Mechanical Systems and Signal Processing 66-67 (2016) 715–722

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

Potential of neuro-fuzzy methodology to estimate noise level of wind turbines

Vlastimir Nikolić [a], Dalibor Petković [a,*], Por Lip Yee [b], Shahaboddin Shamshirband [b], Mazdak Zamani [c], Žarko Ćojbašić [a], Shervin Motamedi [d]

[a] University of Niš, Faculty of Mechanical Engineering, Department for Mechatronics and Control, Aleksandra Medvedeva 14, 18000 Niš, Serbia
[b] Department of Computer System and Technology, Faculty of Computer Science and Information Technology, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Advanced Informatics School (AIS), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
[d] Institute of Ocean and Earth Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 26 November 2014
Received in revised form
24 March 2015
Accepted 1 May 2015
Available online 23 May 2015

Keywords:
Wind turbine noise
Sound power level
Noises assessment
Neuro-fuzzy
ANFIS

ABSTRACT

Wind turbines noise effect became large problem because of increasing of wind farms numbers since renewable energy becomes the most influential energy sources. However, wind turbine noise generation and propagation is not understandable in all aspects. Mechanical noise of wind turbines can be ignored since aerodynamic noise of wind turbine blades is the main source of the noise generation. Numerical simulations of the noise effects of the wind turbine can be very challenging task. Therefore in this article soft computing method is used to evaluate noise level of wind turbines. The main goal of the study is to estimate wind turbine noise in regard of wind speed at different heights and for different sound frequency. Adaptive neuro-fuzzy inference system (ANFIS) is used to estimate the wind turbine noise levels.

1. Introduction

Wind turbine (WT) noise effect can be considered as one of the main technical issue to the implementation of WT. There are two noise sources of WT, mechanical and aerodynamic noise. Mechanical noise can be dropped by structuring of the mechanical components. On the other hand, the aerodynamic noise is very challenging task to overcome. There are two types of the aerodynamic noises: discrete (tonal) and broadband noise. Tonal noise low frequency noise and it is generated by the movement of WT blades which caused disturbance in flow. On the other hand, the broadband noise, which is higher frequency noise, is generated by turbulent flows. It is needed to predict and estimate aerodynamic noise of WT in order to reduce the noise.

Many researchers investigated the WT noises so far. The change of WT noise due to blade flexibility was investigated in [1]. It was shown that the more flexibly blades produces less noise. In article [2] the turbulence effect of the noise generation was analysed. One numerical method for prediction of the WT noise was developed in [3] which were based on Reynolds-averaged Navier–Stokes (RANS) based solver. Another numerical method based on Ray theory was used to characterize the WT noise

* Corresponding author. Tel.: +381 643283048.
E-mail address: dalibortc@gmail.com (D. Petković).

http://dx.doi.org/10.1016/j.ymssp.2015.05.005
0888-3270/

propagation in [4]. Measurement platform based on LABVIEW software was implemented for WT noise assessment in [5]. In [6] optimization of airfoils was performed in order to reduce noise emission. Investigation in [7] showed that rotor speed is important factor for noise measurement of WT. Determination of noise sources in WT was performed in [8] in order to identify the influence of each noise source. Linking of the WT noise emission with the individual perception was investigated in [9–11]. In [12] it was concluded that wake effect plays an important role in WT noise generation. Fifty participants with normal hearing abilities were used in [13] for experimental investigation of noise level propagation and detection of WT. Noise emission from small WT was investigated in [14]. In [15] one prediction method for estimation of WT noise using wind tunnel test was developed.

WT noise effect has been analysed by numerical or computational fluid dynamics (CFD) models. In this article the WT noise emission is estimated based on wind speed. Soft computing approach is used since CFD methodology is time consuming and challenging task. Adaptive neuro-fuzzy inference system (ANFIS) is used to estimate the WT noise level in regard to effective wind speed at different heights and sound frequency.

ANFIS is a type of neural network system [16]. ANFIS was used in many engineering applications and different systems [17–25]. In this investigation ANFIS is established for WT noise level estimation in relation to wind speed at 10 m height, wind speed at 80 m and sound frequency.

2. Materials and methods

2.1. Sound

Sound can be generated from many different mechanisms. Sound waves have amplitude or magnitude, wavelength (λ), frequency (f) and velocity (v), where v is [26]

$$v = f\lambda \tag{1}$$

Sound power level and sound pressure level can be used to measure magnitude of sound. Sound power gives only acoustic power. Sound pressure can be measured by observer by a microphone [27].

Sound intensity, I, can be defined as the power of the sound per unit area as [27]

$$I = 10\,\log_{10}(-I/I_0) \tag{2}$$

where the reference intensity, I_0, is often the threshold of hearing at 1000 Hz: $I_0 = 10^{-12}$ W/m^2.

The sound power level L_W is given by Bloemhof [27] in decibels [dB]:

$$L_W = 10\,\log_{10}(P/P_0) \tag{3}$$

where P is equal to the sound power level in units of power density and P_0 a reference sound power.

The sound pressure level of a sound, L_p, is given by Bloemhof [27] in decibels [dB]:

$$L_p = 20\,\log_{10}(p/p_0) \tag{4}$$

where p is equal to the effective sound pressure and p_0 a reference sound pressure.

2.2. Wind turbine noise impact assessment

The wind turbine used in the investigation has a 100 m rotor diameter [28]. Each blade is connected to the main shaft via the hub. The turbine is positioned on an 80 m hub height. The noise impact analysis for the Project was completed using the ANSYS environmental noise modelling software. The noise modelling was performed in according to the international standard ISO 9613-2. The noise predictions were calculated using downwind propagation from each source to each point of reception. This method produces a theoretical worst case prediction at each point of reception. The noise impact calculations were completed using octave band spectral values in the range of 63–8000 Hz for each integer 10 m height wind speed from 3 to 9 m/s and each integer 80 m hub height wind speed from 4.2 to 12.5 m/s.

The apparent sound power levels L_W are initially calculated as a function of the hub height wind speed V_{HH} [26,27]:

$$V_{10m} = V_{HH}\frac{\ln(10\text{ m}/Z_{0ref})}{\ln(\text{hub height}/Z_{0ref})} \tag{5}$$

The corresponding wind speeds $V_{10\text{ m}}$ at 10 m height above ground level have been evaluated assuming a logarithmic wind profile. In this case a surface roughness of $Z_{0ref} = 0.05$ m has been used, which is representative of average terrain conditions.

2.3. CFD wind turbine noise estimation

ANSYS solver was used for the ET noise modelling. The CFD wind turbine noise simulation procedure is shown in Fig. 1.