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The voice of wind & marine energy

BRIEF **SUMMARY**

Wind Turbine Amplitude Modulation:

Research to Improve Understanding as to its Cause and Effect

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Introduction

The wind energy industry today publishes detailed scientific research into the identification, occurrence and resolution of an acoustic characteristic known as Other Amplitude Modulation (OAM). This work, led by RenewableUK is the largest study of its kind to date. The findings represent a significant advancement in the scientific understanding of the acoustic characteristics associated with OAM, including its causes and mitigations.

Background

Wind turbines produce aerodynamic noise, which is the noise produced by the rotating wind turbine blades. This noise contains a periodically fluctuating, or amplitude modulated (AM), component. This form of AM, commonly referred to as "blade swish", is an inherent feature of the operation of all wind turbines and is perfectly normal[1]. However, the wind industry recognised that some AM exhibited characteristics that fell outside those expected of Normal AM (NAM) and that these other AM characteristics (described in this research as OAM) were annoying to some people. The findings of this research, conducted in two phases between 2010[2] and 2013, identify solutions for resolving any existing issues on sites where it is found to occur.

The industry has also developed a new form of planning condition designed to provide confidence to communities and local councils.

This research

RenewableUK commissioned this research in 2010. This first phase of research concluded in 2012 and addressed the following areas:

1) Investigation into possible causes of amplitude modulation

This work was done in two parts and modelled levels of amplitude modulation in the near and far field of a wind turbine, identified key drivers and causes of OAM and gave initial thoughts on measures that could be taken to reduce or avoid these characteristics. The work found that partial blade stall was the most likely cause of OAM in specific conditions. If partial blade stall could be resolved, so too could OAM be resolved.

2) The development of an objective measurement method for OAM

Here, a number of methodologies for objectively quantifying the level of OAM in a sample of acoustic data were investigated. This resulted in the adoption of an objective assessment method necessary to enable acoustic specialists and Environmental Health Officers to accurately identify and quantify OAM in the field.

3) The development of an objective method for measuring the annoyance caused by OAM

In this study, a clear relationship was established between the levels of OAM experienced and the levels of annoyance felt by people who hear it. This was developed through a highly-credible listening test in an audiometry chamber, with a sample of listeners from the general population. This information was then used in the creation of a planning condition.

4) Collation and analysis of existing acoustic recordings

In parallel to the above work streams, a review of available and published evidence of recorded samples of wind turbine noise containing OAM was conducted throughout the research programme as further information became available from the wind turbine acoustic community. The results of this analysis and a selection of the reviewed audio samples were used as an input to other work packages.

5) Measurement and analysis of new acoustic recordings

Based on the findings of the above research, a programme of further field measurements was developed to collect supplementary data. Accurate meteorological information and turbine operational information was gathered along with acoustic recordings to provide more detail on the likely cause of OAM. It was the experience of the project team that, even on wind farm sites where OAM has been reported or identified to occur, the occurrence of OAM can be infrequent.

Following the conclusion of the above research, the key findings of these six reports were summarised, concluding this first phase of research in 2012.

6) Effects of different weather conditions on blade pitch and sound emissions

RenewableUK then commissioned a second phase of research in early 2013[3]. This research further investigated the mechanisms and causes of OAM, focussing principally on the impact that changes in wind speed (wind shear), wind direction (wind veer), and inflow turbulence may have on the inflow conditions seen by the blades as they rotate. The research concluded with an assessment of how these variable inflow conditions relate to the pitch of the blades and the possible link of these interactions with partial blade stall and the potential for this to result in OAM.
The research found that:

- significant wind shear and wind turbulence can cause changes in the angle at which a wind turbine blade comes into contact with the wind (the angle of attack of turbine blades) as they rotate through each 360 degree cycle;
- in more extreme cases, these changes can push the blades into partial stall over part of their rotation;
- in such conditions of partial blade stall, OAM can occur;
- this OAM will likely be experienced in the far field but not necessarily in the immediate vicinity of the turbine;
- practical strategies exist including the use of individual cyclical pitch control could remove the risk of stall, while minimising any loss in energy yield

Planning condition

RenewableUK has developed a planning condition with acoustics specialists which if required, can be applied to projects when they receive planning permission. This condition differs from previous conditions that have tried to address OAM as it relies on an objective and repeatable method for identifying and rating OAM. This method, unlike other methods, recognises that all amplitude modulation is, by definition, a periodic phenomenon directly related to the rotational speed of the wind turbine.

Next steps

The UK onshore wind industry is committed to ensuring that our relationships with local communities remain strong and that we continue to be good neighbours to the communities in which we operate. We therefore aim to resolve OAM on sites where it is scientifically proven to occur and to addressing its occurrence on new sites. Following the publication of this research and planning condition, the industry will be working closely with Government, the Institute of Acoustics, and local authorities to provide information and answer any questions that they or local communities may have about the work.

If anyone has a query regarding an existing or proposed wind farm close to them, please contact the wind farm owner or developer, or local council in the first instance. People can also contact RenewableUK directly, who will be happy to help.

[1] Normal AM can be explained by well understood mechanisms and is the result of the directivity characteristics of the noise created by the air flowing over a turbine blade as it rotates. Because this type of AM is an inherent feature of the operation of wind turbines, whose origin can be explained and modelled, the present project adopts as its definition the term "normal amplitude modulation" (NAM).

[2] This first phase of research was conducted by the National Aerospace Laboratory of the Netherlands (NLR) and a research consortium comprising the University of Southampton, the University of Salford, Robert Davis Associates and led by Hoare Lea Acoustics.

[3] This second phase was conducted by the Wind Energy Department of the Technical University of Denmark

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