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Wind Energy – A Step towards Non-Conventional Energy Resources

Shailendra Kumar Bohidar[1], Ritesh Sharma[2], Prabhat Ranjan Mishra[3]
[1, 2, 3] Students,M.Tech,Turbomachinery,
MATS school of Engineering and I.T.,Raipur

Abstract

Wind energy is now recognized as an important energy resource throughout the world. Utilization of renewable energy resources appears to be one of the most efficient and effective ways in achieving sustainable development, that is now widely seen as important to worldwide public opinion. Among renewable energy sources, wind energy, which is a free, clean, and renewable source of energy, which will never run out, plays a big role. With this rapid growth, it is important to achieve a better understanding of how wind energy is being perceived by the public. Results regarding general wind energy attitudes signify overall public support for wind energy. In addition, those living closest to the wind farm indicate the lowest levels of support, while those living farthest away indicate much stronger support. This paper presents a critical review of the existing literature of wind power. This paper explores following research strands:

1. *Introduction.*
2. *Historical background.*
3. *Positive impact of wind turbine.*
4. *Negative impact of wind turbine.*

The paper will focus light on above issues and each plays an important role within the wind power literature and ultimately influences on planning and development practices. It is expected that this comprehensive contribution will be very beneficial to everyone involved or interested in Wind Energy.

1. Introduction

It is observed that there are growing concerns about future global energy demand and environmental pollution. To reduce these concerns to some extent, global communities are trying to find and implement different energy saving strategies, technology, and alternative sources of energy for different sectors that rely on energy produced from different sources. In that regard wind energy development will play a significant role to meet future energy demand and reduce environmental pollution to a certain extent. Energy is available in two different alternatives, non-renewable (coal, fuel, natural gas) and renewable (solar, wind, hydro, wave) sources.

Especially, after the industrial revolution, in the 19th century, first coal and then fuel oil are used as primary energy sources for the needs of modern communities. As known fossil fuels have limited potential and at current rates of exploitation they are expected to deplete within the next centuries.

This is one of the reasons why clean, sustainable and environmentally friendly alternative energy resources are currently sought.

The accumulation of carbon dioxide in the lower layers of the atmosphere gives way to climate change, floods, intensive rainfalls and droughts. In order to reduce these dangerous effects, it is the responsibility of each country to improve the quality of the energy resources, and if possible, to replace fossil fuels (coal and oil) with renewable alternatives wind, solar and other energy sources. Faced with energy crises in 1973 western countries began to search for their own clean and renewable energy (RE) sources (wind, solar, biomass, etc.) which are effective but they must inevitably compete against the conventional energy sources. In this competition, energy sources with huge and renewable raw materials have the advantage in the long run. Atmospheric environment is polluted due to thermoelectric power plants and petroleum materials since the industrial revolution.

The pollution crises are the catalysts for the search and development of RE sources. The environmental impact of fossil fuels, in the form of air pollution, acid rain and greenhouse effects in addition to their limited availability gave added importance to the use of conventional and renewable alternative energy sources, such as solar, wind and solar-hydrogen energies. Recently, renewable and clean energy generation technological developments facilities became available on the energy market.

Among the renewable alternatives, wind energy has an important potential role, and wind-power farms are becoming widely used all over the world. Wind energy can be utilized for a variety of functions ranging from windmills to pumping water and sailing boats. With increasing significance of environmental problems, clean energy generation becomes essential in every aspect of energy consumption. Wind energy is very clean but not persistent for long periods of time. In potential wind energy generation studies fossil fuels must be supplemented by wind energy.

There are many scientific studies in wind energy domain, which have treated the problem with various approaches [01, 02 and 03]. General trends towards wind and other RE resources increased after the energy crises of the 20th century [04].During the last decade, wind energy is developed and extended to industrial use in some European countries including Germany, Denmark and Spain. Their success in wind energy generation has encouraged other countries to consider wind energy also in their electricity generation systems. Its clean, economic, practical and renewable interaction with the environment soon draws attention from political, business circles and individuals.

The concept of RE is utilized since 5000 BC, and wind energy is one of the oldest of these energy sources. Today, humanity is attempting to rediscover its lost or forgotten energy sources [05, 06]. Opinion surveys from Europe indicate that most people support wind energy uses. Over 2000 year, water and windmills powered the world's first industries with new technology and materials. Modern wind turbines are used to generate the clean electricity needed for lighting, heating, refrigeration and other uses. Wind energy is a rather young industry, but one which already makes good economic sense.

It is a proven success and its use is increasing and the downward trend in its costs is expected to continue. Already over 20,000 turbines are producing worldwide electricity. Most are operating in 'wind farms' as groups of wind turbines generating electricity on a significant scale. Single wind turbines are also being used for generating electricity, charging batteries, driving pumps and producing heat. In the search for RE power, the most important decisions are concerned with exploitation of local, clean and sustainable energy resources.

The determination of wind energy potential depends very much on the meteorological measurements of the wind direction, velocity, and solar irradiation. Unfortunately, in many parts of the world, it is difficult to obtain such data. The physics behavior of wind shows great temporal and spatial variability. In meteorology, wind is air in motion, whose driving force is the uneven heating and cooling of the earth's surface. The horizontal movement of air parallel to the earth's surface is a measure of the wind in both direction and magnitude, which change most frequently. As a result, wind prediction is very difficult due to random change both in wind direction and speed. This changeability adds another measure importance to wind power.

Wind power has unique characteristics for energy technology. The most significant impact on the environment is the visibility of wind turbines. Those who support the movement towards clean, sustainable energy production should take into consideration aesthetically pleasing symbols of a better future, especially when compared with the effects of acid rain, global climate change, radioactivity, land and water contamination in addition to other environmental problems associated with conventional energy sources.

Figure 1.1 World Energy Demand Growths.

According to international energy outlook 2009,world energy consumption will increase from 472 quadrillion Btu in 2006 to 552 quadrillion Btu in 2015 and 678 quadrillion Btu in 2030 – a total increase of 44% over the projected period 2006–2030 as shown in Figure 1.1[07].

2. Historical background

Windmills have been used for at least 3000 years, mainly for grinding grain or pumping water, while in sailing ships the wind has been an essential source of power for even longer. From as early as the thirteenth century, horizontal-axis windmills were an integral part of the rural economy and only fell into disuse with the advent of cheap fossil-fuelled engines and then the spread of rural electrification.

The use of windmills (or wind turbines) to generate electricity can be traced back to the late nineteenth century with the 12 kW DC windmill generator constructed by Brush in the USA and the research undertaken by LaCour in Denmark. The power of the wind has been utilized for at least 3000 years. Wind energy first used for boat navigation on the Nile River 5000 BC.

During the same period, windmills pumped water in China. The first written information on wind turbines is based on a simple structural horizontal axis wind turbine during the region of Alexander the Great.

It is known that the Persians used vertical axis wind turbines during 700 BC. Windmills are introduced to the western world at the beginning of the 12th century from Islamic world [08]. During this century, AboulIz who lived in Diyarbakir, Turkey, developed the first modern vertical wind turbine [09, 10].

Until the early 20th century wind power is used to provide mechanical power to pump water or to grind cereals. The earliest windmills had vertical axis. These windmills are simple drag devices and they are used to grind grain in the Afghan highlands since the 7th century BC. The first details about horizontal axis windmills are found in historical documents from Persia, Tibet and China from about 1000 AD. This windmill type has a horizontal shaft and blades (or sails) revolving in vertical plane. From Persia and the Middle-East, the horizontal axis windmill spread across the Mediterranean to central Europe. The first horizontal axis windmill appeared in UK around 1150 AD, in France 1180, in Flanders 1190, in Germany 1222 and in Denmark 1259 AD. This rapid spread is most likely influenced by the Crusaders who carried the knowledge of windmills from Persian to Europe.

In Europe, windmill performance is continuously improved between the 12th and 19th centuries. By the end of the 19th century, the typical European windmill used a rotor of 25 m in diameter and the stocks reached to 30 m. Windmills are not only used for grinding grain, but also for pumping water to drain lakes and marshes.

By 1800, about 20,000 modern European windmills are in operation in France alone. In the Netherlands, 90% of the power used in industry is based on wind energy. Industrialization led to a gradual decline in windmills, but even in 1904, wind energy provided 11% of the Dutch industrial energy requirements and Germany had more than 18,000 units raised. By the time, European windmills began to disappear settlers introduced them to North America. Small windmills, pumping water for livestock became very popularly known as American windmills, which are completely self regulated, hence they could be left unattended. The self regulating mechanism pointed the rotor windward during strong wind speeds. European style windmills usually had to be turned out of the wind or the sailing blades had to be rolled up during extreme wind speeds, to avoid damage to the windmill.

The popularity of windmills in the US reached its peak between 1920 and 1930 when about 600,000 units were in operation. The historical development of wind-turbine technology is documented in many publications [11, 12]. In 1891, the Dane, Poul LaCour built the first wind-turbine generated electricity. Danish engineers improved the technology during the World Wars I and II and used the technology to overcome energy shortages.

The wind turbines built by the Danish company F.L. Smith in 1941 – 1942 can be considered the fore runners of modern wind turbine generators. The Smith turbines are the first examples that use modern airfoils based on the knowledge of aerodynamics. In the mean time, the American, Palmer Putnam built a giant wind turbine with a diameter of 53 m for the Morgan Smith Co. Both the size and design philosophy of this machine are significantly different.

The Danish design is based on an upwind rotor with a stall regulation, operating at slow speeds. Putnam's design was based on a downwind rotor with a variable pitch regulation. Putnam's turbine, however, was very successful [11]. In Denmark, after World War II, Johannes Juul further developed the Danish design philosophy. His turbine, in Gedser, Denmark, generated about 2.2 million kWh between

1956 and 1967. At the same time, the German, Hutter developed a new approach which is known as Hutter's turbine and became known for its high efficiency [11, 12, and 13].

Despite the early success of Juul and Hutter's wind turbines, the interest in large-scale wind power generation declined after World War II. Only small-scale wind turbines received interest for power systems in remote areas, or for battery charging. With the oil crises in the beginning of the 1970s, interest in wind-power generation resumed. As a result, financial support for research and development of wind energy became available. Germany, US, Spain and Denmark developed large-scale wind turbine prototypes in the MW range.

It is universally acknowledged that today's wind turbines capacities are advanced from those of 15 – 20 years ago. Since then, there have been some advances in understanding the aerodynamics and other fundamental technological areas, such as aerofoil design, tower interaction and noise production. Most progress, however, has occurred in the areas of production quality, mass production and in improving reliability.

In addition to these, profitability has been the main design driver during this development period. At the end of 1989, a 300 kW wind turbine with a 30-m diameter was a state of the art. Only 12 years later, 2500 kW turbines are constructed in many wind farms. Four and five MW wind turbines are expected to become available at the end of 2002 or in the beginning of 2003 **(Table 2.1) [12, 14]**.

Table 2.1 Development of wind turbine size between 1985 and 2002

Year	Capacity(kw)	Rotor Diameter(m)
1985	50	15
1989	300	30
1992	500	37
1994	600	46
1998	1500	70
2001	2000	72
2002	2500	80

3. Positive impact of wind turbine

Wind energy may help to reduce the air pollutions by replacing the current sources of conventional energy. As a result, emissions especially carbon dioxide, nitrogen oxide and sulfhur dioxide can be reduced. The main culprits are the greenhouse gases emitted by burning of fossil fuels, in particular carbon dioxide (CO_2).Wind power can provide energy while reducing the emission of CO2. According to the World Energy Commission, use of one million kWh of wind power can save 600 tonnes of CO_2 emission. Therefore, massive use of wind power will help mitigate climate change. Positive impact of wind power are discussed in following points.

3.1 Conservation of Water

It may be mentioned that conventional power plants use large amounts of water for the condensing portion of the thermodynamic cycle. For coal power plants, water is also used to clean and process fuel. Amount of water used can be millions of liters per day. By reducing the usage of water,water can be preserved and used for other purposes. California energy commission estimated the amount of water consumption for conventional power plants as shown in **(Table 3.1.1) [15, 16]**

It shows water consumptions by the different technologies of power generation.It has been found that water usage for wind turbine is lower than the conventional power plants and solar energy system.

Table 3.1.1 - Water Consumption of Conventional power plant and renewable energy based sources.

Technology	Gal/kwh	L/kwh
Nuclear	0.62	2.30
Coal	0.49	1.90
Oil	0.43	1.60
Combined cycle gas	0.25	0.95
Wind	0.001	0.004
Solar	0.030	0.110

3.2 Reduction of carbon dioxide emission

Wind energy has zero air pollution. It does not produce carbon dioxide, sulfur dioxide, mercury, particulates, or any other type of air pollution, as do fossil fuel power sources. A study by the Irish national grid stated that "Producing electricity from wind reduces the consumption of fossil fuels and therefore leads to emissions savings", and estimated reductions in CO_2 emissions ranging from 0.33 to 0.59 tonnes of CO_2 per MWh.Amount of pollutants that can be reduced is shown in **(Table 3.2.1) [17].**

Table 3.2.1 - Amount of Pollutants

Gases	CO_2	NO_x	SO_2
Reduction on emission per year (short -tonnes)	3251	20	421

According to data from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, approximately 67 million tonnes of CO_2 was avoided in 2006 by generating electricity through wind, biomass, photovoltaics and hydropower.Among these few types of electricity generation systems, wind energy plays the most important role.

Table 4.1.1 - Regional and Overall bats fatality rates in United states

Region	Studies	MW	Rotor Diameter		Bats/turbine/ year			Bats/MW/year		
			Min	Max	Avg	Min	Max	Avg	Min	Max
Northwest	4	397	47	65	1.2	0.7	3.2	1.7	0.8	2.5
Rocky Mts.	2	68	41	44	1.2	1.0	1.3	1.9	1.3	2.2
U. Midwest	4	254	33	48	1.7	0.1	4.3	2.7	0.2	6.5
East	2	68	47	72	46.3	28.5	47.5	32.0	31.7	43.2
Overall	12	787	33	72	3.4	0.1	47.5	4.6	0.9	43.2

Table 4.1.2 - Regional and Overall Raptors fatality rates in United states

Region	Studies	MW	Rotor Diameter		Raptors/turbine/ year			Raptors/MW/ year		
			Min	Max	Avg	Min	Max	Avg	Min	Max
Northwest	4	397	47	65	0.05	0.00	0.07	0.07	0.00	0.09
Rocky Mts.	2	68	42	44	0.03	0.03	0.04	0.05	0.05	0.06
U. Midwest	4	254	33	48	0.00	0.00	0.01	0.00	0.00	0.04
East	2	68	47	72	0.02	0.00	0.02	0.01	0.00	0.02
Overall	12	787	33	72	0.03	0.00	0.07	0.04	0.00	0.09
California	3	~878	13	33	0.15	0.01	0.24	1.37	<0.1	2.24

4. Negative impact of wind turbine

Apart from positive Impact wind Energy has some negative Impact.The most significant negative impact of a wind turbine technology is the wildlife, noise impact which will be discussed in the following sections. Some other impacts include the distraction of radar or television reception due to magnetic forces generated by the wind turbine and the increased possibility of being struck by lightning.

4.1 Impacts on wildlife

The wildlife impacts can be categorized into direct and indirect impacts. The direct impact is the mortality from collisions with wind energy plant while the indirect impacts are avoidance, habitat disruption and displacement. Studies show that birds may become disoriented in poor weather or foggy night. Subsequently, the avian are attracted to light emitted from wind energy plants which leads to the increasing number of avian fly through the wind plants and their vulnerability from collision with wind turbine blades.

To reduce the number of avian mortality, prevention and protection must be carried out. If negative impacts of wind energy on wildlife are reduced, wind energy will become more environmental friendly and can be used widely all around the world.

New wind projects should be carefully planned to minimize the environmental impact. In United Kingdom, a society (Royal Society for the Protection of Birds, RSPB) is formed to protect the bird mortality due to wind turbine installment.

In California, the wind energy industry joined with other stakeholders such as government officials and environmental groups to form the National Wind Coordinating Committee.These societies are engaged in resolving problems and issues on wildlife associated with wind energy development. They also give funding for researches on wind energy and wildlife issues.Bats mortality contributes a significant number due to wind turbine installation around the world.

Regional and overall bats fatality rates in United States are shown in **(Table 4.1.1) [18]**.The regional and overall raptors fatality rates in United States is shown in **(Table 4.1.2) [18].** A significantly low number of raptors fatality compared to birds and bats fatality in United States is found.

4.2 Noise impact

One of the major negative impact of wind energy is Noise Pollution. Noise emitted by a wind turbine can be divided into mechanical and aerodynamic types. Mechanical noise is produced by the moving components such as gear box, electrical generator and bearings. Aerodynamic noise is developed by the flow of air over and past the blades of a turbine.

Such a noise tends to increase with the speed of the rotor. Mechanical noise can be minimized at the design stage (side toothed gear wheels), or by acoustic insulation on the inside of the turbine housing. Mechanical noise can also be reduced during operation by acoustic insulation curtains and anti vibration support footings. Aerodynamic noise can be reduced by careful design of the blades by the manufacturers who can minimize this type of noise.

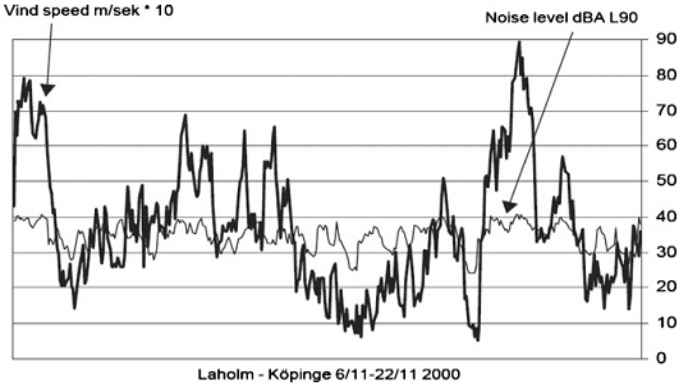

Figure 4.2.1 - Wind Speed and Noise level in dBA L_{90} versus time.

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 situated with the wind direction from the plant towards the receiving point. **Figure 4.2.1 [19]** shows the relationship between noise level and wind speed from a wind turbine [19]. The sound level is represented with the L90 metric, which is the best descriptor for the continuous sound from the wind turbine.

5. Conclusion

Among renewable energy sources, wind energy is a free, clean and renewable source of energy, which will never run out, is of a big importance. wind energy, which is a type of renewable energy has the potential to be utilized for power generation. Power generated by wind energy is not just relatively simpler but is also much more environmental friendly compared to power generation using non-renewable sources like the fossil fuels and coals.Considering that energy usage worldwide has been increasing throughout the years, switching to wind energy can be a viable move. Energy produced by wind turbine is not free from negative impacts.

It has been found that wildlife is killed with the collision of wind turbines in many cases. This source of energy also creates sound noise which is annoying to the vicinity of wind turbine installation project. Visual performance is also interfered by the wind turbine. If wind turbines are designed and planned carefully, many of these negative impacts can be minimized.

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