R E G I O N E   C A M P A N I A

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PROGETTO

PROGETTO DI REBLADING DEL PARCO EOLICO LACEDONIA-MONTEVERDE (39,60 MW)

PROGETTO DEFINITIVO

COMMITTENTE:

ERG Wind 4

ERG EVOLVING ENERGIES

PROGETTISTA:

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OGGETTO DELL'ELABORATO:

RELAZIONE DI VERIFICA ACUSTICA DELLA PALA DI PROGETTO

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INDICE

1. PREMESSA

La presente relazione ha come oggetto l'analisi delle emissioni acustiche prodotte dalla pala ETA4x ed il successivo raffronto delle stesse con le emissioni prodotte da una pala di riferimento, la V47 attualmente impiegata nell'impianto di Lacedonia-Monteverde.

Grazie ai risultati di tale analisi numerica, effettuata da ECN per conto di ETA Blades, è possibile determinare la curva di rumore della pala e, in aggiunta, identificare particolari condizioni critiche relative al comportamento acustico.

Dai risultati delle simulazioni è emerso che la pala ETA4X e la pala V47 presentano gli stessi livelli di emissione sonora per tutti i range di velocità del vento considerati, risultato considerevole tenuto conto che la ETA4X è lunga un metro in più rispetto alla V47 (e presenta dunque velocità alla punta della pala maggiori) ed inoltre che non è stato adottato nessun particolare costruttivo atto a ridurre il rumore.

Per maggiori dettagli circa l'impatto acustico delle pale di progetto sull'ambiente circostante si rimanda all'elaborato LCD.ENG.REL.11.00 "Studio di Impatto Acustico".

Confidential

Noise Calculation on the ETA4x Wind Turbine Blade

F. Grasso

July 2013
ECN-X--13-078

Executive summary

The goal of this project is to numerically simulate the noise produced by the ETA4x blade, compared to a reference blade, the V47.

New blades (called ETA4x) have been developed by ETAblades for a 660kW wind turbine. ETAblades requested ECN to evaluate the predicted noise produced by the blade and compare it with the noise calculated in the same way for a reference blade. The V47 was assigned by ETA as the reference. By performing this numerical analysis it is possible to predict the noise response of the blade and also, identify particular critical conditions in regards of acoustic behaviour and eventually modify the blade before performing experimental tests. This is important information for ETAblades for the purposes of progressing with the certification of the blade.

The general conclusion from the simulations is that the calculations performed on the ETA4X and the V47 produced the same noise for all the range of wind speeds taken into account. This means that the difference in noise from the blade should not be discernible to the human ear. These results should be pleasing for ETAblades because the new blade is 1 meter longer than the reference blade. Longer blades have higher rotational tip speeds and noise increases with tip speed to the power of 5.

Providing that the blades can be manufactured to the same dimensions as used in the numerical models, the results of this simulation provide a high level of confidence that the noise output from the ETA4x blades alone should be very similar to the V47.

ECN project number: 6.00737
Undertaken in accordance with ECN General Terms and Conditions for execution of orders rev.2011.10.

Contents

Introduction

ETA4x blades have been developed by ETAblades for a 660kW wind turbine. In order to complete the certification procedure, ETAblades requires to evaluate the noise produced by the blade and compare it with the noise calculated in the same way for a reference blade assigned by ETAblades. Therefore, ETAblades requests ECN to generate and provide these data.

The present work is focused on performing noise calculation on the ETA4x blade.

In the next chapter, the results of a preliminary test are presented. Then, the results of the full analysis, together with the conclusions and remarks.

At the end of this report, more details about the noise modelling are presented.

1

Preliminary noise analysis

The noise calculations presented in this document have been performed by using the ECN tool SILANT [1]. The code is based on semi-empirical models based on the work of Brooks, Marcolini and Popes [2,3]. Some details of the modelling can be found in appendix A.

Silant has been validated against experimental measurements obtained during the European project SIROCCO [5]; however, a preliminary noise calculation has been performed during this project to assess the accuracy of the tool in regards of a reference blade assigned by ETAblades. The reference geometry was the V47 wind turbine, in the past already analyzed by ECN from the aerodynamic point of view [6]. The table 1 summarizes some of the main characteristics of the turbine.

Table 1: Summary of the main characteristics of V47 wind turbine.

blades:	3
diameter [m]:	47
hub diameter [m]:	1.1
Power [kW]:	660
rotational speed [RPM]:	28.5
cut-in wind speed [m/s]:	4
cut-out wind speed [m/s]:	25
power control:	active pitch

The experimental data to compare the numerical predictions were the noise measurements performed in open field at a wind speed of 8m/s, at 10m height [7]. The total “A weighted”[1] noise was measured and it was 100.8dB, with an accuracy of +-2dB.

[1] The A weighted noise is the noise produced, but averaged according to the human sound perception. As effect, some frequencies are emphasized, while others are neglected.

The overall noise predicted by SILANT was 101dB, with a numerical accuracy of +-1dB. Considering the accuracy of the measurements, the obtained results are perfectly matching the experiments.

2

Noise analysis of the ETA4x wind turbine rotor

2.1 The ETA4x wind turbine blade

The ETA4x blade has been designed by ECN in cooperation with TSR, where ECN was in charge for the aerodynamic design [8,9] and TSR for the structural part. The blade was designed for low wind conditions.
In table 2, the main characteristics of the blade are summarized.

Table 2: Summary of the main characteristics of ETA4X wind turbine.

Cut in Wind Speed [m/s]:	3
Nominal Wind Speed [m/s]:	7.5
Cut Out Wind Speed [m/s]:	25
Rotor Speed [rpm]:	28.5
Max. Tip Speed [m/s]:	75
Max. Power [kW]:	660
Power Control:	active pitch
Rotor Diameter [m]:	49
Number of Blades	3

2.2 Results of the noise analysis

The scope of the noise calculations performed by ECN was to predict the noise produced by the ETA4X blade for different wind speed values. The “A weighted” overall noise has been used as indicator of the noise produced. The overall noise includes several contributions depending on the possible sources of noise. Some details about the modelling can be found in Appendix A.
The same analysis has been performed for the V47 in order to have a direct comparison. Table 3 summarizes the results (the numerical accuracy of 1dB has been taken into account). The calculations have been performed at wind speeds between 4 and 12 m/s, as representative of low wind speed conditions.

Table 2: Overall noise produced by the ETA4X wind turbine. * the noise reported is the A weighted overall noise.

wind speed [m/s]	Total noise [dB(A)]*	
	V47	ETA4x
4	96.7	96.7
5	97.2	97.2
6	98	98
8	101	101
10	105	105
11	106	106
12	103	103

As it can be seen, the two blades produce the same overall noise. This is a very good result when it is considered that in designing the ETA4X no special solutions were taken into account to reduce the noise. Even more important, the ETA4X is 1 meter longer in radius than the V47. Due to the fact that the rotational speed is the same for the two turbines, the tip speed values for the ETA4X are larger. This has direct effect on the noise since the noise increases with the tip speed at the power 5.

3

Conclusions and recommendations

In order to support ETAblades in developing their ETA4X blade, noise calculations have been performed for several wind speeds to investigate the noise response of the blade.
Preliminary tests performed on a reference turbine (V47) proved that the prediction are in very good agreement with the measurements.
The calculations performed on the ETA4X and the V47 produced the same noise for the all range of wind speeds taken into account. Considering that, in designing the ETA4X no special solutions were taken into account to reduce the noise, the outcome of the analyses is positive. In particular, the ETA4X is 1 meter longer in radius than the V47, so the tip speed values of the ETA4X are larger. This has direct effect on the noise since the noise increases with the tip speed at the power 5.

References

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Appendix A: Noise modelling in Silant

General overview

SILANT originated in 1996 from a Dutch consortium consisting of Stork Product Engineering BV, the Netherlands Organisation for Applied Scientific Research (TNO) and the Dutch Aerospace Laboratory (NLR). The model was designed to calculate noise emission of wind turbines, based on the sources that are considered most important: trailing edge noise (including separation-stall noise) and inflow noise. After ECN became the manager of the tool several improvements have been made, partly in cooperation with NLR. The improvements include the addition of models for prediction of tip noise.

Noise source modelling

The sources included in SILANT are trailing edge noise, inflow noise and tip noise. The modeling of these sources is discussed separately below.

Trailing edge noise

Turbulence in the airfoil boundary layer convecting past the trailing edge is considered the main source of trailing edge noise. Therefore the BPM turbulent boundary layer trailing edge noise model [2] is implemented, which necessitates the input of boundary layer displacement thickness
at the trailing edge for both airfoil pressure and suction side. The displacement thicknesses come from an a priori created database which contains the thicknesses as a function of airfoil angle of attack and Reynolds number. Therefore the effective local incoming velocity and angle of attack of each element needs to be supplied from an aerodynamic code, e.g. BEM or a vortex line method. The database can be obtained from wind tunnel tests or calculations as long as the profile geometry is known. Equation 1 shows the resulting formula.

$$PWL = 10log[4\pi\delta^* M^5 s] + A(f, \alpha, U_e, \delta^*) \quad (1)$$

With:

PWL [dB] Power Watt Level
δ^*[m] trailing edge boundary layer displacement thickness
Ue [m/s] local effective incoming velocity
M [-] Mach number based on Ue

s [m] segment width
α [deg] local angle of attack
f [Hz] frequency
A [dB] spectral function

The spectral shape is determined using the frequency dependent function A. For angles of attack above stall there is a contribution of the separated flow with the airfoil solid surface. The model then switches to separation-stall noise by modifying the frequency dependent function A.

Inflow noise

The interaction of the airfoil with turbulence in the oncoming flow results in inflow noise. The model of Amiet [3] is used for prediction of this noise type, using equation 2 below:

$$PWL = 10log[4\pi M^5 sL \frac{u'^2}{U_e{}^2} B(f, U_e, L, c)] + 181.3 \qquad (2)$$

PWL [dB] Power Watt Level
Ue [m/s] local effective incoming velocity
M [-] Mach number based on Ue
s [m] segment width
f [Hz] frequency
c [m] local chord
L [m] turbulence length scale
u02 [mm/ss] variance of turbulent velocity fluctuations
B [-] spectral function

The spectral shape is determined using the frequency dependent function B. The turbulence length scale and variance of turbulent velocity fluctuations are determined using the specified roughness length and element height as defined by ESDU [4].

Tip noise

The formation of the tip vortex creates turbulent flow interacting with the trailing edge of the airfoil tip region. This contribution is concentrated in the tip element using the BPM model [2]. The level and spectral content of the tip noise are determined using the spanwise extent of separation l at the trailing edge due to the tip vortex. Equation 3 shows the resulting formula:

$$PWL = 10log[4\pi M^5 (1 + 0.036\alpha)^3 l^2] + C(f, l, U_e, \alpha) \qquad (3)$$

With:
PWL [dB] Power Watt Level
Ue [m/s] local effective incoming velocity
M [-] Mach number based on Ue
α [deg] local angle of attack
l [m] spanwise extent of separation

f [Hz] frequency
C [dB] spectral function

The spectral shape is determined using the frequency dependent function C. The spanwise extent of separation is determined using:

$$l/c \approx 0.008\alpha \qquad (4)$$

With:
c [m] chord of tip region.

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