy buildings.

In coming days, if we continue to use renewable sources of energy for energy production and we stop relying on conventional sources, we will be saving a huge amount of conventional sources as well as energy for future use.

Development in the wind turbines based technologies includes the development of small wind turbines. Using small wind turbines, one can trap or utilise the power generated for domestic purpose or the power which is generated on-site very effectively and very efficiently. Small wind turbines are very useful for the people and authorities who wish to install the wind energy based power plants in or on their homes and buildings to make them energy efficient[3]-[5].

Small wind turbines are very popular all over the world because of their many more advantages over other turbines. These turbines being of small sizes, require less space. So, they can be installed at the rooftops of the home or the buildings or they can also be installed at the open area in front of the homes and buildings. Small turbines can be used at small level for domestic as well as commercial purpose. Second advantage of using small small wind turbines for energy generation using wind's kinetic energy is that the small wind turbines have comparatively less visual impact than the other turbines. Birds and other animals don't find any difficulty by these small turbines. They are installed

closer to the ground because they have comparatively lesser height than the other larger wind turbines. So, the birds don't face any kind of difficulty due to these small size wind turbines in their path.

Having small sizes these wind turbines are put closer to the ground. They don't need higher wind speed to start producing energy. Modest level of wind speed that is found closer to the ground, is sufficient to start these type of generators to produce electrical energy. Large size wind turbines require a good and huge infrastructure and proper transmission and distribution system [6]-[7]. Whereas small wind turbines don't require any huge infrastructure for distribution and transmission lines because small wind turbines provide the on-site generation. Here there is no utility which is transmitting the electricity from generating end to the consumer end. Here the electricity is being generated very closer to the user end. So, there is no such concept of distribution also in the case of small wind turbines.

Wind energy based system having turbines of small sizes can be used as stand alone systems or they can also be connected to the grid. There has been a huge popularity of small wind turbines all over the world because of the advantages they are having. Technologies related to these small wind turbines are getting developed.

2 Vertical axis wind turbines

Vertical axis wind turbines (VAWT) are the wind turbines which have their shaft rotating vertically. The main difference between horizontal axis wind turbines and vertical axis wind turbines is of the axis of their shaft. Vertical axis wind turbines have their rotor axis vertically and also it rotates vertically. Two to three blades are mounted on that axis which rotates parallel to the ground. In vertical axis wind turbines, it is not necessary for the turbines to be pointed or faced to the wind because of the design of the blades the turbine is having. It can catch wind from any direction and use it for the power generation purpose. This is a benefit of using vertical axis wind turbines because we need not to put additional equipment for identifying the wind's direction, its speed etc. and for orientation purpose also. It can easily be used at the places where unpredictable wind direction and wind speed is the major issue.

The vertical axis wind turbines moves on the concept of drag whereas the horizontal axis wind turbines works on lift concept. Small wind turbines can be of both types - horizontal axis wind turbines and vertical axis wind turbines. Between both of these two, the horizontal axis wind turbines are most effective and efficient. Due to this reason these turbines are used mostly but having some disadvantages these turbines can not be used for residential purpose. so , here vertical axis wind

turbines come into picture. These turbines are the most popular turbines for residential purpose. Hence they can be installed at residential as well as commercial buildings.

This type of wind turbines are usually installed near the ground. They have some advantages over horizontal axis type of turbines. The major advantage out of all is that these vertical axis wind turbines don't need any kind of yaw mechanism in their design. Since, the axis of rotor mounted on the turbine rotates vertically and these turbines can sense the wind's direction and speed, there is no need to move the complete structure according to the wind. That is why no equipment related to yaw mechanism is added to these kind of turbine system. Another advantage is that they can be start with low value of wind speed in comparison with the horizontal axis wind turbines. They require small wind speed for startup purpose. Third advantage includes that the fact that the vertical axis wind turbines are generally small in size in comparison with the horizontal axis wind turbines. So, they can easily be located at the areas where the establishment of large sized wind turbines can not be installed such as on the rooftops of the buildings. If the height of the wind turbine is half the height of the building, then the efficiency of the wind turbine is maximum. The vertical axis wind turbines require less maintenance during the operation of the plant because of it's comparatively lesser sensitivity towards the wind speed any direction.

Apart from having these advantages the turbines of vertical axis type also have some disadvantages. These turbines need small wind speed to start and to generate electrical output. Due to this reason the turbines can not take advantage of high wind speed. Also they are installed closer to the ground so they utilise only small amount of wind speed. At the time when there is high wind speed, this turbine can generate high electrical output and increase the system performance. But being located closer to the ground, these turbines can not utilise that amount of wind speed and stay restricted to their small energy output. Another drawback of such type of turbines is that they use drag mechanism to generate electrical energy output. In the drag mechanism, the problem of turbulence occur which leads to the decrement in the energy output of the turbine. Because of the problem of turbulence, the actual energy output of the plant becomes lesser than the energy that is expected to be the output of the plant. Hence, the overall efficiency gets decreased. In the case of horizontal axis wind turbines, when the wind is there and it strikes to the blades, each and every blade moves and contributes in the production of energy. But in the case of vertical axis wind turbines, not every blade contributes to the power generation. Only few blades are able to generate the torque required for energy generation. This is the reason why the vertical axis wind turbines have lesser efficiency in comparison with horizontal axis wind turbines. When it comes to reliability, the vertical axis wind turbines have lesser reliability than the horizontal axis wind turbines.

Vertical axis wind turbines are getting developed nowadays. Vertical axis wind turbines of different size, different shapes, and different technologies have been developed. Mainly the vertical axis wind turbines can be divided into two parts - savonius wind turbines and darrieus wind turbines.

2.1 Savonius wind turbines

These are the turbines having the simplest design and easiest operation. This turbine runs on the drag principle. Since it uses drag principle to rotate and generate the electricity output, there will the case of turbulence in the turbine. Theis turbulence does nothing but reduces the efficiency of the turbine. So the fact that savonius type vertical axis wind turbines works on drag principle, makes them less efficient than the other vertical axis wind turbines or horizontal axis wind turbines. These turbines have blades of shape - 'S'. Due to this type of design and structure only the blades get sufficient drag to rotate even at the small speeds of the wind. As normal vertical axis turbines, these turbines are mounted or established near to the ground. So the can easily be started at small value of wind speed. Savonius wind turbines are installed at lower heights from the ground, so they can not take benefit of the wind having higher speeds. Even at higher wind speeds, the output generation of energy of these turbines will be limited.

2.3 Darrieus wind turbines

The darrieus type of wind turbines uses lift mechanism of the rotation of the blades. So they are lift type vertical axis wind turbines. The main thing about these types of wind turbines is that they have tip speed ratio greater than one. Tip speed ratio is the ratio from the blade speed to the wind speed. Thus the tip speed ratio is the measure that by what value of wind speeds how much the blade can rotate. Having tip speed ratio greater than one implies that for very small wind speed the blades start rotating with good speed. Darrieus turbine blades have the shape of eggbeater. The main drawback to these types of turbines is that they do not have the capability of getting self start. The savonius wind turbines have quicker starting then the darrieus one. To start the rotation of the blades, a very small sized motor having small ratings is used in darrieus wind turbines. So due to this motor the turbine blades gets sufficient speed and then according to the wind speed, it rotates. It has lower efficiency than the savonius wind turbines.

Many further developments have been made on darrieus wind turbines. H-shaped wind turbines, garlove wind turbines are some of the advanced version of the darrieus wind turbines, which have small differentiation in the design but the basic mechanism of lifting remains same in the advanced version also. Garlov darrieus wind turbines are the most advanced turbines in all and they have maximum efficiency amongst all the darrieus wind turbines.

3 Building Augmented Wind Turbines (BAWT)

Wind is used to generate electricity and meet the loads accordingly. To save energy in a particular building or to make that building an energy efficient building, one need to use energy efficient devices for the buildings. Other solution can be to use renewable sources for on-site energy generation and fulfilling the loads of that building using that energy generated by the renewable source. Out of the all, wind can easily be used for energy generation purpose for a building. Generating the energy on-site equal to the total energy consumption of the building, leads to the concept of zero energy building. To make a building zero energy building or an energy efficient building, small wind turbines can be installed on or around the buildings.

The technology has been grown so much that now the wind turbines are installed around or on the buildings but apart from this the design and structure of some buildings are made in such a way that the wind turbines are located within the building. These type of technologies and these turbines are called building augmented turbines. Here, the turbines are not installed separately but they are a part of the building itself. Building are designed and constructed accordingly.

These building augmented wind turbines can be of both types- the building augmented wind turbines having vertical axis and horizontal axis. The wind flowing around the building will strike to the turbine blades but also it will strike to the building and will create turbulence. Due to this turbulence we can not get the maximum efficiency from the turbine. So, the energy output that we will get from the wind turbine will now somewhat be lesser than the expected value of the energy output.

So, to overcome this problem and to get maximum efficiency from the turbine new concept came into picture. This concept says that the wind and the surrounding of the building interacts while the flow of wind. By this interaction between both of them, some air currents are generated at that place. These air currents are useful and can make the blades rotate. So, we should put or design our building in such a way that the wind turbines come in the area of this air current. This leads to the decrement in the effect of turbulence and hence the efficiency of the wind turbines gets increased by some percentage. Thus this thing must also be taken into consideration while designing the building structure and putting the wind turbines inside it.

The building structure includes the wind turbines in itself. So including these wind turbines, can be done in various ways. The wind turbines can be installed at the top of the building structure or it can be mounted in between two building or it can be installed at the edge of the building. According to these possible cases, the building augmented wind turbines are divided into basically three configurations. These configurations are as below:

1. Building augmented wind turbines that are installed close to the building
2. Building augmented wind turbines that are installed between two buildings.
3. Building augmented wind turbines that are installed within the air conducts inside the building.

All these three type of configurations are described below. Among all the three the third one is having maximum efficiency.

4 Building augmented wind turbines installed close to the building

In this type of category of building augmented wind turbines, the wind turbines are installed at the rooftops or at the edges of the buildings. The designs of the buildings are made such that wind turbines can be located at their rooftops or at the edges of the buildings. In this case the turbines are situated close to the building but in this case because they are close to the building, the air flow at the top of the building or at the corners of the building creates turbulence. This turbulence is the main reason for decrement in the efficiency of these types of wind turbines.

This problem of turbulence is very common in small sized wind turbine. To cope up this problem there is a solution regarding the design of the building. One can design the roof surface of the building curved. When the curved rooftops are designed for the buildings, the air flow will cause comparatively lesser turbulence and hence the efficiency gets increased. Another thing that can be done to remove the turbulence is that the wind turbines should be put in the areas where the air currents are generated. This air current leads to the turbulence free airflow and efficiency is increased.

This type of building augmented wind turbines have been installed in a building in london. The height of that turbine is around 150 meters from the ground. In present it is capable of generating 50 MWh energy per year. So, using such turbines and such advanced technologies the whole load of the building can be supplied using these building augmented turbines and a lot of energy can be saved by this. This increases the energy efficiency of the building also. Below is the Fig.1 by which one can easily understand how the airflow is there in these type of wind turbines. This shows how the turbulence is created and how curved surface can decrease the problem of turbulence.

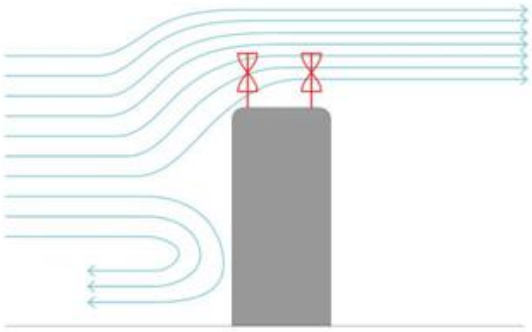

Fig. 1. Building augmented wind turbines closer to the buildings

5 Building augmented wind turbines installed between two buildings

In this configuration what happens is that the wind turbines are established between two buildings. The architecture of the building, their sizes, distance between them, angle between them all these constraints are taken into consideration and according to that the designing of the building and the wind turbines is done. The construction and angle between both the buildings is taken in a way so that the maximum wind flow can face the wind turbine and it creates minimum turbulence. The designing of the building and wind turbines according to that is a very tedious job itself.

Here, the shape of the gap between both the buildings is kept funnel shaped generally and the wind turbine is located at the second or small end of the funnel. Because of this shape the wind turbine gets maximum speed that can be possible in that area. Due to the small area the wind speed will be maximum at the turbine's side.

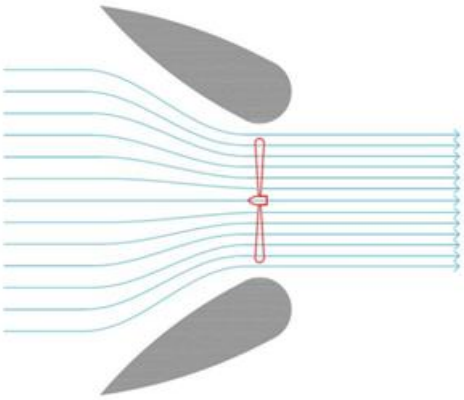

Fig. 2. Building augmented wind turbines between buildings

Here, in the Fig.2, the basic configurational design of buildings having wind turbines between them is shown. The place where the wind turbine is located has high pressure. So as a result the speed of the wind will also be high over that place.

6 Building augmented wind turbines installed within the air conducts inside the building

The last configuration that can be possible in the case of building augmented wind turbines is that the wind turbines can be located inside the building. When wind comes in the building for the ventilation purpose, at that time the wind interacts with the building environment. This interaction between both creates air conducts and the air flow increases due to this. This air flow created by this interaction is also helpful in removing the turbulence which is decreasing the turbine's efficiency.
Inside the building, the air flows from high pressure place to low pressure place. This difference in pressure causes wind to flow within the building. To utilise this complete air flow and the difference in pressure, the wind turbines should be placed in between these two different pressure places. So that the air strike the turbine and turbine starts rotating.

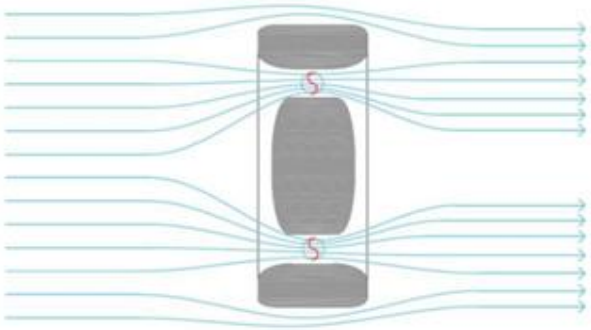

Fig. 3. Building augmented wind turbines inside air conducts throughout buildings

In the Fig.3, it can be seen that the turbines are placed in low pressure area. So according to bernoulli's theorem this place will have higher wind speed. This can be concluded by studying all the three configurations that the configuration having building augmented wind turbines inside the buildings will provide maximum efficiency in comparison with other two configurations.

7 Some other technical solutions for buildings

In present time, many new and advanced technologies for wind turbines have been introduced. Small wind turbines technology is developed. Wind turbines having various power ratings and various sizes are available in market.

Wind turbines that are used for building augmented techniques are also well established. But apart from all these technologies the wind turbines have some more other designs, having greater efficiency and more advantages than other one. Some out of these turbines are discussed below in this section. These types of turbines can also be used in buildings according to any of the three configurations mentioned above.

7.1 Darrieus and Gorlov wind turbine

Gorlov wind turbine is the advanced version of darrieus wind turbine. Being of advanced and developed design and technology, the Gorlov wind turbine has maximum efficiency among all type of darrieus wind turbines. Since they are the most efficient one, they are the only wind turbines that are able to generate the power output of 10 kW. This is the main advantage of Gorlov wind turbines. The basic principle at which Gorlov wind turbines work, is exactly the same as its main wind turbine from which it is developed i.e. darrieus vertical axis wind turbine.

Among turbines having same ratings and same sizes, the Gorlov wind turbine will provide the maximum energy output. Apart from these advantages, this kind of wind turbines has some disadvantages also. The major one amongst them is that they are inherently more breakable and having less strength than the savonius type wind turbine. Due to their structure they are not much capable of facing more wind speed and have less strength. This leads to a major limitation of these types of turbines.

Derrius turbines are generally made up of carbon steel, vetronite and steel, aluminum or aluminum with steel. Whereas, to construct the gorlov wind turbines mainly glass fiber is used. It focuses on glass fiber only but sometimes mixed with steel. Some of the companies that produce these types of wind turbines are UGE, venger wind, free tree etc.

7.2 Savonius wind turbines

The savonius type wind turbines are based on the mechanism of lifting for the rotation of the the turbine blades. These turbines don't follow the drag operation. This is why they have comparatively less turbulence and greater efficiency than any other drag operation based wind turbine. The savonius turbines are self start type turbines and can be start quickly in comparison to other darrieus and Gorlov turbines.

Savonius wind turbines are limited for wind speed. They can not exceed the wind speed higher than a fixed value. As a result their output is also limited. To start savonius wind turbines, high value of wind speed is required unlike the derrius or gorlov wind turbines.

Some producers that produce and install savonius wind turbines are Helix wind turbine, Venger wind, Turbina energy etc. Aluminum is the mainly used material that is used for the development of these type of wind turbines. Apart from that aluminum is also mixed with steel sometimes. Expanded

polyurethane, other polymers are usually taken for the construction of wind turbines which are of savonius type.

7.3 3D printing

Development in the technologies of the design and constructions of the wind turbines includes this main technology named 3D printing. It is very latest technology which helped in removing the constructional as well as some technical issues of the turbines blades. 3D printing is a manufacturing process. In this process a three dimension solid turbines blades are manufactured. By this process the design of the turbines blades are improved as well as the energy consumption by those blades decreases i.e. the losses decreases, which results in increased efficiency and power output generated. 3D printed wind turbines are generally of small sizes and small capacity. Recently a 3D based wind turbine is constructed which is able to generate electrical energy output of 600 watts. So these kinds of wind turbines can be useful for small purposes like charging the phone, laptops etc.

7.4 Invelox

Nowadays new invelox system based wind turbines are also into picture. This kind of technology consists of the single tower that can efficiently provide power to more than one turbine. Invelox is the only one technology that includes such structured turbines.

The main principle of invelox based wind turbines, at which they work is venturi effect. A invelox wind turbine has a different funnel shaped structure. First the wind enters the structure having omnidirectional input area. After that it enters the funnel shaped structure, which is having low pressure area. So, because of low pressure the wind speed gets increased as per the venturi effect. This enhanced wind speed is then provided to multiple turbine generators to convert that kinetic energy of wind into electrical energy. After the turbine generators, some diffusers are placed to again decrease the speed of wind according to the environment. This is how invelox wind turbines work. After discussing the working of these turbines it can easily be noted that these turbines require only small wind speed to get started because the wind speed will itself get increased due to the structure of the turbine itself.

7.5 Solar envy

Solar envy is a technology which is based on traditional schemes in which people used to decorate the walls of their homes using some different papers, materials etc. in this technology as the name suggests, the walls and corners of the building are covered with the solar cells which have conductive ink printed on them. These solar cells are designed in such a way that it collects the solar radiation

from the sun and provide electrical energy. These kinds of designs are preferable for buildings because they provide us a way for generating power but apart from that they also give pleasing look to the buildings. The first company which provided this concept of solar envy type wind turbines was SMIT. These solar envy based wind turbines take the energy from sunlight as well as wind and generates the electrical output.

7.6 Ewicon

Ewicon is another advanced technology for enhancing the efficiency of the wind turbines. In this technology wind turbines are taken that have no blades and no moving parts in it. Blades are always the main component for producing electricity. They produce electricity by rotating and transferring this rotational energy of wind to the turbine generator. Without blades these ewicon wind turbines generates electricity by using the droplets of charged water. So, we can say that in new emerging technologies like ewicon bladeless turbines are also invented.

Structure of ewicon consists of a frame made of steel. This frame consists of many insulate tubes which are placed in series with each other and horizontally. These tubes have many electrodes in them. These electrodes have job to emit water particles into the environment. The water particles are positively charged. In this type of wind turbines, the dependency of generated output power by the turbine is not only limited to the wind speed. Here the power output is dependent on the number of positively charged water droplets that are emitted by the electrodes.

8 Conclusions

Since non-renewable energy sources are moving towards depletion and are polluting the environment, the world is moving to renewable sources for energy production purpose. This movement has developed many technologies and many researches regarding using the renewable energy sources to increase energy efficiency and conserve the energy at domestic and commercial level. One of the ideas includes the installation of wind turbines in or on the building as well as installing them within the buildings. The structure of building includes the wind turbines in its structure only so that the wind that is passing in the environment of the building can be used for energy generation purpose also for the building itself. This will lead the complete world towards the concept of zero energy buildings in practicality. Each building can generate the energy required by the loads of that building by its own. In these type of building augmented wind turbines many things are need to be taken into consideration such as the size and distance between the buildings, the materials used for the buildings, the direction and intensity of the wind speed etc. According to that only a basic design of construction for buildings is developed and then the idea is implemented. Using these latest technologies the efficiency of the wind turbines gets increased. Along with the increase in energy efficiency of the wind turbines the new technologies include turbines blades having new and

innovative designs. Using these innovative and new designs the turbines blades give energy as the output at comparatively smaller wind speed. Apart from the building augmented wind turbines some other new technologies have also been developed till the date. These technologies include the 3D printed wind turbine, invelox based wind turbines, solar envy, ewicon etc.

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