Effects of the Conventional Wind Farms on Environment

Maftounı N.[1,*], Yazdanjou R.[2]

[1]Faculty Member at Mechanical Engineering Department, Engineering Faculty, Alzahra University, Tehran, Iran.

[2]MS student at Mechanical Engineering Department, Engineering Faculty, Alzahra University, Tehran, Iran.

*corresponding author:

e-mail: n.maftouni@alzahra.ac.ir, maftouni@gmail.com

Abstract Regarding high demand of energy, lack of traditional energy resources and also pollution associated with fossil fuels, there is a significant tendency toward renewable energies like wind and solar energy. Wind energy has shown the benefits as relatively low cost and simple required technology. But the belief that wind energy has no weak points is completely wrong. This renewable energy may badly affect environment and ecosystem and also human's life. There are some problems when using wind turbines to harvest this kind of energy. Among them death of wildlife, producing some bothering mechanical and aerodynamical noises and also visual impacts are the most commons. In this paper the environmental impacts of the conventional wind turbines and related farms are studied and aggregated. The results indicate that there should be an attempt toward modifying the traditional wind farms and also to generate new wind technologies in which these problems are considered to be solved.

Keywords: Environment, Energy, Wind.

1. Introduction

High speed world technologic and economic growth have resulted in huge demand for energy. Classic fuels such as oil, coal and natural gas are finishing and also producing deep negative effects in environment. These situations lead to global interest towards renewable clean energy resources. Wind offers a mature technique and is commercially reliable. This resource is usually applied in large-scale electricity generation (Deal, 2011). It is forecasted that wind energy will provide more than 5% of the global energy in 2020 (Joselinson, 2017). The wind energy that is used today mostly comes from onshore winds, but there is a growing interest in offshore wind, as the wind is normally stronger and more uniform at sea than on land. In countries like the US, where beach winds are unlimited, offshore wind may become a major energy source for domestic applications (Musial, 2016).

Although wind power has worked well in these years, its strong environmental impacts, such as noise, visual and climatic impact should be considered. These effects look small in comparison with fossil fuels, but should not be ignored. It is required to study these problems, particularly the long-term impacts, and to find ways to solve them. In this paper the environmental impact of conventional wind turbines on humans and wild life are studied in following parts: visual impacts, noise based impacts, wild life impacts and climate changes.

2. Environmental impact

Unlike fossil fuels, wind turbines do not produces greenhouse gases. So wind power is considered environment friendly, but the reality is that it imposes some impacts on human and wild life. Especially the probable long-term effects cannot be neglected. Different impacts are analyzed here.

2.1. Noise base impacts

The inherent impact of wind turbines on the environment is always limited to the immediate surroundings. The most critical environmental impact of wind turbine is the noise pollution. Wind turbines cause noise in two main ways: mechanical noise and aerodynamic noise. The latter is an important issue. Its low frequency may cause disease in humane lives. Mechanical noise is the result of opration of the moving parts such as bearings, gear box and electrical generator. Normal tear and wear, bad designs or shortage of protective maintenance can be factors influencing mechanical noise (Juliani, et. al, 2014). Aerodynamic noise is produced by the air flow around the blades of a turbine. This noise increases with the speed of the rotor. Deducing blade tip speed results in less noise. Special concern is about the interaction of wind turbine blades with atmospheric turbulence, which results in a characteristic "whooshing" sound. Mechanical noise can be reduced at the design step for example by using side toothed gear wheels. Also installing acoustic insulation inside of the turbine housing will help. Acoustic insulation curtains and anti vibration support footings are also good suggestions. Careful design of the blades can minimize aerodynamic noise (Richardson, 2015). Wind direction has the tendency to increase noise level relative to the turbine and the receiving point. The highest noise level can be found at the bottom of wind turbine proportional with the wind direction from the plant.

Figure 1 reports the relationship between wind speed and noise level of a wind turbine. It is observed that for the distances more than 300m wind turbine noise is independent of wind speed (Martin, 2014). A small amount of noise is generated by the mechanical components of the turbine.

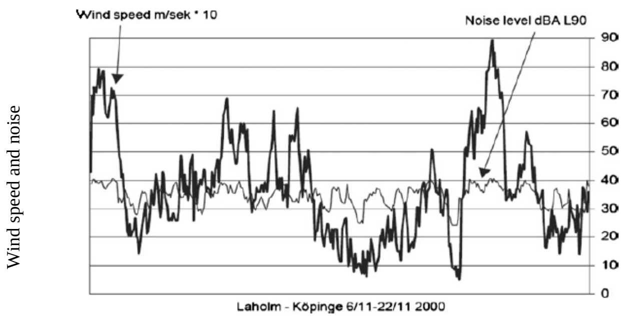

Figure 1. Wind speed and noise level in dBA L90 versus time (Martin, 2014).

Pedersen has discussed the relation between neighbors well-being and the sound pressure levels of wind turbines (Pedersen, 2011). Results indicated that headaches and some other stress symptoms appeared in those who were annoyed by the presence of wind turbines. Punch *et al*. found that the low-frequency aerodynamic noise of wind turbines can annoy human due to hearing loss and sleep disturbances, and may also have impacts on the vestibular system (Punch, 2010).

It is suggested to build wind turbines at least 2 km away from residential area and also optimize the house acoustic structure to prevent noise penetration. Son *et al*., 2014, studied the characteristics of aerodynamic noise of wind farms. They used an integrated numerical method and found that the noise of wind turbines can be minimized by using obstacles in the propagation path of noise waves. The experiment done by Oerlemans *et al*. indicates that an optimized blade or serrated blade can deduce the noise (Oerlemans, 2008).

2.2. Visual impact

There are various view points about visual impacts. Some people think that wind turbines are impressive looking and pleasant, while others have different opinions. Some tourism officials thought that wind turbines could damage local tourism. The visual impact is the hardest one to be evaluated, among all the effects on the environment made by wind farms.

A visual impact evaluation is done by Ian to assess the negative effect of wind turbine (Ian, 2012). Jacobin indicated that the visual impact varies according to the wind energy technology such as contrast or colour, distance from the residences, size, shadow flickering, the time when the turbine is moving or stationary and local turbine history (Jacobin, 2009). It may be mentioned that most of the visual impact assessment was based on the geographical information system (GIS). The affected areas are called zones of visual influences (ZVIs).

Bernd pointed that when wind turbines are painted in white or any grey tone, there will be a minor problem as lightness will tend to recover color differences (Bernd, 2005). Usually wind turbines are painted in light grey color to help the turbine blades to appear like skyline. The color of turbine is made green at the base and slowly changed to grey at top to reduce the contrast levels. This will reduce the visual impact. Ian and David reported that the impact level of contrast caused by wind turbine increases with the increase of contrast with the surroundings.

Figure 2 indicates that the visual impact decreases with the increase of distance of turbine from the residential area. The visual impact is influenced by the movement of wind turbine as ha been analyzed (Jaskelevicius, 2009). They concluded that the negative visual effect during the moving condition is lower than that when the blades are stationary. It may be mentioned that when the turbine is moving, the blades can be quite hard to see.

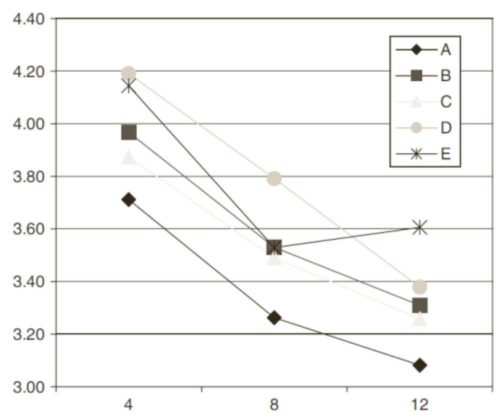

Figure 2. Decline in impact with distance (in km). The value 3.0 is a neutral response. The five lines, A-E, represent the different atmospheric conditions (Magoha, 2013).

Shadow flicker made by moving blades and the reflection of sun ray on the wind turbine body both will cause shadow flickering. Shadow flickering caused by the wind turbine is changed with the light intensity caused by the moving blade casting shadows on the ground. This will annoy people living in the neighbour area. Also the reflection of the sun ray shining on the turbine is caused by the periodic flashes of light. This can be minimized by optimizing the rotor blade surface smoothness and also by coating the turbine with a material having less reflection properties.

2.3. Effects on wild life

It is found that birds are one of the largest victim groups of wind turbines. The danger of wind turbines to birds is a concern to many environment fans, as wind farms may be built in the birds' habitats. Studies show that local birds can rapidly learn to avoid obstacles, and thus that wind turbines would not be an important problem for them. Regional and overall birds' fatality rates in United States are shown in Table 1 (Magoha, 2013). Some studies stated that wind energy killed about twenty times fewer birds than conventional fossil resources. The number of birds killed by wind farms may be ignored comparing with other human activities (Sovacool, 2011). It was found that only 20 deaths out of the total number of birds killed in a year, were regarded to wind turbines (for an a capacity of 1000MW), while 1500 deaths were caused by hunters and 2000 caused by the collisions with vehicles and electricity transmission lines. Summing up, it is important to understand that whatever impacts wind turbines have, on the one hand they are very obvious, and on the other hand, it is possible to minimize them through proper design and planning. In contrast, the impacts of thermal or nuclear energy production are slow to appear, are long term and no matter how much effort and money are spent, it is impossible to minimize them. In conclusion, it must decided that if it is necessary to produce electricity, it is certainly better to produce it in a way which has the smallest impact on the environment.

Table 1. Regional and overall birds fatality rates in United States (Magoha, 2013).

Average rotor diameter(m)	**Birds/turbine/year**	**Birds/MW/ year**
56	1.9	2.7
42	1.5	2.3
40	2.7	4.2
60	4.3	3
52	2.3	3.1

Bats' mortality contributes a significant number due to wind turbine installation around the world. There is a very lower number of raptors' death compared to death of birds and bat (Baer, 2016).

To reduce the numbers of avian mortality, the main reason of the avian mortality caused by the collision of wind turbines should be found. Studies show that birds may become more disoriented in poor weather or foggy night. The flyings are attracted to light of wind farms that leads to the increasing number of avian fly through the wind plants and their problems from collision with wind turbine blades (Marionov, 2011).

In the research of Gregory *et al*. it was found that only 3 out of 48 fatalities occur in normal (Gregory, 2000). Although migrating birds generally fly at altitudes higher than 150 m, migrants tend to fly lower during heavy overcast weather such as rain, high winds and low clouds. This increases the birds' potential of flying through the wind turbines, especially when light attraction may be an issue.

Magoha found that the relatively high bird mortality at Altamont Pass is due to the large numbers of older wind turbines located there (Magoha, 2013). The design of the majority of these older turbines has shorter rotor diameters and lower hub heights which caused the blades to spin at high RPM, and tighter turbine spacing compared to typical newer wind turbines. Older turbines often have the lattice towers which motivate birds to make their homes there.

Saran stated that fewer birds that flew near sites with turbine strings compared to reference sites. Authors found that the birds flying through turbine strings will adjust their flight patterns when turbine blades are rotated (Saran, 2016). Table 2 presents the percentage of birds at different heights of flight and different distances from wind turbines. The rotor blade height is normally 21m and 16-17.5% of birds that flew at this range of height have risks in collision with rotors. About 5-14.1% of birds that flew within 16m from turbines put themselves in risk of collision with rotors.

Table 2. The percentage of killed birds at different heights of flight (Saran, 2016)

Percentage of birds	Height of flight (m)	Percentage of birds	Distance from turbine (m)
70-75%	≤21	74.8-80%	≥31
16-17.5%	21-51	5-14.1%	≤16

Birds will still be killed by wind turbines, but the amount of birds that will be killed this way is negligible compared to the deadly results of other human activities such as deforestation and urbanization, no matter how extensively wind energy is used in the future. Some measures can also be put in place to protect birds from wind turbines. In a wind project in Texas, avian radars are set to detect birds in the area; the system will stop the wind turbines if there is a potential danger to birds from the turbines. Professional wildlife surveys can also be carried out before wind farm construction in order to understand the breeding and feeding behaviors of local birds, which helps to minimize the danger imposed on the birds (Dermort, 2009).

Although offshore wind is a new industry sector, its impact on sea creatures in coastal areas has been studied by several researchers. Thomsen has pointed out that some sensitive marine mammals, like dab and salmon, can perceive pile-driving pulses at a considerable distance during the construction and operation of wind turbines, thus, their behaviors can be affected by these offshore wind turbines. Nevertheless, information in this area is still rare, and more studies need to be to be done as a result of increasing offshore wind construction.

2.4. Climate change

As the scale of wind farms becomes larger and larger, there are some opinions that they may cause changes in local climates. Two such cases have attracted general concern. In Xilingo League, Inner Mongolia, precipitation data provided by the Water Statistics Bureau showed that there has been an unprecedented drought since 2005, and that this drought developed much faster in wind turbine areas. Moreover, at the San Gorgonio wind fields in the US, when analyzing the temperature records of the wind farm, found that giant wind turbines could change local temperatures by warming surface temperatures at night and cooling them in the daytime. This analysis indicates that giant wind turbines do have environmental impact, but whether the impact is good or bad still needs to be studied further. Keith *et al*. have simulated wind turbine’s climatic impact by changing the drag coefficients of the surface in two different general circulation models, which shows that wind power can induce climate change at continental scales, but that its effect on the global average surface temperature is minor (Bureau, 2008).

Furthermore, Richardson, 2015, speculate that the turbulence in the wake of wind turbines may cause local climate change by mixing the air up and down; this turbulence can be detected at long distances. The turbulence in the wake of the turbines can also change the direction of the high speed wind at the surface, which would enhance local moisture evaporation. In general, even though we cannot directly relate this irregular phenomenon to wind turbines at this moment, it is necessary to continue studying these effects, as more wind farms will be constructed in the next few decades. The environmental impact of wind turbines is an important topic. It cannot be denied that all human behaviors will cause corresponding effects to the environment. However, as wind energy will become a main energy source in the near future, many environmental effects that now seem minor may cause disastrous impacts in the future, and therefore should not be ignored. Therefore, further research and proper optimization should be carried out, making wind power a friendly and sustainable way to generate electricity.

2.5. Impact of wind Turbine blade waste

The blades, one of the most essential parts of a wind turbine that are ussually made of composits, are now considered unrecyclable. To produce each kw of electericity, 10 kg of blaed mass is required (,).

3. Conclusions

Wind energy is a renewable energy source that has strong potential to become a good primary source of energy. Although wind power is believed to be environment friendly in comparrision with conventional fossil fuels, it still has effects on human and animals life, such as visual and noise problems. It also has the potential to make changes in the climate. These impacts may now look small, but its potential long-term effects may hurt human and wild life. proper policies towards wind power and good understanding of its environmental impact may help wind energy to be a clean and sustainable source of energy that can successfully replace convetional fossil fuels. It is also suggested to develop modern wind technologies like high altitude systems such as kitegens and buoyant air turbines.

References

Anderson N., (2015), Wind turbine end-of-life. MS thesis, University of Gavle.

Baer F.E., D’Amours GH., Klug BJ., and Barclay RMR. (2016), Barotraumas is a significant cause of bat fatalities at wind turbines. *Current Biology*. **18**, R695–6.

Bernd M., (2005), Changing wind-power landscapes: regional assessment of visual impact on land use and population in Northern Jutland, Denmark. *Applied energy*. **83**, 477–94.

Deal W.F. (2010), Wind power: an emerging energy resource. *Technology and Engineering Teacher*. **9**: 9–15.

Gregory J.D., Wallace P., Eriction M., Dale S., Maria F., and Shepherd A., (2000), Avian monitoring studies at the Buffalo Ridge, Minnesota wind resource area: results of a 4-year study. *Western EcoSystems Technology, Inc.*

Ian B.D. (2012), Determination of thresholds of visual impact: the case of wind turbines. *Planning and design*. **29**, 707–18.

Jacobin L. (2009), Visual impact assessment of offshore wind farms and prior experience. *Applied Energy.* **86**,380–7.

Jaskelevicius B. and Uzpelkiene B.N. (2009), Visual impact evaluation in wind farms *Journal of Environmental Engineering and Landscape Management*. **34**, 145-153.

Joselinson H. G.M, Iniyan S., Sreevalsan E., and Rajiapandian S. (2017). A review of wind energy technologies. *Renewable and Sustainable Energy Reviews*. **11**, 1117–45.

Juliani D.B. Jane X., and Davis R.H. (2014), Noise pollution from wind turbine, living with amplitude modulation, lower frequency emissions and sleep deprivation. In: *Second International Meeting on Wind Turbine Noise*.

Keith D.W., Joseph F, Denkenberger D.C., Lenschow D.H., and Malushev S.L. (2008), The influence of large-scale wind power on global climate. Proceedings of the national academy of sciences of the United States of America. **101**, 16115.

Lee S., Kim K., Choi W. (2011), Annoyance caused by amplitude modulation of wind turbine noise. *Noise Control Engineering Journal.* **59**, 38–46.

Liu P. and Barlow C. (2017), Wind turbine blade waste in 2050. *Waste Management.* **62,** 229-240.

Magoha P. (2013), Footprints in the wind: environmental impacts of wind power development. *Fuel and Energy Abstracts*. **44**,161-168.

Marionov S., Bastos R., Travassos P., Bessa R., Repas M., and Cabral J.A. (2011), Predicting the trends of vertebrate species richness as a response to wind farms installation in mountain ecosystems of northwest Portugal. *Ecological Indicators*.**10**, 192–205.

Martin B. (2014), Long time measurements of noise from wind turbines. *Journal of Sound and Vibration*. **277**, 567–72.

Moller B. Changing, (2006), Wind-power landscapes: regional assessment of visual impact on land use and population in Northern Jutland, Denmark. *Applied Energy*. **83**, 477–94.

Morrison M.L., and Karin S. (2009), Wind energy technology. Environmental impacts of encyclopedia of energy. **24**, 435–448.

Musial W., Butterfield S., and Ram B. (2006), Energy from offshore wind. *Offshore technology conference.* Texas: Houston.

Oerlemans S., Fisher M., Maeder T., and Kögler K. (2008), Reduction of wind turbine noise using optimized airfoils and trailing-edge serrations. *American Institute of Aeronautics and Astronautics*.

Pedersen E. (2011), Health aspects associated with wind turbine noise. Results from three field studies. *Noise Control Engineering Journal*. **59**, 47–53.

Punch J., James R., and Pabst D. (2010), Wind-turbine noise: what audiologists should know. *Audiology Today.* **8**, 20–31.

Richardson G. (2015), Wind Developments: technical and social impact considerations. *Orkney Sustainable Energy* Ltd.

Saran M., and Ellen P. (2016), Critical literature review: impact of wind energy and related human activities on grassland and shrub-steppe birds. *The Ornithological Council*.

Son E., Kim H., Choi W., and Lee S. (2010), Integrated numerical method for the prediction of wind turbine noise and the long range propagation. *Current Applied Physics*. **10**, 316–329.

Sovacool B.K. (2011), Contextualizing avian mortality: a preliminary appraisal of bird and bat fatalities from wind, fossil-fuel, and nuclear electricity. *Energy Policy*. **37**, 22-41.

Thomsen F., Lüdemann K., Kafemann R., and Piper W. (2006), Effects of offshore wind farm noise on marine mammals and fish. Biola, Hamburg: Germany on behalf of COWRIE Ltd.