Airloom Type Vertical Axis Wind Turbine*

*ECE 445 Senior Design Project

Team #26
Sponsor: Jiahuan Cui
TA: YanbingYang/HaoranCui
March 15, 2025

Chengsheng Jiang
Mechanical Engineering
ZJU-UIUC Institute
jiang98@illinois.edu

Yiyang Zhou
Mechanical Engineering
ZJU-UIUC Institute
yiyang27@illinois.edu

Jiayi Guo
Computer Engineering
ZJU-UIUC Institute
jiayig8@illinois.edu

Jiayao Lin
Computer Engineering
ZJU-UIUC Institute
jiayaol3@illinois.edu

***Abstract*—This is a proposal for our senior design project. Our project focuses on constructing an Airloom type vertical axis wind turbine which has low construction cost and good performance.**

***Index Terms*—Vertical Axis Wind Turbine, Airloom**

I. Introduction

A. Objective and Background

The world energy crisis has become an increasingly pressing issue as the demand for energy continues to rise worldwide while reserves of fossil fuel deplete [1], [2]. In response to this challenge, renewable energy have gained significant attention, among which wind energy stands out because of its abundance, sustainability, and pro-environment. Thus, harnessing wind energy through wind turbines offers a promising solution to lower the dependence on fossil fuels. However, vertical axis wind turbines (VAWTs) generally exhibit lower efficiency and Scaling up VAWTs for utility-scale applications remains difficult due to expensive structural construction cost and lower power output per unit.

Our design aims to enhance the efficiency of VAWT by changing the motion track of blades to be elliptical and designing energy conversion circuit of higher efficiency. Also, we try to use 3D-printing components to decrease the construction cost.

B. High-Level Requirements List

1) requirement 1: With the wind speed of 9 m/s, tip speed ratio can reach 2 and VAWT can generate more than 200 W mechanical energy. Every component can bear the periodic force and be used for more than 1000h. The cost of construction should be less than 1500 yuan.

2) requirement 2: The current rectification of the DC wind turbine generator will yield a fixed voltage output (provisionally set at 48V) which will be connected to the charging circuit. This circuit will use a boost circuit for voltage regulation and an MPPT algorithm to control the circuit output to enhance power generation efficiency.

3) requirement 3: It must incorporate protection mechanisms to prevent overcharging, overdischarging,overcurrent, and overtemperature. In addition, the controller shall provide real-time monitoring of charging parameters, such as voltage, current, and temperature, via an LCD display, ensuring transparency and control over the charging process.

II. Design

A. Block Diagram

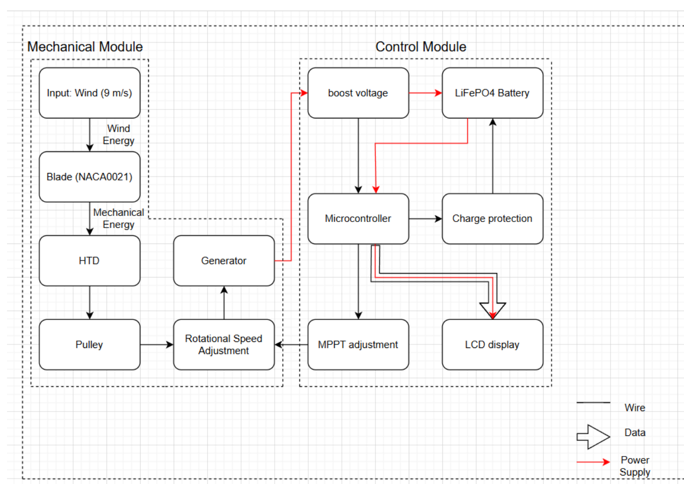

Fig. 1. Mechanical Module

B. Block Descriptions

1) Mechanical Module: Mechanical Module is an elliptical lift-type VAWT to convert wind energy to mechanical energy. In details, using NACA0021 blades, wind generates positive work on blades under certain angles [3]. Blades are fixed on the HTD. Moving HTD drives pulley to rotate. Shaft of Aluminum is fixed with pulley and gives torque to generator.

2) Control Module: This control module has two main functions, boost voltage in order while maximizing efficiency, and manage batter while displaying data.

For voltage boosting and maximizing efficiency part, We plan to use a development board named CBB24210 (based on the STM microcontroller and boost circuit) to guarantee a fixed voltage output (provisionally set at 48V). This development board features a relatively complete hardware configuration and a heat dissipation function, which can reduce design risks.

For battery management and data display part, we are using EV2759-Q-01A, a highly integrated switching charger designed for portable devices with 1- to 6-cell series Li ion or Li polymer battery packs as battery management since it is also equipped with a protection mechanism. And we want to use a 5.5 inch LCD display real-time charging current (0A to 10 A with ±0.5A accuracy), voltage (40V to 60 V for 48V batteries with ±0.5V accuracy), and battery state of charge (SOC) (0% to 100% with ±1% accuracy).

C. Risk Analysis

1) risk 1: The 3-d printed components may face failure due to periodic forces. The high-speed characteristic of HTD may make pulley worn-out.

2) risk 2: How to maximize the efficiency and reduce the fluctuation of the charging voltage will be a rather challenging problem. And possible thermal risks also need to be tested experimentally.

3) risk 3: If the MPPT algorithm is not well-designed, it may result in inefficient charging or even damage to the battery.

4) risk 4: The controller may perform unstably under extreme environmental conditions. For example, in high-temperature environments, the controller may fail due to insufficient heat dissipation, causing the protection mechanisms to malfunction.

III. Ethics & Safety

A. Ethics

1) Following the IEEE Code of Ethics: - As a project team, we're committed to following the IEEE Code of Ethics [4]. This means being honest and respectful in all our communications about the project, including our goals, methods, and outcomes.

2) Caring for the Environment: - Our wind energy system will be designed with sustainability, striving to minimize its environmental impact. By focusing on renewable energy, we're playing our part in conserving the environment, which aligns with IEEE's vision of using technology for the greater good.

3) Integrity in Research: - The research and data collection we conduct will be guided by ethical standards. We'll make sure to cite all our sources properly and present our data honestly, avoiding any kind of misrepresentation.

4) Respecting Intellectual Property: - We'll respect intellectual property rights by obtaining necessary permits and licenses for the technologies we use. It's also essential to acknowledge the contributions of others in our research and project development.

B. Safety

1) Following IEEE Safety Standards: - During the design and implementation of our project, we'll adhere to relevant IEEE safety standards, like IEEE 1547, which deals with connecting distributed resources to electric power systems. This compliance is crucial for preventing electrical safety hazards.

2) Conducting a Risk Assessment: - We'll perform a detailed risk assessment to pinpoint potential hazards that could arise during the installation and operation of the wind energy system, such as electrical issues, mechanical failures, and environmental impacts.

3) Electrical Safety Protocols: - We'll only use electrical components that meet established safety standards. Safety features, like circuit breakers, fuses, and grounding systems, will be included to reduce electrical hazards.

4) Preparing for Emergencies: - Developing and communicating emergency response plans for potential issues, like mechanical failures or severe weather, is essential. Everyone involved will be trained on these plans to ensure effective action if something goes wrong.

References

[1] P. Papon, "AIE (Agence internationale de l'énergie)," World Energy Outlook 2024, Paris: AIE, pp. 398, 2024.

[2] M. M. Rienecker, et al, "MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications," J. Clim., pp. 3624–3648, 2011.

[3] R. E. Sheldahl and P. C. Klimas, "Aerodynamic characteristics of seven symmetrical airfoil sections through 180-degree angle of attack for use in aerodynamic analysis of vertical axis wind turbines," pp. 52-62, 1981.

[4] IEEE Standards Association, "IEEE Standard 7000-2021: Model Process for Addressing Ethical Concerns during System Design," 2021.