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Italian regulations on wind farm noise: A state of the art

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Abstract

Italy is facing for the next decade a period in which noise will be more and more important in the scale of constraints for positioning a wind farm. As a matter of facts Italian population density is high. Windy zones are therefore closer and closer to inhabited places. At the same time turbine technology is going towards bigger and noisier machines. This means that a major effort has to be put in evaluating noise effects on population.

In Italy, the guidelines for noise control are contained in the national regulation 'DPCM 1/3/1991' and in 'L. 447 /1995'. This laws are not specific for wind industry, and contain some norms that are in open conflict with wind turbine technology. As for example the limitation to evaluate noise up to of wind at 5 m/s at the observer.

The first purpose of this paper is to give a complete overview on Italian noise regulation, above all underlining its faults and limits: in few words, what Italian noise regulation doesn't contains and what the possible effects of these lacking norms.

Moreover, some example cases will be analyzed and discussed in order to understand how the Italian laws can be conservative or not for people's health.

The last part will be dedicated to a brief review of the most discussed issues on wind turbine noise estimation in Italy: measuring techniques, characteristic parameters, most useful sample rates to adopt and examples of correlation between noise levels estimated on ground level and wind data measured at hub height.

Finally we analyze what are 'state of the art' techniques to comply with one of the most important problems of today's norms: noise background evaluation with large number of receivers with an undetermined classification. We evaluate what are the possibilities to create models of background noise map for large size areas.

Introduction

Besides all eco-sustainability purposes, wind energy in Italy still represents an excellent business. Italian Laws and European Electricity Market offer very high incentive tariffs and good energy sale prices. Thus, as wind farms can produce thousands of equivalent hours every year, also in not very windy geographic sites, they can bring high profits and short pay-back times for investors.

Energy supplied by Large Wind Farms (above 1 MWp) can be bought, sold and traded within the Electricity Market. The sellers can also add to this profit another

benefit whose size is related to the green energy supply: the official authority (GSE i.e. "Gestore Servizi Elettrici") release energy stocks (CV i.e. "Certificati Verdi") which can be bought by all the owners of fossil-fuel power stations.

Recent estimations revealed that wind energy is the cheapest among the other renewable technologies: in a windy site it costs amost 5 c€/kWh for a 20-year investment. On the other hand, if we take into account the total amount of money that can be gain by adding the Italian incentive tariff plus the energy sale, the average assessment rate for 2011 is 15.4 c€/kWh. So it's not hard to understand why wind energy has involved many companies and businessmen more than ‘the gold rush’.

Italian tariffs are very high in comparison with the other ones applied by the others members of EU. This is also due to the high complexity of the Italian authorization process for renewable energy projects, thus tariffs are high in order to attract developers.

In fact, the mortality rate of projects is very high: 21 % of request with accepted solution for the connection to national grid, have reached the end of the authorization processes. That consequence depends on the fact that Italian authorization process can be extremely tricky. In addition to your usual local building permits, environmental impact studies and right of way issues among others, the actual final FIT (Feed-In Tariff) approval process varies from region to region. The building permit called A.U. (Autorizzazione Unica) is mostly preferred by investors as the most secure license because it is based on a specific regional authorization for a specific project and clearly outlines the requirements for final award of the license and therefore the ability to sell the electricity to the GSE.

Despite many difficulties wind energy in Italy grows faster and faster.

Moreover, International Environmental Policy encourages nations to prevent global warming by limiting the emissions of C02, promoting renewable energies as scheduled by Kyoto Protocol and Copenhagen Convention on Climate Change.

As outlined in GWEC’s Global Wind Energy Outlook 2008, wind power is on track to supply 10-12% of global electricity demand by 2020, reducing CO2 emissions by 1.5 billion tons per year, far more than any other power sector technology . It will help revitalize economies, and create millions of jobs in the process.

Europe has also stated the legally binding target of 20% of final energy consumption from renewable energy by 2020 and that will keep the attention of the members on wind energy. Italy is focusing on wind power energy, in order to reach this goal.

Recently Italy ranked as the european’s third largest producer of wind power praising an installed nameplate capacity of 4849 MW at the beginning of 2010 with 6.70 TWh electricity generated, behind Germany, Spain and ahead of France and the United Kingdom.

In fact, according to the last estimations, now Italian wind farms can produce an amount of energy that alone represents 14% of national energy produced from renewable sources (10% onshore; 4% offshore).

The Italian Wind Energy Association (ANEV) reports that the current target for installed capacity by end-2020 is 16200 MW, with generation of 27.2 TWh.

Unfortunally, Italy is a small country and even if it is not lacking in wind, the windy sites without environmental constraints are already full. So the last tendency is to install big and noisy wind turbines still in the countryside or mountainside but nearer and nearer industrial and of course inhabited areas.

Besides the exponential growth of new wind farms, in older wind farms it happens that turbines become more and more noisy as time passes, because of electro-mechanic components wear. As a consequence of that evidence some anthropic receivers can become annoyed by turbines noise even if their relative distance from wind farm was judged not dangerous for noise impact. Moreover owing to many new turbines installations, also cumulative noise impact problems can rise.

So noise analysis is becoming one of the main issues in arranging new wind farms layout and in preventing noise impacts caused by old wind farms.

Thus a new approach is needed, according to which noise impact must be the first constraint in projecting and monitoring wind farms. In that way, engineers can prevent that people living or working nearby could be annoyed by the turbine noise or at least to manage noise impact.

The Italian Acoustic Regulation

Acoustic matters are very young in the huge evolution of Italian laws life. During the last two decades many DLGS ('Decreti Legislativi'), DPCM ('Decreti del Presidente del Consiglio') or DM ('Decreti Ministeriali') were issued by the government in order to legally introduce noise limits and ensure acoustic safety in houses and working places.

Now, Italian acoustic regulation includes a considerable body of laws, but it's more functional to refer to three main legal directives which contain references to the other ones:

- Legge quadro (LQ) sull'inquinamento acustico del 26/10/95 n.447 e relativi decreti;

- D.P.C.M. 14/11/97 "Determinazione dei valori limite delle sorgenti sonore";

-D.M. 16/3/98 " Tecniche di rilevamento e di misurazione dell'inquinamento acustico".

A quick description of each one is required.

LQ 477/95

The law named LQ 477/95 gives the "general guidelines on acoustic pollution" and is structured in 17 articles whose finality is to establish the fundamental principles in subject of guardianship of indoor and outdoor spaces by acoustic pollution.

The main issues introduced by law 447/95 were:

- Articulated definition of the limits for the environmental noisiness;
- Recognition of the professionalism of the "technical expert in acoustics";

- Obligations for public and private corporate body with temporal expirations and sanctions;
- Characterization of all the environmental acoustic problems (among which noise produced by roads, railroads, airports, autodromes, etc.);
- Characterization of the passive acoustic requirements of buildings, whose regulation is delayed to a specific decree.

The law 447/95 sets the bases for the various problems and cross-refer to specific degrees to put in act the directives.

DPCM 14/11/97

The guidelines given by LQ 447/95 aimed to regulate organically the subject of noise. Then a series decrees put in act those principles. The first important law was the Decree of the President of the Council of Ministers *14/11/97* about the determination of the legal limits of acoustic sources.

Some definitions quoted by LQ 447/95 were officialized and extended (Table 1).

Moreover the DPCM 14/11/97 confirmed the outline introduced by the previous DPCM 1/3/91, by setting the absolute input limits in a unique table for all kind of acoustic sources (Table 2).

Both the differential limits agree with the same one gave by DPCM 1/3/91:

Emission Limit (Limite di emissione)	Maximum noise level that can be emitted by an acoustic source
Input Limit (Limite di immissione)	Maximum noise level that can propagate towards environment or inside inhabited places, caused by a single acoustic source or more than one. It can be absolute or differential (Total noise less Background noise).
Warning Value (Valore di attenzione)	Noise level that marks a potential risk edge
Quality Value (Soglia di qualità)	Acceptable Acoustic Level for short medium or long time.

Table 1 – Noise levels definitions in DPCM 14/11/97.

In houses with open windows absolute noise can't exceed background noise more than 3 dB during the night and 5 dB during the day. This criterion doesn't apply in industrial areas and nearby roads.

Use Class	Day-Time (6.00-22.00)	Night-Time (22.00-6.00)
I - Protected Areas	50 dB	40 dB
II - Residencial Areas	55 dB	45 dB
III – Mixed Areas	60 dB	50 dB
IV – Intense Human Activity Areas	65 dB	55 dB
V – Prevalently Industrial Areas	70 dB	60 dB
VI - Indistrial Areas	70 dB	70 dB

Table 2 – Acoustic classifications and noise limits of the areas within township lines.

An analog Table is also defined for emission levels according to the different use classes: it's the same of Table 2 but it has been applied a subtraction of 5 dB to each value.

For municipality that didn't provide an acoustic classification, DPCM 1/3/91 also, prescribes the following countrywide noise limits:

Use Class	Day-Time (6.00-22.00)	Night-Time (22.00-6.00)
All National Territory	70 dB(A)	60 dB(A)
Zone A (DM n.1444/68)	65 dB(A)	55 dB(A)
Zone B (DM n.1444/68)	60 dB(A)	50 dB(A)
Indistrial Areas	70 dB(A)	70 dB(A)

Table 3 – Countrywide noise limits.

Zone A – Historical urban districts or areas which are considered relevant for their architecture belong to this area;

Zone B – District which are characterized by high population density belong to this area.

DM 16/3/98

The purpose of DM 16/3/98 was to provide suitable general method for measurement and analysis of sound from any kind of acoustic sources which can be heard in both public and private activities. The law provides guidance on the main useful and noticeable parameters for sound estimation and characterization at noise sensitive locations. However it leaves the acoustic technician free to assume some different choices beside some basic prescriptions.

We can summarize this decree in four big topics:

1. Definitions and parameters.

   Some of the most relevant are: The Equivalent Sound Level –Leq (quantifies the noise signal as a single value of sound level for any desired duration); Measure Time-Range - TM (it is the time range in which we can identify a clear develop of the characteristic sound phenomena); Environmental noise level - LA (it represents the Leq of all audible noise at the selected sensitive location); Residual noise level – LR (it represents the Leq of all audible noise at the selected sensitive location but after that one relevant source has been disabled); Differential noise level –LD (it can be estimated by computing the subtraction LA-LR); Corrected noise level – LC (it represents the measured noise increased by a penalty factor, if sound is characterized by impulsivity, tonality or low frequencies).

2. Description of suitable measuring conditions.

   The content doesn't give specific and strict rules about the choice of the microphone position, about how to manage residual noise in the case of multiple noise sources or about the choice of noise events that have to be excluded as believed not typical of the acoustic environment of the site. Thus, impliedly, the degree permits many discretional choices and different interpretations. However, measurement must be taken without any form of influence caused by weather conditions (average wind speed less than 5 m/s, no rain, no snow) and microphone has to be placed not too close to other objects or people (at least 1m far from walls, electricity poles, and so on; moreover the operator has to keep himself apart from the microphone more than 3 m).

3. A specific method for roads and railroads noise.

   Section C of DM 16/3/98 describes an extend methodology and some basic prescriptions to evaluate noise near roads and railroads.

4. Prescriptions on results description in noise reports.
   Acoustic technician must include in his final report some specifications like:
   a) date, hour, measuring time-ranges and weather conditions;
   b) a complete description of the acoustic measure , including a brief description of the acoustic instruments;
   c) Final sound levels;
   d) The area use class to whom belong the site;
   e) Conclusions;

f) a list containing the names of all the technicians who has collaborated to the acoustic measure campaign;

g) Id and original signature of the acoustic technician who related the final report.

The IEC 61400-11

The picture given by the description of Italian acoustic regulation has shown that Italian laws are too general to give clear and univocal outlines in order to evaluate noise emitted from wind farms. One of the most crucial issue is that Italian regulation doesn't consider valid noise measurements in windy conditions (more than 5 m/s at ground; DM 16/3/98) and, of course, doesn't consider any correlation between sources noise and wind direction, neither between wind intensity and residual nose.

Thus, sometimes it's useful to follow the International Standard IEC 61400-11 as it represents a more precise and fitting directive for wind farms noise. Unfortunally, IEC 61400-11 gives all the right issues to measure wind farm noise at ground level but just for one single turbine. If we want to know noise levels at anthropic receivers, we have to extend measured data by an acoustic model which can predict how noise spreads.

The noise emitted from a wind turbine is very depending on wind speed and direction. Thus, noise and wind speed must be measured in parallel in order to correlate noise with wind speed. The first version of the standard IEC predicted that wind speed should be measured upwind from the wind turbine and by an anemometric sensor at 10 m height. Last versions adopted a different approach due to a poor correlation between wind speed at 10 m height and at hub height for big wind turbines (hub height above 50 m). Now, wind speed is derived in part from the certified power curve and partly estimated from the anemometer on the nacelle.

However, anemometric measures at 10 m height are still needed while the background noise is measured, as the power curve can't be used when wind turbines are parked.

Figure 1 shows how must be arranged the experimental setup.

A reference microphone must be located downwind of the turbine at a distance equal to the hub height plus half the rotor diameter. The microphone is placed on a circular plywood ground board that is one meter in diameter and 13 mm thick. The ground board is placed on a flat surface with no cavities beneath and the edges of the board are covered with dirt.

Three additional microphones and ground boards can be placed around some turbines for special tests. IEC Standard recommends to consider wind speeds of 6–10 m/s, but is very often to get measurements outside this range for some turbines.

An anemometer is placed upwind with respect to the selected wind turbine in order to measure wind speed when the machine is parked for background noise measurements. The distance b to the anemometer is between 2 and 4 rotor diameters. In circumstances of intrusive background noise, such as airplanes, automobiles or animals, the test data must be discarded.

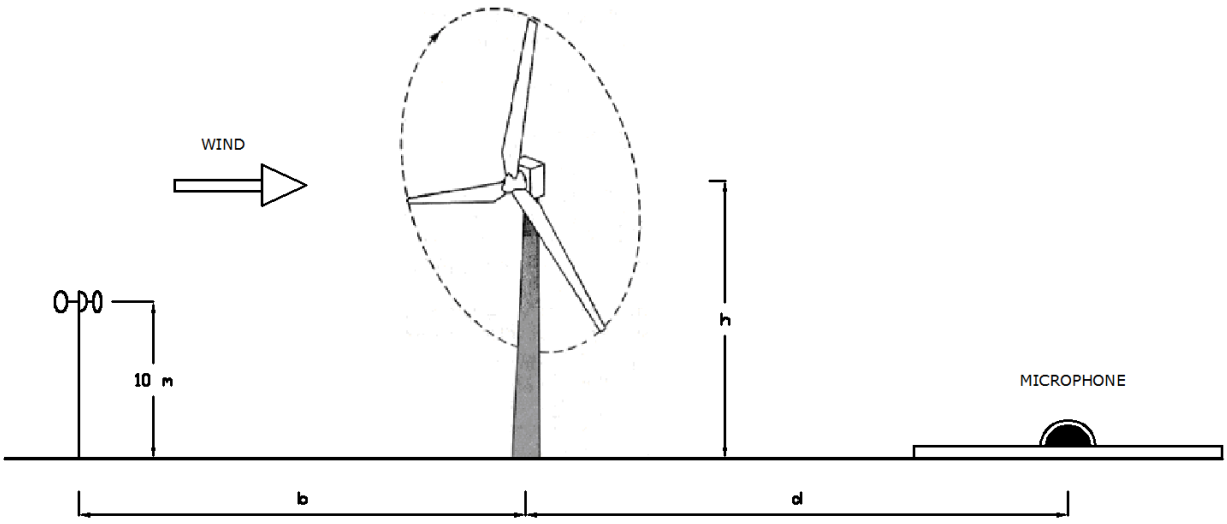

Figure 1– Noise measurement setup according to IEC 61400-11.

Each measurements shall be done over at least 1 min at each integer wind speed. Background noise is also measured in order to apply corrections to the turbine noise.

For average background sound pressure levels (Ln) that are 6 dB or more below the total noise level (wind turbine plus background; Ls+n), a correction must be applied to the turbine noise level in order to decrease it to the final value Ls.

If the equivalent continuous sound pressure level of the wind turbine plus background noise (Ls+n) is less than 6 dB but more than 3 dB higher than the background level, Ls+n is corrected by subtraction of 1.3 dB.

IEC 61400-11 also gives some basic requirements for acoustic instrumentation, pursuing the will to ensure a quality standard to measurements.

Acoustic Data Analysis

In this section we present the description of a typical study case in which the main purpose is to evaluate sound levels in one anthropic receiver that could be annoyed by several turbines noise.

Thus besides all measuring techniques just described before, now we focus on data analysis and post processing.

Measure campaign generally takes a couple of days in order to evaluate both night-time and day-time conditions. Residual background noise is evaluated while turbines are parked. Absolute noise is measured while turbines are operating. Every measure can concern variable time-ranges: typically form 10 to 40 minutes. The sample rate is set to be 100 ms in agreement with DM 16/3/98 suggestions.

After measurements, noise signals are post processed in order to exclude any sort of disturbance peak such as: noise produced by the operator, motor vehicles, dogs,

birds singing near the microphone etc.. Then, LAeq values are estimated every 5 sec from clean time-history. This procedure was necessary to correlate noise data with local anemometric wind measurements (one wind mean speed every 5 s). So for each survey were determined every 5s: an equivalent continuous level (LAeq), wind speed, wind direction, temperature and relative humidity.

The observation of wind characteristics takes place with an anemometric pole placed in the area where acoustic measurements are made. All data are stored in a logger 'Ammonit Meteo 32'. All instruments are calibrated according to IEC 61400. The time is synchronized. Direct wind measurements in situ are correlated with anemometric data from hubs of the turbines which mainly may affect the anthropic receiver in object.

In order to apply Italian acoustic regulation one single value for 'environmental noise level' and 'residual noise level' must be evaluated. So they can easily be estimated from the clean noise signal (a time-history with a sample rate of 100 ms) both for day-time and night-time. Differential noise level can be derived by subtracting residual noise from absolute noise in the respective time period.

Moreover, LAeq data derived from down-sampling (5 s) original time series are used to model a theoretical curve which describe noise trend while wind is increasing (Fègeant, 1999; Bartolazzi & Mariani 2009).

In that way we can get two curves for background noise for both day-time and night-time: N(dB)=f(W). This curve is useful because by applying an offset of 3 dB or 5 dB (related to the analyzed time period: night or day) we can plot the Italian regulation limits for differential noise depending on wind speed.

The absolute limits can be drawn by plotting a straight line on the maximum noise level that law can admit.

Thus, if we put experimental measures on this graph we can appreciate which is the crucial wind class if the final LAeq values of noise don't satisfy Italian legal limits.

The results of acoustic measurement campaign are summarized in the following plots.

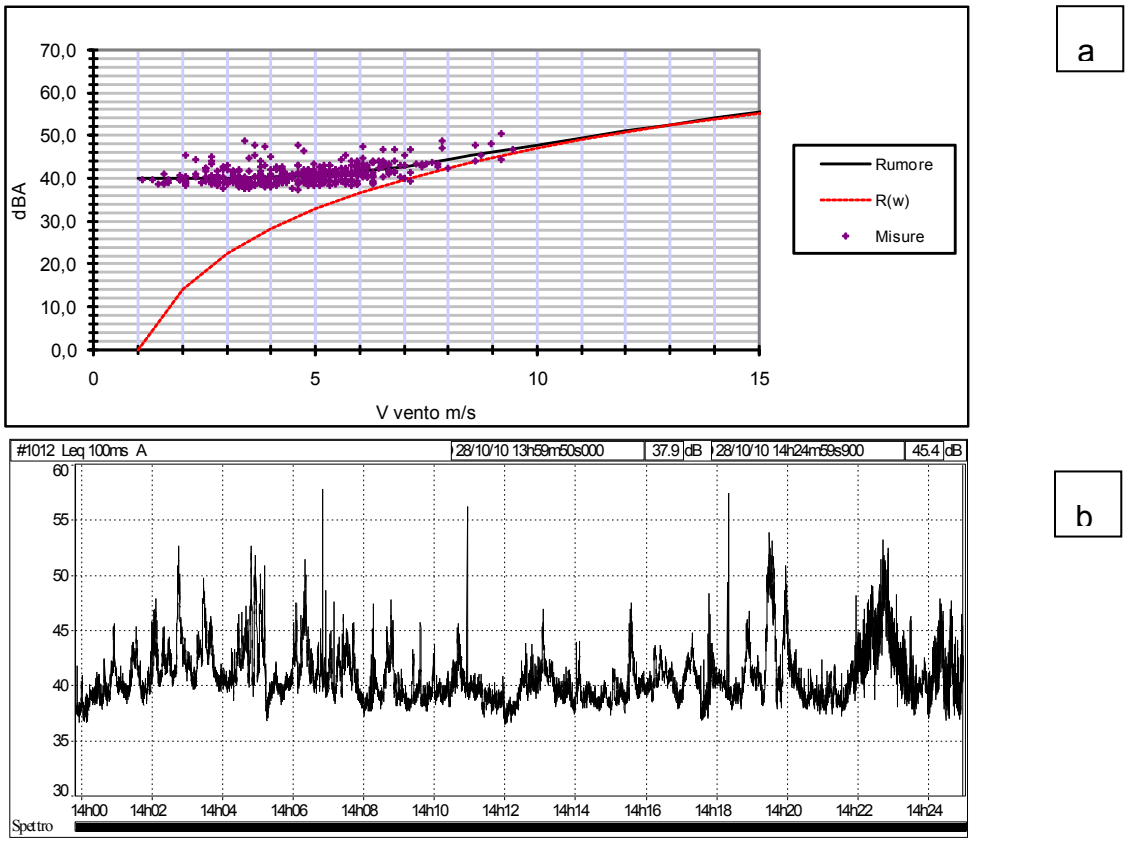

Figure 2– a: Measured background noise (purple dots) is modeled with a continuous curve ("Rumore") where wind is estimated at 10 m a.g.l.; b: Original noise signal that has been acquired with 100 ms as sample rate.

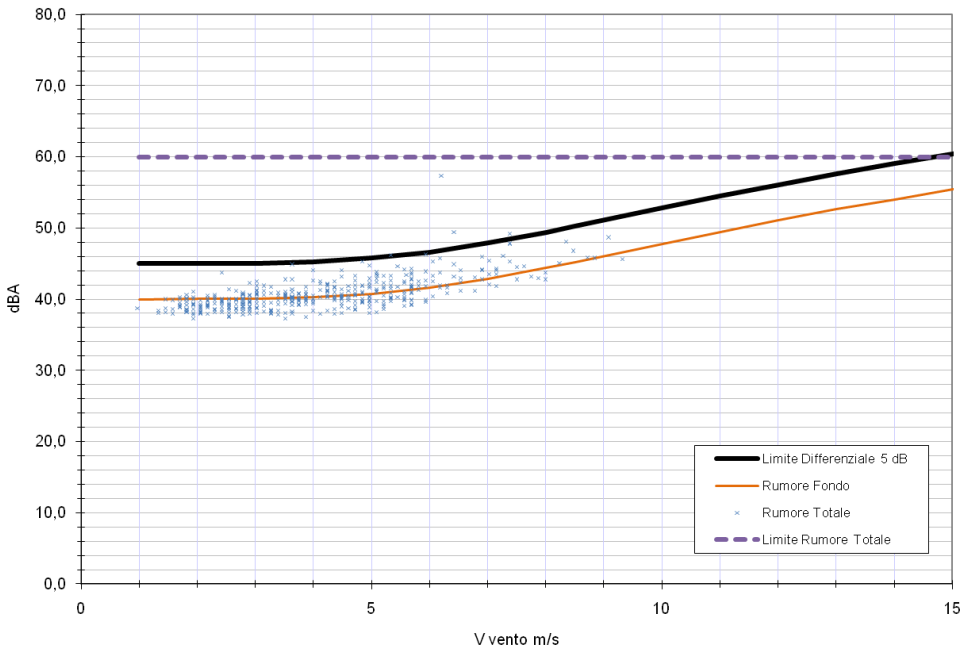

Figure 3– Final check of legal limits: black curve represents differential noise limits; purple curve represents absolute noise limits; orange curve represents the modeled background noise curve; blue crosses are the experimental measures of the total noise; wind is estimated at 10 m a.g.l..

Sometimes if the equivalent level of background noise and total noise are very close each other, it could happen that the absolute noise input is slightly lower than the residual value. This condition is already an indication of a lack of influence of noise generated by wind farm. In this case it is useful to refer to the statistical value L90 estimated for the background noise in order to get a statistically maximized differential value and therefore very precautionary. This methodology is useful because, if the residual noise and the absolute noise are very close together, the result obtained from direct subtraction (LAeq total- LAeq background) falls within the range of statistical error. This experimental evidence is even more noticeable if the noises belonging to different wind classes are compared each other.

Discussion

As described the typical phases that must be performed in evaluating the noise of a future wind park are the following:

- Analysis of the receivers
- Measurement of background noise at the receivers
- Calculation of turbine noise at the receiver points
- Confrontation with legal limits
- Suggestion of modifications to comply with constraints

Each of the phases presents problems that must be faced.

The **analysis of the receivers** has usually as a result 1 to 10 sensible receivers. But if we make an analysis of all the construction that are at less than 1 km from a wind park we usually identify tens or hundreds receivers. Most of them are usually ruins, small barracks used for country cultivation or inhabited, but what is the key point in deciding that a house is or isn't a receiver?

Adding to this problem there is a tendency in Italy to restructure old houses, sometimes in ruins, to spend some time in the country. So we maybe identify a ruin that in two years becomes a country house we someone spend his vacations.

Italian parliament recently put a definition in the National Guidelines for Renewables, deciding that from an acoustic point only inhabited houses count. Who certifies if a house is inhabited or not?

The number of possible receivers is also a relevant problem during **measurement of background**. As a matter of facts to measure 5 receiver is pretty feasible, but to measure one hundred receivers is almost impossible given the usual times and budget for these works. This leads to procedures of background noise forecast based on the extension of few measurement points to a larger area. This process introduces another key uncertainty.

The main problem with measurement of background is its intrinsic validity. To be clearer it is extremely difficult to have a good repeatability of measurements. The reasons for that is that background noise changes much with many factors:

- direction and intensity of the wind

- position of the measurement in the surroundings of the house
- season (summer/winter),
- working season (in some periods there is much more work in the fields)
- period of the week (week or weekend)

A difficulty in the measures is the practical impossibility to perform measurements from inside the houses. The law describes measurements with open windows or with closed windows. But in the reality most of the works are usually done outside the house, because of the difficulty of accessing the houses. From a noise point of of view the surroundings of the houses are changing a lot, in relation to possible sources of noise like for example trees, animals and so on.

Also wind measurment point is a major weakness of this kind of analysis. As a matter of facts, the law doesn't indicate a precise point. The reader is forced to understand that this point should be nearby the measurement. But this point of measurement as a very weak relation with the wind blowing at the turbines hub.

To further complicate the matter there is a weak relation between the wind direction and speed measured in different parts of the site. A Rotation of 90° or more degrees from one turbine to another, or from a measurment point to the hub of a turbine, is pretty common. Particularly in Italian sites that are on hills or mountains. For example, we experienced a site where there is a good wind from NorthWest while some part of the turbines receive a wind from East. This means 120° degrees of rotation. A situation that changes completely the noise scenario.

This situation is even more important when **calculating the turbine noise at the receiver points**. Following a common methodology (CONCAWE), there are around 5 dB difference between noise upwind and downwind.

The norm IEC 61400 considers noise measured downwind. This approach is more conservative (even if it introduces a pessimistic or noise scenario)

Suggestion for the new noise guidelines

Some key points must be suggested in extending the actual law to wind parks:

- Noise measurments must be put in relation with wind
- One of the wind measurement points must indicate or be well related with a global turbine functioning level
- New regulations must give some suggestion on how extend noise data from monitorized receivers in order to model a background noise map, and how estimate turbines noise from power curve. This can be useful to evaluate noise impact while projecting winfarms;
- How much measures are repeatable, and what is a reasonable reference sampling time range for this kind of environmental noise studies.

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