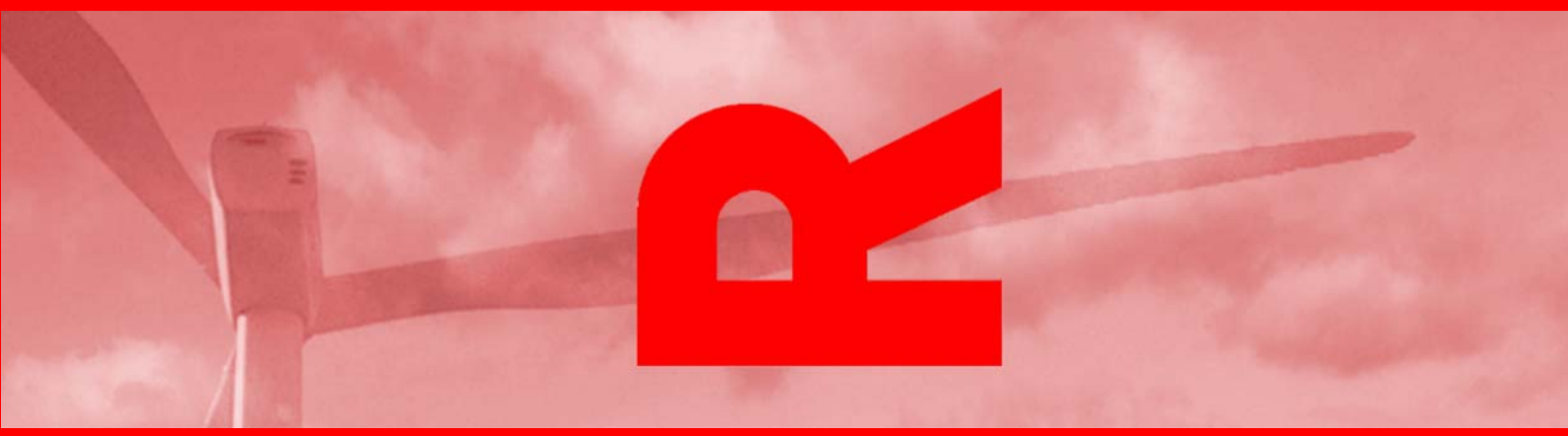
WIND POWER

Acoustic and Vibrations Engineering Services



"Far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question, which can always be made precise."

John W. Tukey

Right questions lead to right answers

"I am not bound to swear allegiance to the dogmas of any master."

Horace

The good thing of a problem without an obvious Solution is the pleasure in finding it

"I support that symbiogenesis is the result of a long time coexistence and that is the main source of evolutionary novelty in all superior non-bacterian organisms."

Lynn Margulis

Fluent communication is the key to progress

ICR

Ingeniería para el Control del Ruido (ICR) is an acousitc engineering located in Barcelona dedicated to solving noise and vibration problems. Founded in 1995 by professionals with more tan 20 years of experience in the field of vibro-acoustics, ICR offers recent analysis methods for railways, automotive, wind power, industry and civil engineering sectors.

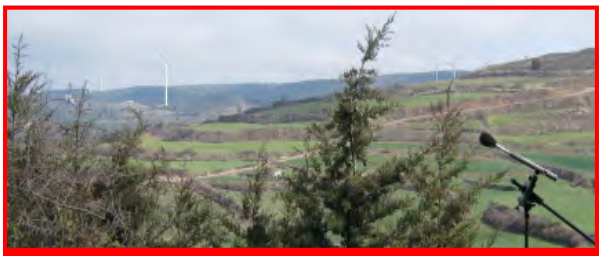
The company's goal has always been to offer the right and most efficient solution for each vibro-acoustic problem. To do so, most of ICR efforts have been focused on R+D, with the objective to develop new predictive and analysis methods.This company innovative profile has allowed ICR to take part in numerous highly technological projects, both national and international. In some cases, these projects were focused on a technology transfer from ICR to their clients.

ICR clients have complete transparency in each of the steps taken during the project, obtaining the necessary know-how to choose the best option for each situation. Futhermore, services include conducting ICR software and methods of measurement for those customers that are deemed essential to equip itself to solve their own problems.

ICR measuring equipment is capable to simultaneously analyze a vast quantity of measurement points, allowing the efficient determination of the solutions required for real vibro-acoustic problems.

ICR offers solutionsto noise and vibrations problems of its customers. This can be done either by solving the problems once they are detected, or what is better, by trying to prevent and avoid them at the product design stage. Every problem receives an individual attention and the best analysis options and proceeding alternatives are chosen for it.

The company staff is formed by PhD, physicists and engineers. This combined knowledge allows the company to analyze any vibro-acoustic problem from a global and specialized point of view. The result is always a good diagnostic of the noise and vibration problem and the proposal of the best solution.



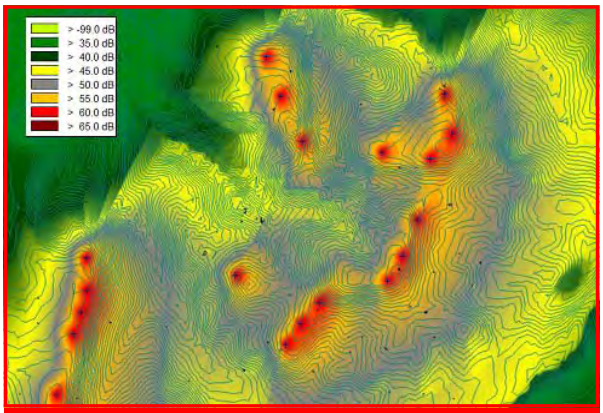
Noise measurements in a wind farm.

Theory and tests

Thanks to its experience, ICR has managed to adapt to the needs of the market and the company has been working in the wind energy sector for years, with the aim of establishing the viability of the same in terms of environmental acoustic impact via extensive research and to determine compliance with regulations.

The proliferation of wind farms has led to a series of technical requirements with regard to noise and vibration, affecting both the farms as a whole and the wind turbines. For this reason ICR is active in each of the implementation phases of a farm: the phase involving the design of the wind turbines the aim of which is to obtain real estimates of the future vibro-acoustic behaviour of the mechanism, complete analyses for both the evaluation of the environmental acoustic impactge-

Noise measurement in a wind farm.



Acoustic impact prediction in a wind farm under development

Noise and Vibrations under development

For the purpose of finding out the noise or vibrations that may be emitted by mechanisms such as a wind turbine before its construction, ICR integrates the theoretical analysis with a series of measurements *in situ*. As a result, different specific methods have been adapted in order to predict and confirm a posteriori the acoustic or vibrational behaviour of the wind turbine.

Some of these methods are intended to perform prediction computations and experimental analysis of the behaviour of the product in its development stage in order to prevent future problems.

The purpose is not only to limit noise emissions but also to reduce the vibrations in order to prevent dynamic loads that may cause ruptures and, simultaneously, to bring down the maintenance costs, such as gear units.

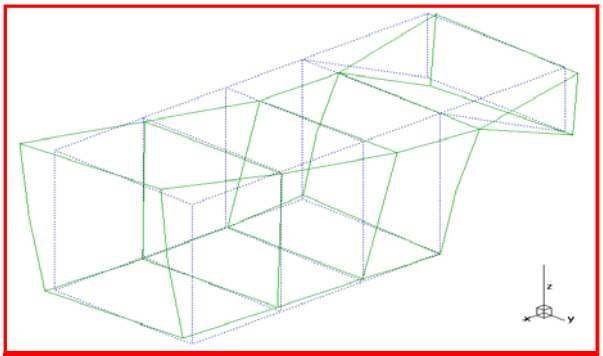
Some of these methods are:

- Finite Element Method (FEM)
- Boundary Element Method (BEM)
- *Ray-Tracing*
- Statistical Energy Analysis (SEA)
- Aeroacoustics calculations
- Modal Analysis
- TPA/ATPA (*Advanced Transfer Path Analysis*)
- Model Inversion
- Acoustic holography

Modal Analysis

By means of the **Experimental Modal Analysis** (**EMA**) it is possible to establish the vibration modes (mode shepes, natural frequency and damping) of a structure using a protocol involving the measurement of vibration-force transfer function. Based on this information, it is possible to create an entire dynamic model of the system. For instance, this model allows obtaining the responses to any external excitation. In this sense, any troublesome resonance is identified and corrected and the localization of the supporting points of fragile equipment are optimized.

A common case is the modal analysis of the nacelle structure and its devices (gearbox, generator, electric cabinet). ICR boasts a significant expertise in experimental modal analysis of wind turbines at the manufacturer´s plant or already installed in the wind farm.



Flexural mode of vibration of the frame of a wind turbine nacelle

As far as R&D is concerned, ICR has carried out exhaustive researches in the implementation of the **Operational Modal Analysis** (**OMA**) in wind turbines, thus developing state-of-the-art methods.

The OMA is the modal analysis of vibrations from wind turbines in operating conditions. Unlike the traditional EMA method, this does not require the measuring of forces. Measurements carried out when a wind turbine is in operation enables us to obtain an experimental model that considers its "real-life" operational characteristics.

Measurements according to IEC 61400

ICR identifies the sound power level emitted by wind turbines according to the sound pressure measurements established by the regulation IEC 61400. This regulation provides a measurement procedure capable of identifying the noise emission characteristics of a wind turbine on the basis of the wind speed and direction.

ICR performs these measurements in a rigorous and strict way. As established by the regulation, it also carries out directivity measurements that constitute the basic parameter for the subsequent calculation of noise levels emitted by wind turbines system.

Sound power level measurement according to standard IEC 61400 part 11

Environmental noise impact assessment of a wind farm

Acoustic impact study

Wind farms are increasingly gaining ground towards populated areas, producing a noise that has become an essential factor as regards feasibility plans. For this purpose and the purpose of complying with the current environmental regulations, ICR carries out comprehensive studies both to assess the environmental acoustic impact emitted by a wind farm in operation as well as to predict the impact of a wind farm to be designed.

The method developed by ICR is divided into several stages: first of all, it identifies the acoustic characteristics of an area through *in situ* measurements for the purpose of determining its previous conditions. Once the required data is gathered, a theoretical model is simulated by combining the environment acoustics with the noise characteristics of wind turbines. As a last step, ICR proposes the most appropriate solutions for each case.

After adapting the previous noise measurements to the numerical model, it is possible to calibrate it, thus obtaining the highest reliable results.

ICR develops the acoustic feasibility of a farm from the design stage up to its implementation and further

Customised Training

ICR offers specific training services for the professionals in each applicable sector.

As regards the wind sector, courses are given to wind turbines manufacturers and the professionals in charge of the planning, managing and building of wind farms. There are specific subjects adapted to the professional´s needs. These include an introduction to acoustics concepts and all related current regulations.

Course of environmental noise impact

The most important companies in the country
have already taken courses with ICR

Course of Environmental noise impact assessment in a Wind Farm

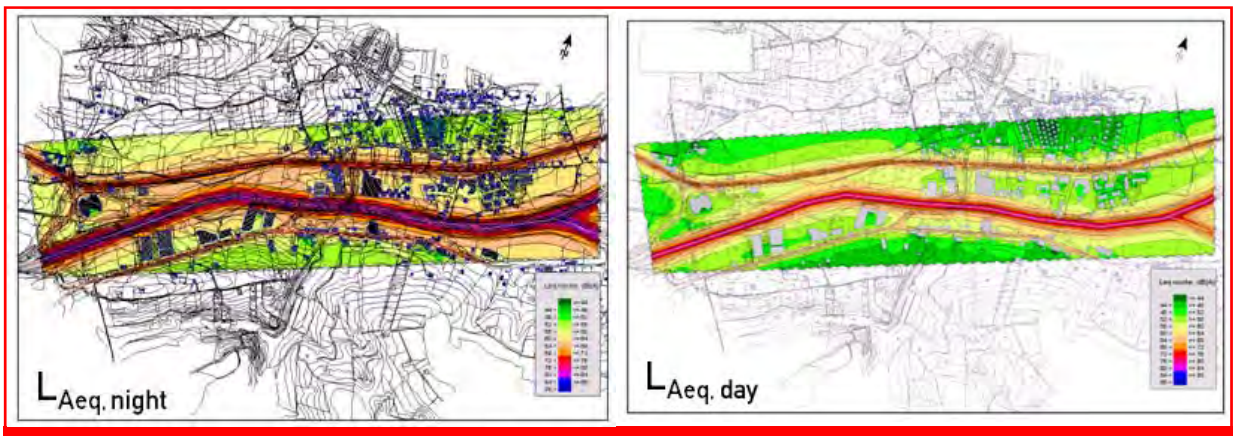
Environmental noise impact assessment in a wind farm course is designed for any person that, when lacking previous acoustics knowledge, is able obtain its own acoustic criteria to interpret the regulation, both regarding noise environmental measurement and calculation.

This course is divided in three parts:

1. Introduction to basic acoustics to interpret and achieve good knowledge of the environmental regulations
2. Study of the environmental noise impact in a wind farm

The milestone of the course is the environmental noise impact assessment in a wind farm that focuses on white noise measurements as specified by NFS 31-010 and Pr NFS 31-114, and a forecast acoustic model as per regulation ISO 9613-2.

The duration of the course is three days, though it may vary upon the subjects, since ICR gives the possibility for the clients to adapt each course to their needs, reaching the point of having personalized formation. Therefore, this course is gaining good acceptance among the main representatives of the sector in the country.



Course of environmental noise impact - Comparison of calculation L_{Aeq}

Projects of engineering in wind energy

Below are listed some of the main projects in which ICR has participated in this sector:

- Abnormal Frog noise detection in the Landes Couesme (France) Wind Farm. Noise measurements in five campaigns: three with the equipment installed inside the rotor and controlled from the nacelle *in situ*, and two in Buñuel facilities with only the rotor and a tool simulating the picth motor forces. Alstom Wind.
- Course on environmental noise impact for wind farms design. The course presents the basic concepts of acoustic and analyzes its relationship with current standards. Alstom Wind.
- Environmental noise impact course in wind farms due to the installation of a new wind farm. Suzlon Wind Energy España.
- Noise study in a ABB transformer in Shangai. Sound power measurements according to IEC60076-1 standard, tonality test according to IEC61400 standard and proposal of solutions. ABB.
- R+D Project "InVent for the Operational Modal Analysis (OMA): dynamic characterization of wind turbines using Operational Modal Analysis (OMA) and software design". Formation to Alstom Wind engineers in the use of the software. From temporal registers, in different wind speeds, the software generates automatically evolution diagrams of the wind turbine frequencies in relation to wind speed. Additionally, an operational deflection shape module has been included in the InVent software. Alstom Wind.
- Experimental Modal Analysis (EMA) of the drive train of the ECO100 wind turbine in two different configurations: with static load and without static load. Buñuel (Navarra). Alstom Wind.
- Engineering consultancy services to assess noise impact generated by wind turbines installed at Les Forques I wind farm. Noise measurements, noise levels estimation through acoustic software CadnaA based on ISO 9613 and proposal of acoustic barriers solutions. Gamesa Corporación Tecnológica S.A.
- Environmental noise impact prediction due to the operation of three new wind farms in Catalonia (Spain) and proposal of solutions. Gamesa Corporación Tecnológica S.A.
- Experimental Modal Analysis (EMA) of the interior equipments of the ECO100s1 wind turbine nacelle structure. Buñuel (Spain). Alstom Wind.
- Prediction of the environmental noise impact due to the operation of a new wind farm in Gomera (18 MW), Spain. Gamesa Corporación Tecnológica S.A.
- Study of the power level generated by the ventilation system of the ECO100 wind turbine. Model Inversion method to obtein the power values of each one of the modeled sources and sound level measurements acording to IEC 61400 standard. Alstom Wind.
- Study of the acoustic resonances present in the elastic coupling disc located between the generator and the multiplier of the ECO100 wind turbine prototype. Alstom Ecotecnia.
- Sound power measurements in a wind turbine prototype ECO100 according to IEC 61400/11 standard. Development of an acoustic model by numerical simulation and determination of the acoustic characteristics of the wind turbine. Villavaliente (Albacete). Alstom Ecotecnia.
- Acoustic environmental impact course in a wind farm tailored for the client. Vestas.

BACKGROUND

- Experimental Modal Analysis (EMA) of the ECO80 wind turbine nacelle structure. Buñuel (Spain). Alstom Ecotecnia.
- Experimental Modal Analysis (EMA) of the interior equipments of the ECO100s1 wind turbine: transformer, generator, drive train and electric cabinets. Measurements in Buñuel. Alstom Wind. Buñuel (Spain). Alstom Wind.
- Noise measurement carried out in a wind turbine prototype through Modal Analysis Method (OMA) to assess the influence on overall noise of its ventilation systems. Alstom Wind.
- Operational Deflection Shape (ODS) of the drive train of the protoype of the ECO100 wind turbine. Alstom Ecotecnia.
- ATPA (Advanced Transfer Path Analysis) of noise and vibration in a wind turbine ECO100 prototype in order to evaluate the contribution of the ventilation system to the total noise. Alstom Ecotecnia.
- Aeroacoustics course based on an environmental study of a wind farm. Alstom Wind.
- Custom made course of environmental acoustics due to the construction of a new wind farm. Gamesa Corporación Tecnológica S.A.
- Course of acoustics and aeroacoustics of rotors based on basic acoustics, aeroacoustics and rotary engine applications. Alstom Wind.
- Sound power measurements in ECO100 wind turbine prototype according to IEC6140 standard. Alstom Ecotecnia.
- Experimental tests and study of the acoustic resonances present in the elastic coupling disc located between the generator and the multiplier of the ECO100 wind turbine protoype (Jaure). Alstom Ecotecnia.
- Experimental Modal Analysis (EMA) of the drive train of the prototype of the ECO100 wind turbine inside the mounted wind turbine. Measurements in the prototype in el Perelló. Alstom Wind.
- Experimental Modal Analysis (EMA) of the interior equipments of the ECO80 wind turbine, generator, drive train and electric cabinets. Measurements in Buñuel. Alstom Ecotecnia.

Ingeniería para el Control del Ruido

Berruguete, 52. [Vila Olímpica Vall d'Hebrón]
08035 Barcelona. España - Tel/Fax. +34 93 428 63 39
E-mail: icr@icrsl.com
www.icrsl.com