iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** IX **Month of publication:** September 2022

DOI: https://doi.org/10.22214/ijraset.2022.46896

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue IX Sep 2022- Available at www.ijraset.com

Acoustic Noise Emission in Wind Turbine: An Overview

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Abstract: Wind energy embarks its development from the California era to the construction of huge onshore and offshore wind farms worldwide, highlighting the main challenges of wind energy applications while meeting the target 1000 GW of wind power by 2030. Though wind energy is considered a techno-economically matured energy, it is not entirely free from impacts on the environment and human health.

Concurrently, large and small wind turbines are emerging even closer to human habitats, where acoustic noise would be of greater concern. Noise regulations and standards can effectively and fairly facilitate decision-making processes if developed and followed properly.

For instance Denmark has a special legislation concerning wind turbines, while others like Sweden, and have used recommendations originally developed for different noise sources. In Germany, the noise level could be related to absolute level or background noise level (standardized, measured or related to wind speed) as in France. There showed a correspondence between sound pressure level and noise annoyance in the field studies performed across the globe among people living in the vicinity of wind turbines.

Globally the annoyance and adverse health effects are analyzed by approaches such as epidemiological studies that rely on masked survey and clinical case studies. Wind turbine noise its propagation, relevant regulations, and impacts from wind farms were reviewed in this paper by summarizing existing studies. The intention of this paper is to provide state-of-art about wind turbine noise associated with wind turbines/farms to developers and planners.

Keywords: Wind Turbines, Noise Sources, Regulations, Setback Distances, Health Impact

I. INTRODUCTION

As one of the most matured renewable energy technologies wind energy has showcased tremendous growth during the past decade. Wind power has now become the preferred option of energy for planners in several countries and national governments, who are seeking for alternate green energy resources, to reduce CO_2 emissions. Although wind energy exploitation dates back to five thousand years, the current societies for meeting their electrical energy needs depend on fossil / nuclear fuels (78%). On the other hand, during the last thirty years, energy supply and respective environmental issues has returned the interest for renewable energy applications.

The evolution and further advancement in the system was pronounced from 19th century to till date. The first large-scale wind energy was encountered in California with capacity ranging from 20 to 350 kW (a total of 1.7 GW), were installed between 1981 and 1990 (kaldellis et al., 2011, murgrove., 2010, righter., 1996). Over the years, the development of the total global wind power installation has increased to 318.105GW according to Global Wind Report at the end of 2013. India ranks fourth with an installed capacity of 26867.11 MW in the wind energy as on 2016. Thus, knowing the fact that wind energy is a techno-economically full-grown and clean technology, it also concerns with noise impact from the wind farms. Actually, wind farm developers might face resistance from people who reside in the close proximity of new wind farm projects, which owe to be disrupting their regular activities (Kaldellis et al 2012, Dai et al 2015, Kaldellis et al 2011). As a result, one of the main limitations considered for extensive development of wind energy using small/ large wind turbines in human habitats is the noise generation and its propagation from wind turbine operation.

In this paper, the authors reviewed wind turbine noise with respect to background basis, field measurements, health correlation, Analytical models and Laboratory simulation. This review study would provide wind energy planners and developers with an understanding on the physical characteristics of wind turbine noise, its propagation and the impact of such noise on human.

II. WIND TURBINES AND ITS TYPICAL COMPONENTS

The turbines power is generated by capturing the wind and in turn converting it into rotational torque which can turn the generator and there by pushing electrons to the grid in the form of electricity (Dai et al., 2015).Wind turbines structurally classified into three components as shown in Figure 1. First, wind turbines possess a rotor which rotates by induced motion of one or more blades designed to rotate when exposed to wind or flow of air. Wind turbines are categorized as either horizontal or vertical axis turbines depending on the axis of blade rotation. The second component is the generator which converts mechanical energy to electrical energy. With respect to wind direction the generator and its components regulates pitch angle of the blade and the rotational plane. Most of the sound is radiated forward of the blade in the direction of rotation, while little is radiated behind. Third, is the tower that supports the rotor and the generator. The dynamic couple interaction of rotor blade with the tower is also a source of noise. Commonly used horizontal axis wind turbines place the rotor upstream of the tower, thus eliminating the wake- rotor interaction. However, unsteady lift and noise is created when the blades pass through a region of perturbed flow of upstream of the tower (Doolan et al 2012, Wagner et al 2006, Warren et al 2010).

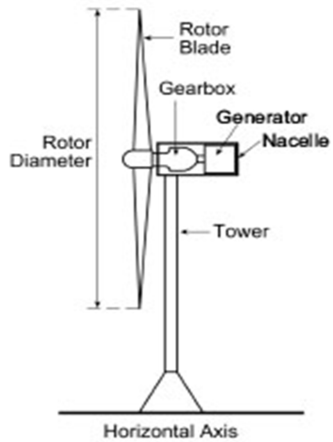

Fig. 1 Components of a horizontal-axis wind turbine

Wind turbines are erected in onshore or offshore either in isolation or in specific formation (called micro-sitting). Currently, height of turbines range approximately 2m to 200m and with capacities in 50W, 7.5MW with blade length of 60m. The size of a wind turbine can be specified either as a dimension or as an electrical output (e.g., tower height measured from the top of a blade at its highest point or in watts). Wind energy manufacturers and developers seek areas that have good potential in terms of wind flow availability(Wind resource assessment) for a longer season and close access to energy grids. The number of windfarms established in the past decade were also driven by environmental issues viz., climate change, sustainability and strategic energy considerations. Besides these wind turbines have several criticisms because of its visual impacts on landscape, shadow flicker from blades, fears of noise annoyance, sleep disruption and wild life disturbances. These form barriers in social acceptance, indicating citizens opposing to having the windturbines in their close immediate residential proximity (Claudio Guarnaccia et al 2011, Rand et al 2011).

III. ACOUSTIC CHARACTERISATION OF WIND TURBINE NOISE

Noise is one of the key societal environmental hindrances for the development of wind power industry in several developed countries. Noise from wind turbines can be more or less distinguished depending on the difference in characteristics of wind turbine noise and the background (ambient) noise. The background noise with respect to wind speed vary from day to night and site to site, for example in community noise viz., traffic noise, industrial noise and the whistling in bushes and tree (Pedersen et al 2003). Wind farm noise is often a broadband low-amplitude noise constantly shifting in character. Wind turbine noise increases with respect to either wind speed (m/s) or electrical output (watts) considering the meteorological parameters. Wind farm noise analysis poses distinct challenges of identifying the acoustic energy that can be directly attributed to wind turbines. There is audible noise perceived by the ear/brain system and the inaudible infrasound felt by the body.

The threshold of hearing is greater than 80 dB, at frequencies of 20Hz and threshold of pain is about 120 dB at frequency of 10 Hz. The ear detects sound and loudness as pressure waves and pitch of the sound. The ear/brain system perception for audible sound is effective from about 50 to 4,000 Hz with a gradual decrease in sensitivity (Harrison 2011). Doubling of the loudness is perceived by the ear/brain system as the sound pressure wave increases by three fold.

Perception of noise depends on local topography, meteorological conditions, area type such as rural or urban , the number of residents and their positional distance from the wind farm site and the affected community (residential, industrial, tourist). The interaction of the above mentioned might enhance or reduce the noise perception depending on the individual (Kaldellis et al 2012, Zhu et al 2005).

When two or more wind turbine blades are nearby, such that the blade passing pulses (concurrent arrival of pulses changes over time and place) coincide and then go out of phase again , there tends to be an amplification of potential noise (Fuglsang et al 1996, Van den Berg 2006, Thorne 2011).

The frequency weighting filters contribute to the overall sound level. Figure 2 shows the attenuation provided by the A, and C weighting filters that are expressed in decibels. For complex situations where dominant tonal components are present that is in case of measuring special audible characteristics require procedures for determining tonal adjustment requiring one-tonal octave band frequency or narrow-band analysis(Thorne 2011, Zwicker et al 1999, Bruel and Kjar 2006). A-Weighting is the most common scale for assessing environmental and occupational noise. B-Weighting approximates the ear for medium-loud sounds, around 70 dB. C-Weighting approximates response of human ear to loud sounds. It is used for measuring low-frequency sound.

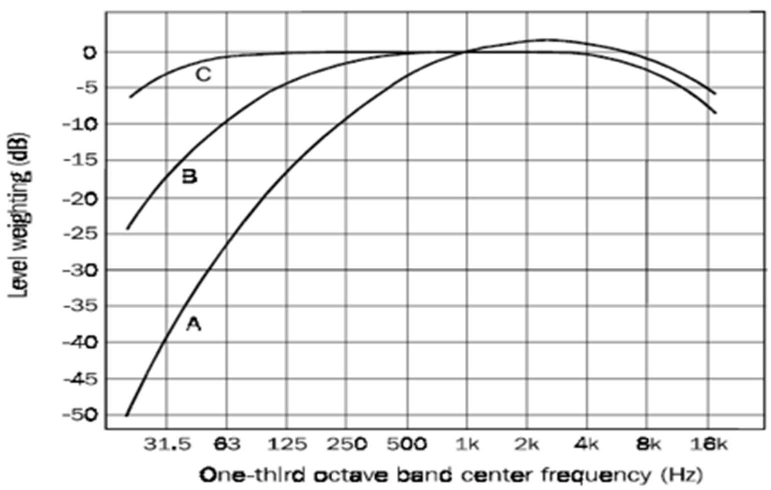

Fig 2 . Frequency weighting characteristics for A and C networks (Burns et al 1970)

Sound levels are expressed as an average level, or as a percentile measure, such as the level exceeded for 90% of the time. Commonly used sound indices are Lmin, L90, Leq, L10 and Lmax. Time averaged sound level Leq or the background sound level L90 are the most commonly used noise compliance assessment methods. Figure 3 provides a time history plot demonstrating some examples of common sound indices as determined over time (Marshall day acoustics 2011).

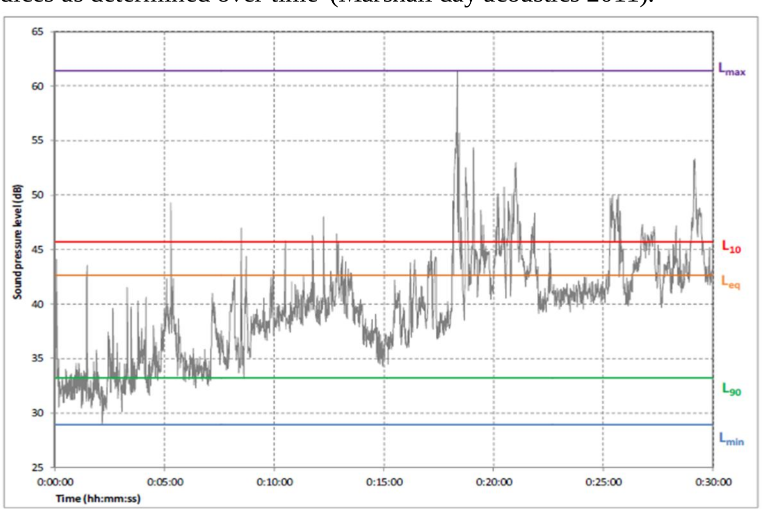

Fig 3. Noise level indices to measure time varying sound levels (Daniel et al 2011)

As shown in figure 3 the sound level change over a time period which may be derived by the summary of fluctuating levels in that time period. The unique noise events such as bangs or thuds from wind turbine shifting can be captured over a relatively short time period of 10 minutes. The sound energy is averaged over a whole hour, if the time period is relatively long.

The widest band used for frequency analysis is the octave band. Each octave band is described by the geometric mean of the upper and lower frequency limits called 'centre frequency' (Burns and Robinson,1970, Shepherd et al.,2011). Dunbabin.,1996 has stated that modulated noise from wind turbines has the beat of the rotor blades and with respect to the experimental studies amplitude modulation found to be apparent in 1 and

2kHz octave band with amplitude of ±2-3 dB. Table 1 represents preferred octave and one-third octave frequency bands. The sequence 31.5, 40,50 and 63 has the logarithms 1.5, 1.6, 1.7 and 1.8 and the corresponding frequency bands are referred to as the 15^{th}, 16^{th} etc frequency bands.

Table 1. Preferred octave and one-third octave frequency band(Colin H Hansen, Alberts, 2006)

Band number	Octave band center frequency (Hz)	One-third octave band centre frequency (Hz)	Band limits	
			Lower (Hz)	Upper(Hz)
14 15 16	31.5	25 31.5 40	22 28 35	28 35 44
17 18 19	63	50 63 80	44 57 71	57 71 88
20 21 22	125	100 125 160	88 113 141	113 141 176
23 24 25	250	200 250 315	176 225 283	225 283 353
26 27 28	500	400 500 630	353 440 565	440 565 707
29 30 31	1000	800 1000 1250	707 880 1130	880 1130 1414
32 33 34	2000	1600 2000 2500	1414 1760 2250	1760 2250 2825
35 36 37	4000	3150 4000 5000	2825 3530 4400	3530 4400 5650
38 39 40	8000	6300 8000 10000	5650 7070 8800	7070 8800 11300
41 42 43	16000	12500 16000 20000	11300 14140 17600	14140 17600 22500

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IV. NOISE SOURCES OF WIND TURBINES

The noise of wind turbine includes aerodynamic noise and mechanical noise. Mechanical noise is generated from the turbines internal gears. They may contain a distinguishable tone which makes it particularly noticeable and irritating .On the other hand is the aerodynamic noise comes from the turbine blades passing through the air. Aerodynamic noise contain different frequencies and is considered to be as broadband noise. This noise, perpendicular to the blade rotation surface, varies with turbine size, wind speed, and the blade rotational speed (usually RPM : Revolutions per minute). The dominant aerodynamic noise from the blades is seen in Figure 4. Contrary to the aerodynamic noise, mechanical noise may not increase with turbine dimensions (Lowson, 1996, Hubbard and Shepherd, 2009). However, small wind turbines used in roof-top applications and off-grid applications will have higher mechanical noise owning to higher RPM levels of rotor. The major aerodynamic phenomenon and its influence is shown in Figure 5 and 7a.

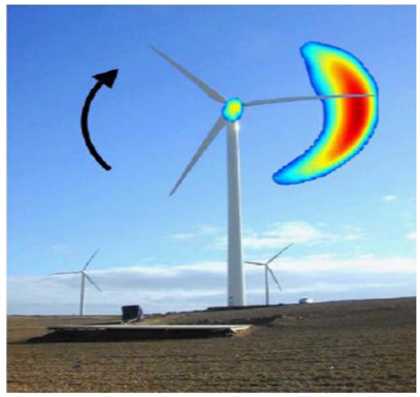


Fig 5. Dominant sound source –aerodynamic noise

As shown in Figure 6, the air flows around a wind turbine blade generates lift and drag forces, where lift acts perpendicular and drag acts along the direction of wind. An air foil performs best when lift is maximized and drag (flow resistance) is minimized. Atmospheric turbulence is seemingly continous and random motion superimposed on the windspeed. Turbulence impacts the loads on wind turbine varyingly.

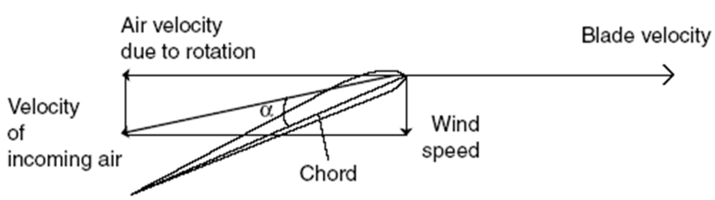
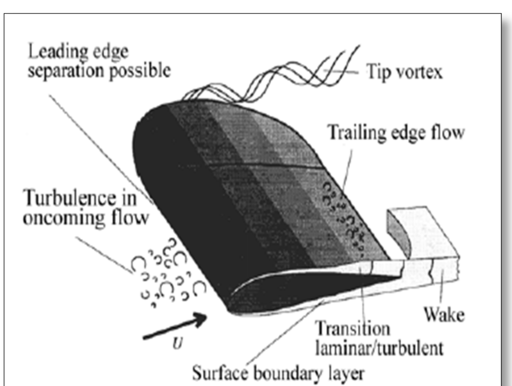


Fig 6.Flow impinging on a turbine blade

At the blade leading edge, dipole like sound source is created due to unsteady lift. This is called inflow or leading edge interaction noise and has a dipole like directivity pattern[5,31].(Lighthill 1952, Doolan 2012)



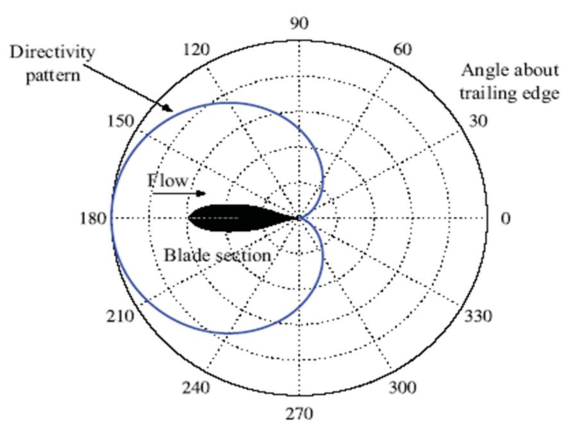
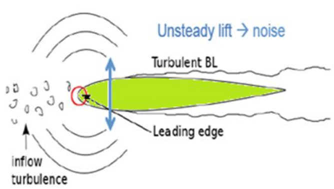
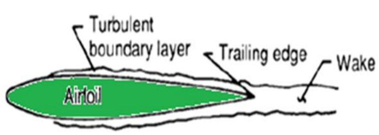
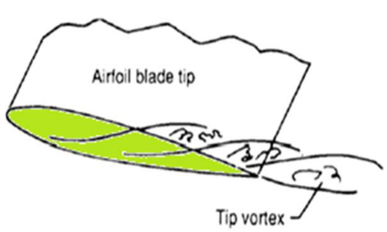
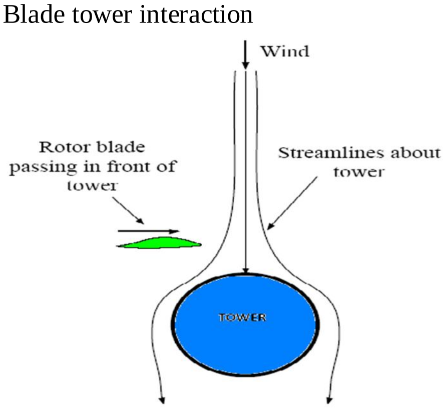


Fig 7a. Influence on aerodynamic noise, 7b. Noise directivity pattern

Figure 7b illustrates the directivity pattern of trailing edge noise, assuming a semi-infinite halfplane. In cardioid directivity pattern most of the sound is radiated forward of the blade in the direction of rotation, while little is radiated behind. This explains the “swish” character of wind turbine noise whereby an observer on the ground will periodically receive fluctuations in acoustic energy as the blade rotates. When the eddies created over the blades upper boundary layer (flow of air above the blade) due to viscous shear present between the blade and the air moves past the trailing edge of the blade, it creates broadband noise. That is turbulence by itself is the radiator of sound, the acoustic waves created by turbulence are reinforced via an edge diffraction mechanism making them much more efficient. This is called trailing edge noise, the major noise source on a wind turbine (Oerlemans et al., 2009, Oerleman and Schepers, 2009, Emrah 2011). Directivity pattern in trailing edge is different from monopole or dipole. Most of the sound is radiated forward of the blade in the direction of rotation while little is radiated behind. As the blade rotates, an observer on the ground will periodically receive fluctuations, this explains the swish character of wind turbine noise. Turbine blade aerodynamic noise generation is described in Table 2.

Table 2.Turbine blade aerodynamic noise generation (Anthony et al.,2006)

Noise source	Mechanism	Sound characteristics
Inflow turbulence 	Atmospheric turbulence in oncoming flow impinging on aerofoil	Broadband sound at lower frequencies
Trailing edge noise 	Typically a turbulent boundary layer develops along the aerofoil (blade) cord, with turbulence being scattered as sound at the aerofoil trailing edge	Broadband sound at higher frequencies
Tip noise 	Difference in pressures on either side of turbine blade results in vortex shedding, which may interact with the aerofoil tip, radiating as noise	Broadband sound at higher frequencies
Blade tower interaction 	Airflow upwind of the tower is disturbed by the presence of the tower downwind, causing a changing in pressure on the aerofoil (blade) as it passes the tower	Broadband sound at lower frequencies, including sound below 20 Hz

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V. A PRAGMATIC VIEW ON WIND TURBINE REGULATIONS

Noise assessment provides methods for prediction, measurement and analysis and plays an important role in the framework of guidelines. Small changes in the assessment methods would impact significantly on the potential renewable energy yield of the site. These are formulated to protect the environment from noise (industrial, traffic and other sources of noise).

Measurement of wind turbine noise for various wind turbines are undertaken according to IEC 61400 11:2002.The standard states that the noise emission includes infrasound, low frequency noise, impulsivity, tones, distinct pulses etc. The prediction of wind turbine sound levels(sound pressure and sound power level) is mostly referred to national or international standards which is based on ISO-9613-2. This algorithm basically accounts for spherical spreading (propagation) of sound waves from source, reflection and absorption by ground, and frequency dependent absorption by the atmosphere (Harrison, 2011). One of the most significant critic Professor Dickinson (2009) has given his comments with respect to the prediction of wind farm sound. He stated that "a compliance assessment using sound measurements is required in the operating stage of wind turbines in the farm regardless of any predictions".

In general, the noise from wind turbines increases with increase in wind speed. This might also tend to diminish in an environment as the background noise level continues to increase. Therefore, wind farm standards and guidelines in Australia and New Zealand set a base noise limit. This is generally applied at lower wind speeds when the background noise is relatively low (Hunt and Chiles,2011). When a windfarm reaches the base noise limit at higher wind speeds, the masking effect of background noise need not be taken as the base line noise limit. It is generally established to ensure that there are no adverse noise impacts, even in a low background noise environment (Adcock et al.,2012). Globally countries assesses the noise from wind farms under a range of Standards and Guidelines applicable to each individual State or Territory, as shown in Table 2 (Adcock et al.,2012, Delaire and Griffin, 2011, Colby et al.,2009, Krogh et al.,2000).

In the comparison of global standards for wind turbine noise level, there exists a common methodology ie., sound levels expressed in dBA not to be exceeded the prescribed limit derived from the sum of the preconstruction total noise and a constant (e.g., LA90+10 dBA)(Delaire and Griffin.,2011,). The following Table 3 represents the comparison of wind turbine noise for different countries.

Table 3. Wind turbine noise guidelines for nine countries

Country	State	Limit (dBA)	Background Plus Constant
Australia	Victoria South Australia	L_{A90} 35 or 40 L_{Aeq} 35 or 40	L_{A90} + 5 dBA L_{A90} + 5 dBA
Australia	Queensland	L_{Aeq} 30 indoors	Health and well-being criteria
Canada Denmark France	Ontario	L_{Aeq} 40 to 51 40	Day: L_{A90} + 5 dBA Night: L_{A90} + 3 dBA
Netherlands		40	
New Zealand		L_{A90} 35, 40	L_{A90} + 5 dBA
United Kingdom		Day: 40 Night: 43	L_{A90} + 5 dBA
United States	Illinois	Day: 50 Night: 46	
	Michigan Oregon	55 35	

VI. QUANTIFYING WIND TURBINE HEALTH IMPACTS

Quality of life which describes an individual's state of dwelling , represents a cornerstone of human health. Noise induced environment means a significant degradation in the quality of life. This represents a degradation in human health according to WHO, health is defined as a state of complete physical, mental and social well- being and not merely the absence of infirmity (Shepherd et al.,2011, Pedersen, 2011). Since 19th century wind power has been harnessed as a source of power, debate is ongoing in terms of audible and inaudible noise with respect to relationship between wind turbines and reported health effects. Referring to wind turbines an Ontario environmental decision found that serious harm to human health includes indirect impacts such as anxiety or anger, this could eventually lead to adverse health effects. Many health effects of noise are psychologically mediated via the indirect pathway (Møller and Pedersen.,2011, Pedersen et al.,2009).

Noise annoyance is not related to wind turbine noise itself, but also biased to factors like attitude to visual impact, residence (urban ,sub urban, rural) and landscape (plain, complex) .The proportion who are fairly annoyed or very annoyed remains quite level through the 29-37 dB(A)range but tend to increase at noise levels above 37 dB(A) (Van den Berg.,2006). To date to collect noise impact data there have been two approaches namely epidemiological studies that rely on masked surveys and direct clinical case studies. These approaches typically focus on the emotional impacts of noise upon sleep disruption and degradation of well-being and increases in stress that arise from sleep disturbance and noise annoyance(Rand et al.,2011, Zwicker and Fastl.,1999,Van den Berg .,2003).

From psychological perspective, noise annoyance can express in through malaise, fear, threat, uncertainty,or defenselessness. On the basis of widespread complaints about wind turbine operation induced health effects, various authorities have recommended setbacks in the range 1.5 to 2km from home and other sensitive areas. There have been field studies conducted to analyze the annoyance in addition to one to one interactions. Perhaps the studies carried out by Pedersen, Van den berg, (2009) were based on the size of the samples , the experience of the investigators and the inter-comparison between the studies(Pedersen and Waye ,2004).

Van Den Berg et al.,2003 annalysed the data-sets at two locations in Germany ranging from 400m to 1500m. He found that wind turbine noise was dominant in the environment 25% of the time and predominantly at night (72% of all 105 measurement hours) compared to daytime (4% of 191 measurement hours). Swedish studies reported by Pedersen 2004 and Persson Waye 2007 generated dose-response relationship between the prevalence of wind turbine and induced annoyance. They delivered questionnaires to 627 households in areas comprising 16 wind turbines. Approximately the response rate were similar and ranged from 60% (< 30 dB(A)) to 78% (>40dB(A)). The results revealed that the proportion of respondents who noticed wind turbine noise increased sharply from 39% (n=27) at 30.0 -32.5 dB(A) to 85% (n=53) at 35.0 -37.52.5 dB(A). Pedersen and Persson Waye 2004 concluded that living in rural landscape in contrast with an urbanized area enhanced the risk of perceiving wind turbine noise, furthermore, the risk of annoyance. Other physical parameters linked with annoyance include the terrain complexity exhibiting various focusing and defocusing effects and great ground reflection. The New Zealand study compared health related quality of life in different proximities to a wind turbine facility between two communities around the radius 2 km and 8 km with similar demographic, socio-economic and geographic characteristics. The study revealed that wind turbine noise increased with A-weighted sound pressure levels., further more annoyed when the noise level exceeded 35-40 dB(A)(Dickinson, 2009, Bowdler 2008). Wind turbine noise (swishing or thumping) from single turbine elicits increased fluctuation of the sound up to 4 to6 dB in a stable atmosphere. Under acoustical perspective Individuals are highly sensitive to frequency modulation variations of approximately 4Hz or greater. Whereas, non-acoustical factors also determine the tolerance of annoyance towards the noise. In relation to wind farms, the following personal factors given in Table 4 appeared to increase the odds of being annoyed.

Table 4. Non-acoustical factors influencing wind turbine noise annoyance

Non-acoustical factors influencing wind turbine noise annoyance
• Being able to see wind turbines from home • Having negative opinion about wind turbines in general or a negative opinion about the visual impact of turbines on the landscape • Self-reported sensitivity to noise • Perceived predictability of the noise level changing • General attitudes, fear of accidents, and awareness of benefits • Noise sensitivity • Economic benefit (home ownership, compensation, personal benefits from noise source)

In the analysis of combined data, the researchers found that people who reported annoyance outdoors were more likely to report sleep interruption, feeling tense and stressed, and feeling irritable. The impact of noise on sleep interruption did not increase gradually with noise levels; instead, the rates of reported sleep interruption were stable at lower noise levels, and increased at 40 dB in the Swedish study and at 45 dB in the Dutch study(Burns and Robinson ,1970). To date researchers concluded that wind turbine noise is different, and possibly more annoying, than other sources of community noise at similar levels. They also elucidated the limitations on the research that there is no statistical association between annoyance (indoors or outdoors) and other self-reported health outcomes included in the study (including diabetes, high blood pressure, cardiovascular disease, tinnitus, and other outcomes). Further, the exposure response relationship described by the researchers were developed using data from a very small number of field studies.

VII. REGULATING SETBACK DISTANCES

When planning a windfarm it is usual to base the setback of the wind turbines from residence based on the local noise regulation. The protocol is to base the sitting of turbines on the prediction of the noise at a receptor. A setback is defined as the minimum distance between a dwelling and closest position of wind turbine required to protect the health of inhabitants. The setback distances differ depending on a number of factors, including turbine type, terrain and climate (Flindell and Stallen.,1999, Blake.,1986). Approaches to set distances rely on the establishment of dose-response curves relating a health outcome variable and distance. The noise limits for countries around the globe is shown in the Table 5.

Table 5: Recommended distances between wind farms and habitation (Carmen et al.,2001, Lee,2011)

Region	Distance (m)
England (U.K.)	350
Scotland (U.K.)	2000
Wales (U.K.)	500
Belgium	350 in theory (Developers making it no closer than 500)
Denmark	4 × the total height
France	1500 (in practice 500 seems minimum observed)
Germany	Between 300 and 1500
Italy	Between 5 × the height or 20 × the height (not specified if mast or total height)
Netherlands	4 × the height of the mast
Northern Ireland	10 × rotor diameter (with a minimum distance of 500)
Romania	3 × height of the mast
Spain	Between 500 and 1000
Switzerland	300
Sweden	500 (in practice)
Western Australia	1000
Manitoba (Canada)	500 – 550
Ontario (Canada)	550
Prince Edward Island (Canada)	3 × the total height
Illinois (U.S.)	3 × the total height of the tower + the length of one blade
Kansas, Butler County (U.S.)	304.8
Kansas, Geary County (U.S.)	457.2
Massachusetts (U.S.)	1.5 × total height
Minnesota (U.S.)	At least 152.4 and sufficient distance to meet state noise standard
New York (U.S.)	1.5 × total height or 457.2 m
Oregon(U.S.)	1000
Door County, Wisconsin (U.S.)	2 × total height and no less than 304.8
Portland, Michigan (U.S.)	2 × total height and no less than 304.8
North Carolina (U.S)	2.5 × total height
Dixmont, Maine (U.S.)	1609
China	200 for a single wind turbine, 500 for a large wind farm

VIII. CONCLUSION

Windfarms consist of clusters of wind turbines, which, when placed in populated areas, are associated with intrusive and unwanted sound. A relatively new noise source; wind turbine noise has characteristics sufficiently different from other community noise. A single wind turbine on a roof top/garden or a windfarm can have significant societal impact owning to noise, during operation. Concurrently, larger and noisier wind turbines are emerging, and consent is being sought for progressively larger windfarms to be placed even closer to human habitats or amidst agricultural forms. Though the research on wind turbines is spreading fast, planning authorities, environmental agencies, and policy makers in many parts of the world are seeking information on possible links between wind turbine noise and health in order to legislate permissible noise levels or setback distances in their respective governance. Alternatively acoustic noise emanating from wind turbines could be reduced to lower levels by sound dampers (absorbers). Specifically, noise metrics such as L90,Leq , L15 are considered by many in the industry may in fact relate little to health outcome variables such as annoyance or sleep disruption. Thus, at this time with a conservative approach ,a constellation of acoustic and social metrics are to be taken in wind farms in order to access their source of noise production, design of noise reduction systems/ mitigation and its potential threat.

IX. ACKNOWLEDGEMENT

The authors acknowledge National Institute of Wind Energy (NIWE) under Ministry of New and Renewable Energy, Government of India, Chennai, Tamilnadu, for extending technical support and research infrastructure for the study.

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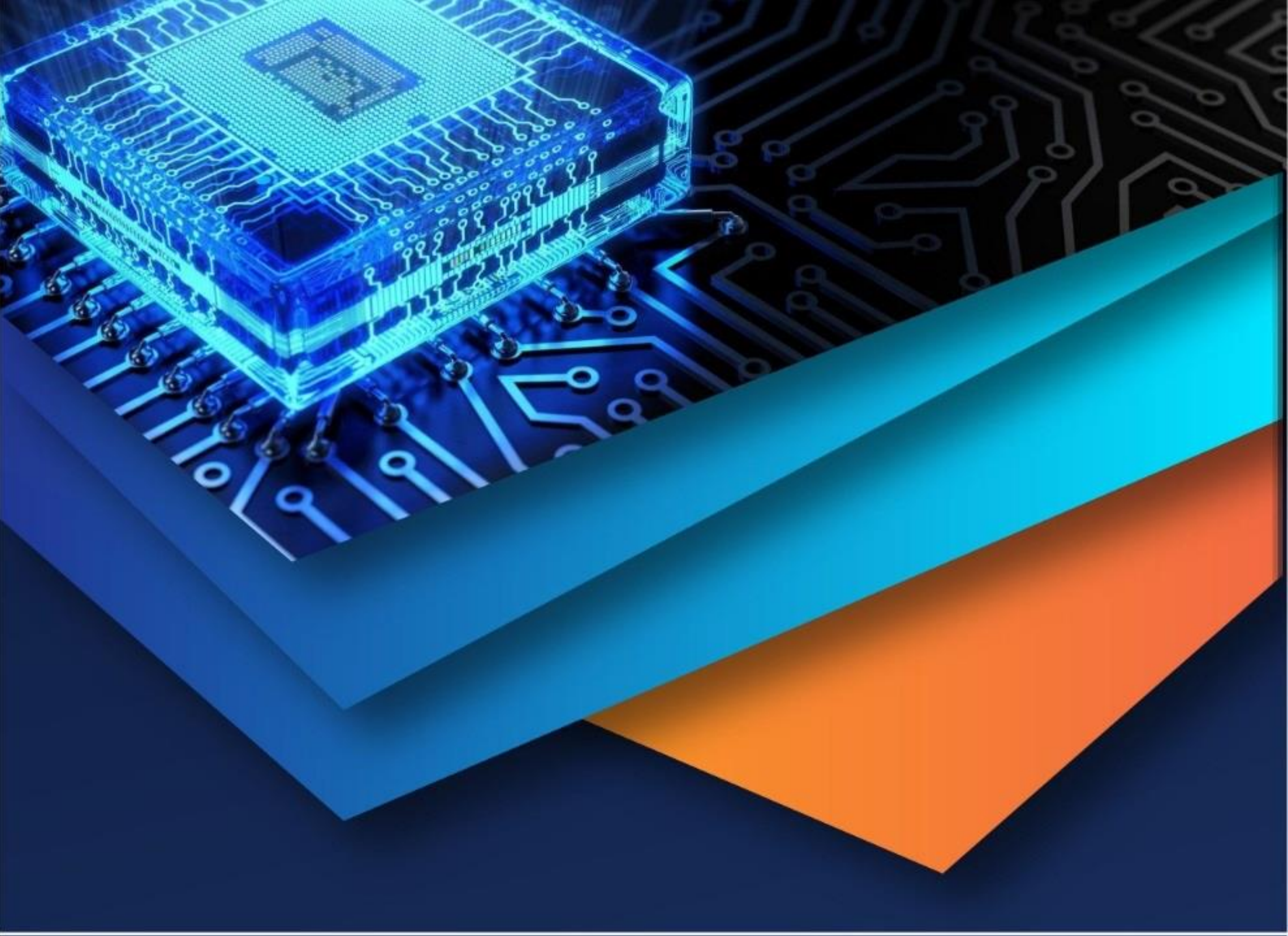

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