REDUCING AERODYNAMIC NOISE IN WIND TURBINES

(Technical Topic)

EXAMINING THE NEGATIVE EFFECTS OF CONTINUOUS ECPOSURE TO AERODYNAMIC NOISE

(STS Topic)

A THESIS PROSPECTUS

Presented to the Faculty of the School of Engineering and Applied Science University of

Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Nathan Jacobson

Fall, 2020

Technical Project Team Members:

Caleb Owen
Meagan Anderson
Levi Otis
Justin Smith

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Technical Advisor: Michael Momot, Department of Mechanical and Aerospace Engineering

Thesis Advisor: Travis Elliot, Department of Engineering and Society

INTRODUCTION

As global temperatures continue to rise due to the emission of greenhouse gasses, our country turns to renewable energy sources for power generation in hopes of decreasing the amount of damage non-renewable energy sources cause to our environment. As of 2018, harvesting energy from the wind via turbines leads all other renewable energy sources other than hydroelectric methods for electricity generation in the United States (Marcy, 2019), making wind turbines an imperative component in the task of weaning our country off fossil fuels.

Although wind turbines come with many positive aspects, their high noise pollution causes concern due to the potential health consequences of exposure to long term vibrational and aerodynamic noise.

Limiting aerodynamic noise in wind turbines via blade modifications motivates this thesis project. Wind turbines generate unpleasant noise via mechanical vibration and aerodynamic noise from air flowing over the trailing edge of turbine blades. Although we do not fully know the effects of long-term exposure to wind turbine noises, complaints of loss of sleep, general stress, and risk of myocardial infarction and stroke generate concern, especially as we look to implement turbines in areas of higher population density.

Viewing this issue from an STS lens, human health and safety drive the research and development of future turbine models. Although turbines are typically designed to produce optimum power output, sacrifices to efficiency may need to be made in favor of pleasing social groups, specifically populations in close proximity to areas in which turbine blades are installed and operating. Government intervention and policy drive the future design of turbine blades by imposing strict regulation on their maximum noise output, causing engineers to approach and test turbine blades considering increasing the importance of limited noise output in their design.

With little regulation based on no substantive research (Duncan 2011) extensive government studies should be conducted to establish stricter safety standards, providing a maximum decibel limit for turbines in certain areas based on population density. Quality testing turbinesand monitoring turbine installation location should come with stricter regulations and checks from the government.

TECHNICAL PORTION

In the technical portion of my thesis, I explore the details of aerodynamic noise in the air, such as what it specifically consists of, what it is caused by, methods of limiting aerodynamic noise, and how many decibels turbines typically produce at various distances after installation. Of the above topics, methods of limiting aerodynamic noise consists of the main focus of my technical paper, specifically the modification of turbine blades to reduce total decibel output for wind turbines. To do so, three different turbine blades with noise reduction modifications will be tested in the wind tunnel: serrated trailing edge, leading edge with nodes, and folded tip blades. Each type of blade will be hooked up to a hub assembly attached to a generator placed behind a wind tunnel that produces a flow of laminar air at a constant, controlled velocity. A small diaphragm will be placed near the base of the assembly to measure the maximum decibeloutput of each turbine design, and the power output generated by each type of design will be measured via the generator. The maximum decibel and power output will be analyzed to determine which blade modification results in the greatest noise reduction when compared to a standard control blade, and how the blade design affects total power generated. The challenge comes when trying to strike a perfect balance between maximum electricity generation and minimal noise production. In addition to the results of the aforementioned testing, I have compiled two sources. (Jianu 2012) gives an overview of turbine noise generation, and the physics of how fluids rushing over a turbine blade produce noise in the firstplace. (Maeder, 2009) discusses how adding trailing edge serrations to turbine blades helps curb turbulent flow and pressure drop, reducing the overall aerodynamic noise.

STS FRAMEWORK

The Social Construction of Technology framework will be used for analysis of the issue of turbine noise pollution. The social construction of technology framework focuses on how social factors and forces, such as the necessity of design regulations for human health and safety, shape the way in which we implement and develop technology, such as wind turbines and their placement near residential areas.

The SCOTS framework originates from an article written in 1987 by Trevor Pinch and Wiebe Bijker (Klein, 2002). The authors focus on how social structures influence the development of technology.

The tenants of this framework include **interpretive flexibility**, which says that technology design is an open process whose outcomes differ based on social pressure, **relevant social groups**, which focuses on how certain groups interpret an artifact, in this case wind turbines, , and how the artifact must be developed until all social groups are satisfied with the final outcome, **closure and stabilization**, a perspective which focuses on continuous design improvement until the final design does not conflict with any social groups, and **the wider context**, the way an artifact effects personal and political environments beyond its original function.

This framework fits nicely into this topic by examining the changes of primary design goals for turbine blades due to social pressure and government regulations. The forefront of turbine design must focus on maximum decibel output and human health and safety, whereas efficiency and power generation are of importance, but must become secondary design goals.

PLAN FOR THESIS

This thesis advocates for the implementation of a cohesive and well-thought-out policy that limits the maximum turbine decibel output based on proximity to human dwelling areas. Extensive research based on negative short- and long-term health effects of exposure to periodic noise, and the maximum decibel limit that is safe for human exposure over an extensive period of time will back the formation of this policy. The policy should include mandatory safety checks, test measurements, and proximity checks before and after turbine installation, and if checks fail, turbine decommissioning must ensue. This policy would advocate for the suspension of currently operating turbines whose maximum decibel output is sufficiently greater than the maximum output determined safe in the aforementioned policyunless modifications are made to satisfactorily reduce their noise output.

The STS research portion of my thesis focuses on the advocation of a national policy, that examines potential negative short- and long-term effects wind turbine noise may have on human health, the importance of government regulation and intervention of the instillation of turbines that are "sufficiently close" to human populations, and how to evaluate these two topics using the framework of Social Construction of Technology. Questions to explore are:

- What are the short and long-term health effects of exposure to repetitive noise?
- What is a maximum repeated decibel amount that is safe for human exposure over an extended period of time that (as far as we know) and will not result in annoyance or adverse health effects?
- How can the government regulate design and place of installation to protect those who may be negatively affected by wind turbine noise?
- What specific effects the previous questions posed have on the future of turbine design process, and should we consider uninstalling turbines that do not meet the regulations laid out in this policy?

To conduct this research, I have compiled five sources that give insight to the previous questions posed

1.) (Klein, 2002): Gives an overview of the history of the Social Construction of Technology framework, its origins, detailed explanation of the core tenants of interpretive flexibility, relative social groups, closure and stabilization, the wider context, and how to employ the method when using it in an STS analysis.

2.) (Poulsen, 2019): A study that examines the effects of wind turbine noise on a subset of the Danish population, how a noise with amplitude modulation throughout an extended period of time differs from a noise with a constant amplitude, and how exposure to wind turbines above a certain decibel level led to a slight risk in the development of Myocardial Infarction and Stroke in the participants

3.) (Duncan 2011): A discussion from the Acoustical Society of America that talks about wind turbine noise being potentially dangerous in rural areas due to a lack of background noise to dull the disturbing "whooshing" sound they generate, and how fewstatewide legislation pieces exist to limit turbine noise, and if they do, they provide littleto no rationale of background references that support them. This source will be used to justify further advocation of a national standard based on rationale and testing.

4.) (Marcy 2019): Presents a figure and brief analysis breaking down the increase of renewable energy generation in the United States over the years by type, proving the importance of improving wind turbine sound production due to its inevitable increasing emergence in the future.

5.) (Alberts, 2006:) Addresses the health concerns specific to turbine wind noise, gives numbers and figures of specific decibel amounts that can lead to adverse health effects from turbine noise, and discusses some noise ordinances that are currently in place that regulate turbine installation location and protect people who live near turbines.

CONCLUSION

When looking at the issue of turbine noise pollution, the problem of residential annoyance and damage to nearby human dwellings is not often at the forefront of engineers' and regulators' minds when creating and installing turbines, however there are potentially serious adverse health effects to be considered. Research containing quantitative data that shows exposure to repeated noise increases likeliness of stroke, myocardial infection, and loss of sleep (and its implications), will help drive the increase in advocation and show the importance of implementing maximum turbine noise regulations. Research with information about current regulations, or lack thereof, and the little to null scientific arguments backing these regulations will make light of why a strict, nation-wide policy is imperative. Many states have implemented loose regulations themselves, but scattered and unsafe standards around the country simply donot cut it when discussing human health and safety.

Potential findings from the technical project may show that a very simple modification to turbine blades will drastically decrease maximum decibel output. In that case, the design process of future turbines could undergo a minimal alteration that would drastically protect many people in the long run from health concerns due to noise pollution. The modification(s) may be simple and powerful enough to be added onto currently operating turbines and curb their noise output to meet regulations of the proposed policy, meaning decommissioning would not have to ensue, saving money and material.

SOURCES

TECHNICAL

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