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مهندسی عمران، معماری و شهرسازی
با رویکرد توسعه پایدار
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Investigating possible solutions to reduce noise pollution in wind turbines

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Abstract— In recent years, the use of wind turbines has increased due to the phenomenon of global warming and climate change in different regions, and it is expected that this growth will continue in the future, as is the noise pollution of turbines. Noise pollution is one of the biggest environmental damages using wind turbines, which is within the range of hearing and inaudibility, and this type of pollution can be perceived by other living beings, which can have a negative impact on their lives. Also, the problems of using propellers, such as the noise caused by them, visual problems, the killing of birds and insects, and atmospheric disturbances have also added to the amount of this problem.

Keywords- Noise Pollution, Wind Turbine, Reduce Pollution, Blades.



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1. Introduction

The potential of using wind resources is far more than the currently used capacity. It is expected that the use of wind turbines will increase in the coming years. It is expected that by 2030, the operating capacity will reach more than 1.2 terawatts (equivalent to 20% of electricity production [1]). Fortunately, it is now possible to design various types of wind turbines for different working conditions, so that it is possible to build small domestic turbines to large marine turbines for installation in areas far from the coast. Small turbines can be easily installed and used in different areas, which have little environmental harm, and their expansion also helps in the development of distributed electricity distribution network. On the other hand, large turbines can be used to exploit large potentials, which are economically less expensive to exploit. These turbines are usually used in multiples, and their collection is called a wind farm. Today, it is possible to make turbines with much larger diameters than in the past, which makes it possible to use more wind energy. The use of wind turbines has its own environmental disadvantages, and in order to expand the use of turbines, these problems must be solved as much as possible. Problems such as the destruction of the environment for the installation of turbine towers, the creation of intermittent bright shadows caused by the rotation of turbine blades, the pressure reduction caused by the flow of eddies downstream of large turbines, and most importantly, the sound pollution (noise) of turbines. Studies show that noise is a problem in the daily life of people who live near wind turbines [2-5]. The range of human hearing is defined from the frequency of 20-20 Hz to kilohertz, and frequencies less than 20 Hz are called the sub-auditory range. Since wind turbines usually have a small number of blades and their rotation speed is low, their noise at low frequencies and in the sub-audible range should be investigated. Research has shown that the noise of wind turbines at low frequencies will have significant harm on human health [6, 7]. It causes problems such as headache, lack of concentration, sleep disorder, fatigue, dizziness and constant ringing in the ears (the set of symptoms of the mentioned disease is known as wind turbine syndrome). For example, with a rotational speed of 30 revolutions per second, the noise produced is in the sub-hearing range and causes disturbance in the life of wind power plant personnel [8]. The noise caused by wind turbines can have a negative effect on the hearing system even at hearing frequencies. Of course, in examining the effects of wind turbine noise, it is necessary to pay attention to its effect on other living organisms. The noise of wind turbines is within the hearing range of many animals, birds and insects, and the negative impact of this phenomenon on living beings can threaten the environment and the diversity of animal species in the region [9].

2. Wind turbine

A wind turbine is generally a machine that converts wind energy into electrical energy. In wind turbines, the blades are designed to rotate with the wind. The rotation of the blades rotates the inner axis of the turbine rotor, and finally, after converting the torque into rotational speed in the gearbox, the mechanical power is converted into electrical power. Based on the orientation of the rotating axis, wind turbines are divided into two categories: horizontal axis and vertical axis:

2.1 Horizontal axis wind turbines

All components of the turbine (blades, gearbox, generator, etc.) are placed on top of a tall tower in line with the wind. In order to achieve the highest efficiency, these turbines must be placed exactly in the direction of the wind, so horizontal axis turbines must have a system to adjust against the wind, which is called a yawing mechanism. so that the whole nacelle can turn towards the wind. In small turbines, the tail of the fan is responsible for this control. But in systems connected to the network, the yaw control system is active, which rotates the nacelle towards the wind by wind direction sensors and motors.



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2.1.1 Advantages of horizontal turbine

The height of the tower provides access to powerful winds. In some places, for every 10 meters increase in height, the wind speed increases by 20% and the efficiency increases by 34%.

Due to the long bases and advanced mechanism, it is possible to use these turbines in the seas.

Due to being directly in front of the wind, they have high efficiency.

2.1.2 Disadvantages of horizontal turbine

They do not work at low altitude.

It is difficult to transport and install them.

Their maintenance is difficult and expensive.

They are affected in the vicinity of the radar.

Their high height and size do not have a beautiful appearance and cause noise pollution.

2.2 Vertical axis wind turbines

The main rotor is placed vertically. The most important advantage of vertical wind turbines is that they don't need to be adjusted in relation to the direction of the wind, and they can also be used at low altitudes. In vertical axis turbines or rotors, the rotation axis is perpendicular to the ground and the blades rotate parallel to the ground. For this reason, the surface moved by the wind has to continue moving in the opposite direction of the wind flow after half a revolution, and this problem causes their power factor to decrease. For this reason, the blade curve is very important in these rotors.

Because these wind turbines must be installed closer to the ground and at low altitude, the wind speed is lower, less energy is produced from the specific size of the turbine. Air flow near the ground and other objects can create turbulent flow, which causes vibration consequences, including noise and bearing fatigue, and as a result, maintenance costs may increase and service life may decrease. These turbines are divided into two main types, Savonius and Darrieus.

2.2.1 Advantages of vertical turbines

Vertical wind turbines are less sensitive to wind direction and flow turbulence, this advantage allows them to be used in different areas, including the roof of buildings. They perform well in turbulent and turbulent winds. Vertical wind turbines can be installed close to the ground, which makes them safe and cheap, as well as easy to maintain. They do not need a yawing system.

2.2.2 Disadvantages of vertical turbines

In vertical turbines, when the wind blows, an opposite force is also applied to the other side of the turbine. Therefore, their efficiency in each period is lower than horizontal axis turbines.

It is difficult to install this type of turbine on tall towers; This means that they should operate in slower air currents with more turbulence and near the ground with lower energy extraction efficiency. Due to the mentioned issues, the design and analysis of the blade (airfoil) of vertical turbines is more difficult and expensive.

Their low efficiency can be improved by compact layout and new designs. Due to high flow disturbance, the structure of vertical wind turbines is subject to fatigue. This issue can also be improved to a great extent by predicting aerodynamic loads.

3. Environmental effects of wind turbine blades

3.1 Noise pollution

The Finite Element (FEM) software is one of the most widely used numerical simulation techniques for investigating engineering-industrial phenomena [10] such as noise pollution [7, 11-15]. Also, the noise of wind turbines is divided into two categories based on the source of its creation:

- Mechanical noise
- Aerodynamic noise

Mechanical noise is caused by components such as gearbox, generator and bearings and has nothing to do with fluid flow. Currently, by designing and manufacturing gearboxes with almost smooth surfaces, with soft cores but hard surfaces, their noise has been reduced significantly. Also, by using anti-vibration joints and couplings, the mechanical noise of other components can be reduced [16, 17].

Aerodynamic noise is divided into three categories based on the origin of production:

low frequency noise;

Turbulence noise of the input flow;

Turbine blade inductance noise.

The low frequency noise is caused by noise sources of constant thickness and constant loading around the rotating blade and the change of the speed profile caused by the barrier of the turbine tower path. The turbulence noise of the input flow is related to the presence of eddies in the flow entering the rotor, and considering that the size and number of eddies in the input flow are completely variable, simulating this noise in turbines is a difficult task and due to the changes in the flow at points Different, it is practically not possible to experimentally test this noise in large turbines. But it can be said that large vortices affect the performance of the vane and cause noise in the low frequency range, but small vortices will only locally cause pressure fluctuations and cause high frequency noise. It should be noted that this noise is more important in small turbines than in large turbines [18].

The turbine blade is known as the most important source of turbine noise, and the noise caused by the turbulence in the boundary layer flow and the eddies resulting from the existence of the blade is called blade noise. The factors that cause noise are the turbulence eddies of the tip of the blades, the separated boundary layer flow and the airfoil remnant, the eddies caused by the instability in the laminar boundary layer flow, the turbulent flow of the boundary layer of the escaping edge and the eddies caused by the width of the escaping edge.

Opponents of wind turbines, due to the fact that the noise produced in wind turbines is infrasound, fuel a condition called wind turbine syndrome and defend their statements that this condition is harmful and causes heart diseases and dizziness. Also, noise pollution can harass animals and insects and make them run away from the wind farm. It can also be dangerous for dolphins and cause increased anxiety, decreased hearing and illness caused by sudden pressure drop, and in the end, they try to breathe quickly and go under water to escape from the noise.

3.2 Birds hitting feathers

Perhaps this is the most sensitive part of the problem of wind turbines, and designers try to place wind farms far from the place of bird migration. According to the available statistics, about 8000 birds are killed due to collision with feathers. In addition to birds being killed, bats are also victims of collisions with blades, and the reason for this is the sudden pressure difference and loss of balance. Bats, which play an important role in the ecosystem as insectivores, are at risk of extinction. In Denmark, the study shows that birds are able to identify

the presence of turbines during migration, but pressure changes around them cause internal problems in them, and designers are trying to create an optimal distance in wind farms.

3.3 Atmospheric disturbances of blades

It has been said that the wind farms themselves cause disruption in air circulation and increase in temperature, which has a negative effect on the atmosphere in the long term. However, according to the research of the French researcher in the "Nature" magazine, the establishment of farms has caused climate changes in Europe to a very small extent and will remain at this level until 2018.

3.4 Studying the continental pattern

In a research conducted at the University of Texas, it was found that wind farms have a negative effect on the warming of that area. Researchers have estimated that the temperature of the areas where there are wind turbines is about 72.0 degrees higher than other areas during 10 years. Energy scientists plan to produce more than 200 gigawatts of electricity in Europe through wind turbines by 2018, while currently 110 gigawatts have been recorded. since 1987 and based on the commitment that European countries were required to make; 20% of Europe's energy should be through wind [19].

3.5 Temperature difference

Comparing the temperature difference between the two environments shows that the maximum temperature difference is 3.0 degrees and this value is higher in winter. Scientists observed some decrease in temperature in the south and increase in temperature in the north, which are caused by the western winds. All these differences are small, and according to Robert and Tard, these differences are very small compared to the differences in the climate system of the world due to greenhouse gases, but research is necessary before the expansion of wind farms.

3.6 Generation of lightning by vanes

Wind turbine blades also cause lightning in certain weather conditions. When these vanes reach their maximum height, they create lightning that is sent up to a height of 2 km above the atmosphere. Juan Montaña from the Polytechnic University of Catalonia conducted an experiment in which it was found that several turbines that are located close to each other can generate lightning at the same time.

3.7 Determination of wind and storm speed by vanes

According to the studies conducted, wind turbines in the sea can prevent the destructive power of storms. A research group from Stanford University came to the conclusion that the installation of wind turbines in the sea can reduce the damage caused by big storms like the hurricanes that hit the United States.

3.8 Disturbing natural views and visual problems

On the way of expansion of wind turbines by the opponents of this industry, there are claims that turbines destroy the natural landscape. In some cases, it is necessary to cut the branches of the trees or the flashing of the wind turbine blades in the horizon and the phenomenon of intermittent flashing occurs due to the passage of light between the blades. If this frequency is between 5 and 20 Hz, it causes a phenomenon called epilepsy, which is a type of vision disease that causes lack of concentration and weakness in the alertness system, but considering that this phenomenon occurs periodically during the daytime hours. It rarely happens, no cases have been observed yet.

3.9 Secondary contamination of the environment

The consumption of fossil fuels for the production, transportation, installation and recycling of blades is one of the other problems of this industry, which is increasing day by day [20].



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4. Solutions to reduce noise pollution in wind turbines

4.1 Deformation of blade profile

Gochman and Ozderm optimized the profiles of six well-known airfoils of small wind turbines using a validated code and using Emmitt and Brooks relations for noise simulation [21]. Using experimental models, Bertagnolio et al showed that by changing the shape of the profile, it is possible to reduce the sound level by 1 to 3.5 dB [22]. Araqua also showed that changing the shape of the tip of the blade can significantly reduce the sound. It should also be noted that noise reduction should not affect the sound [23].

4.2 Changing the three-dimensional layout of the blade

Another method of noise reduction is the three-dimensional change of the blade section. For example, the change of the turbine rotor angle is equivalent to the three-dimensional change of the cross section. By making the turbine conical, the tip of the blade moves down and the diameter of the turbine is reduced, which is considered an advantage because the space required for the turbines is reduced and more turbines can be installed. Due to the displacement of the tip of the blade towards the rear, the maximum allowed angle in the upstream flow will depend on the permitted distance to the turbine tower, and in the downstream turbines, the downstream turbine can be placed in a cone angle close to 90 degrees. By examining the turbulence noise, Lawson showed that conical rotors do not have much noise increase compared to normal rotors. Crawford also investigated the effect of cone shape on low frequency for downstream wind turbines. In general, it can be said that not much research has been done on this issue [24, 25].

4.3 Serration of the trailing edge of the vane

One of the effective methods is serration of the blade (cactus). In 1991, Howe showed that this reduces noise. This was the starting point for research in this field, when it was shown that serrations of flat blades and different airfoils can reduce noise. Brown et al. showed that teeth in straight blades are more effective than teeth in curved blades [26]. Chonk and colleagues were able to reduce the noise with non-flat teeth. The effects of the tooth on all blades are not the same and in some cases it causes an increase in noise [27]. Haag et al., by investigating the noise on a 1 MW turbine, concluded that the noise reduction is up to a frequency of less than 1500 Hz and the noise increase is above 2000 Hz [28]. Jones and Sandberg investigated the effect of short teeth on noise reduction and found that short teeth reduce noise at low frequencies, but long teeth reduce noise at all frequencies. Because the shape of the teeth depends on the geometry and flow of the airfoil, therefore, in the blades where the angle of attack and chord length are variable, these teeth must be accurately calculated [29].

5. Conclusion

The proposed solutions to reduce the noise pollution of turbines are very few and finding an effective solution for this problem requires much more research. One of the proposed solutions is changing the geometry of the blade, which is not applicable in many cases because changing the geometry of the blade will affect the aerodynamic performance of the wind turbine and its production power. Another solution is to use teeth on the trailing edge of the blade, which requires more research. Most of the research in this field has been done on fixed vanes, which cannot take into account the three-dimensional effects of the flow and rotation of the vane. Another solution is to taper the turbine, which can be done by using a hinge at the root of the blade. Blade taper requires the use of a control system to determine the appropriate angle in different working conditions. It should be noted that so far little research has been done on the use of conical turbines. In this research, experimental and semi-experimental models have been used to simulate noise pollution, which are not highly accurate, and in addition, all mechanisms of noise pollution production have not been investigated.



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