Prospectus

Active Stabilization of a Floating Wind Turbine Platform

(Technical Topic)

Technological Momentum Analysis of the Fukushima Floating Offshore Wind Farm

(STS Topic)

By

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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

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Introduction

One of the largest problems our modern society faces is the production and development of energy, specifically renewable energy. While the majority of our energy still comes from fossil fuels (International Energy Agency, 2019), fossil fuels exist in limited quantities and continue to harm the global environment. The development and implementation of renewable sources of energy is critical in minimizing the impact on our current global environment and providing energy for humanity to continue to thrive and expand. A major source of renewable energy comes from the wind power harnessed by wind turbines (US Department of Energy, 2015). Existing wind turbines have almost exclusively been placed on land or in shallow waters. While these locations have their benefits, they provide noise and visual pollution as well as take up valuable land.

In order to further the usefulness and scale of wind power, my team and I hope to make further strides in the design and implementation of wind turbines by designing systems essential in placing them offshore in deep water applications. Specifically, my team and I are researching the active stabilization of such platforms by analyzing their ability to float and remain upright using a motorized stabilization system. This would allow for wind turbines to be placed in deeper water, providing a multitude of benefits to humans and the environment.

Despite the advanced nature of our design, many factors remain in the way of implementing a real-world solution. Evidence of such struggles can be seen in the failure of the Fukushima Offshore Floating Wind Farm which was installed starting in 2013 and lost funding in 2020 from the Japanese government (Kinoshita, Hiratsuka, & Isogai, 2021). The design failed to be profitable in initial years, leading to its downfall. However, by providing a further sociotechnical analysis of the design and implementation of these wind turbines, the issues that led to the downfall of this wind farm can be used in the design and implementation of future wind turbines and farms and directly impact the design of our active stabilization platform.

In order to properly understand the issues and potential of floating wind turbines, the social and technical issues both must be considered. I will analyze the ideation, design, and downfall of the Fukushima Offshore Floating Wind Turbine Farm, specifically its lack of technological momentum on a local and global scale. This evaluation will directly influence the problems and design choices made in my technical project, in which my team and I will be designing an active stabilization system for a floating wind turbine. These projects together will provide a holistic view of the past, present, and future of these systems in the real world and assist us on our path towards using renewable energy on a larger scale.

Technical Problem

The Earth's atmosphere protects the planet from harmful solar rays emitted from the sun and other sources (CK-12, 2019) . This atmosphere is essential to life on this planet. However, as humanity has continued to expand and require more energy, food, and other resources for sustainment, this atmosphere itself has become threatened. A major source of damage caused to the atmosphere comes from dirty sources of energy production, namely coal, gas, and oil (Enova Energy Group, 2018). These sources of energy not only produce gasses that are harmful to the atmosphere, but they also pollute water and cause irreversible harm to the Earth's surface. These damaging atmospheric gasses eat away and degrade the level of protection provided by our atmosphere causing a string of adverse effects on the surface of Earth.

The agreed upon approach by the world leaders to help combat this issue is to shift from dirty to clean sources of energy, such as wind (US Department of Energy, 2015). Each of these clean sources of energy comes with its own set of issues that must be addressed in order to approach the efficiency levels of dirty energy. Resolving these technical issues and improving the output of clean sources of energy will increase their popularity, sustainability, and useability at a large scale.

In 2020, wind energy amounted for 6.15% of the 25,865.75 terawatt-hours of energy produced on this planet (Ritchie & Roser, 2021). The vast majority of this wind energy comes from onshore wind farms. These farms are preferred for a variety of reasons including being easier to install, cheaper to maintain, and closer to the draw of energy (Kiwi Energy, 2019). However, these onshore wind farms come with their own set of issues. One primary concern is the visual and noise pollution disrupting humans living near these turbines. Turbine farms also take up large plots of land which could be used for other purposes. A solution to this problem is placing turbines offshore which allows the land to be used for other purposes and moves the noise and visual pollution away from land. Similarly, these offshore farms come with their own issues, primarily maintenance and installation. Current offshore wind farms are installed with concrete bases placed in shallow water. These bases can be as much as 2.5 times more expensive to install and require difficult and frequent maintenance (Kiwi Energy, 2019).

To counteract this issue, my team will continue development on a floating wind turbine base started by previous students at the University of Virginia. This would simplify installation and maintenance of the base by placing the base at the water level instead of deep underwater. Specifically, my team would focus on the active stabilization of the wind turbine platform. Active stabilization involves a direct force being applied on the structure to maintain its location and prevent the structure from tipping over. Per the requirements stated in the Project Statement, our team has been given an existing base with passive stabilization implemented (Momot, 2021).

We will design an active system to counteract forces the turbine and base may experience such as currents, wind gusts, and waves. The system will maintain location in all three planes and orientations and will be modeled in SolidWorks before being assembled and tested in real life. A formal proposal will be created using data found from real life and online simulation to verify the model's legitimacy.

STS Problem

The 21st century has been a time when many new clean energy technologies have been developed and tested due to the finite fossil fuel resources and push for the reduction of harmful emissions (Union of Concerned Scientists, 2017). All of these technologies have attempted to earn a stake in the international power generation market and seek to take advantage of new and existing opportunities. While these technologies may change and develop over time, the continuous growth and need for more power remains constant (Ritchie & Roser, 2021). This uninterrupted growth has led to a variety of new power generation ideas with varying degrees of success. The goal of all these designs is the same: to have an easy to implement way to generate clean energy that fits within the system we currently use.

One example of such an idea was the Fukushima Floating Offshore Wind Farm (known as Fukushima FORWARD). Fukushima, located in Japan, is most often remembered for its horrific incident in 2011 involving 3 nuclear reactor meltdowns. This nuclear event was one of the worst the world has ever seen, on par with the Chernobyl Meltdown according to the International Nuclear Event Scale (INES) (International Atomic Energy Agency, 2021). In the aftermath of the impact, the Japanese government sought to reduce their dependance on nuclear power and began to invest in other potential sources of energy (World Nuclear Association, 2021). In 2013, the Japanese government invested in one of these new ideas: Fukushima

FORWARD. This plan proposed the installation of 3 floating wind turbines and a substation off the coast of Fukushima to provide power lost from the defunct nuclear plant (Fukushima Offshore Wind Consortium, 2016). These turbines had varying power generation capability (2MW, 5MW, and 7MW) and were marketed as a symbol of the city recovering after the nuclear disaster. The turbines were installed and brought online in 2013.

Several years later, the Japanese government decided to stop funding the turbines and disassemble them starting in 2018 and into 2021 (Kinoshita, Hiratsuka, & Isogai, 2021). The technology, although promising, faced issues and was difficult to perform maintenance on. The Japanese government going back on its word, giving up on a potential future source of energy for years to come, and letting down the residents of Fukushima is not something to be glossed over. The Japanese government stated they were looking for technologies to provide the future for the country and has given up on a potential solution in favor of coal (Tabuchi, 2020). The country failed to commit and invest in what would provide its citizens with hope and help achieve its goal to be carbon neutral in 2050. Although Fukushima FORWARD was implemented in order to provide a new clean energy solution for Japan, the design failed to gain momentum over time due to lack of support from the government despite being strongly favored by the people and helping Japan reach its own carbon-neutral goals.

To complete this analysis, I will be using the Technological Momentum framework published by Thomas Hughes. In a brief summary, Hughes claims that technology gains momentum over time (Hughes, 1987). In its early stages, technology is heavily influenced by the social aspects surrounding it and can be modified by designers easily. As time progresses, modifying the design becomes more difficult and the technology begins to exert pressure on society to conform to existing standards and norms. In other words, technologies move from being influenced by society to influencing society themselves as they become integrated in said society. Specifically, I plan to focus on Hughes theory of the reverse salient, which are components of the system that are unable to keep up with the system itself and provide resistance to the system's momentum. To show how Fukushima was unable to gain this momentum, I will analyze the implementation of the designs themselves, the development of reverse salients, and the reactions of the government using various news sources and government published documentation.

Conclusion

In conclusion, I propose a deep analysis into the existing lack of success of floating wind turbine designs and propose a new design in order to address the issues found in existing or previous implementations. In terms of social analysis, I plan on using technological momentum to show how Fukushima FORWARD did not gain momentum to create a sustainable clean energy solution for Japan. In addition to analyzing the societal issues, my team and I will research and design a solution to the technical problem of expensive base installation for a wind turbine by designing an active stabilization system for a floating base. This combined approach will provide a broad overarching context of floating wind turbines and help prepare for the clean energy push in the coming years.

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