

Project Proposal

VERTICAL AXIS WIND TURBINE

Power Monitoring

Problem Definition

The increasing demand for renewable energy sources has led to a growing interest in Vertical Axis Wind Turbines (VAWTs) as an alternative to traditional Horizontal Axis Wind Turbines (HAWTs). VAWTs offer several advantages, such as the ability to operate in low wind speeds and turbulent conditions, making them suitable for urban and small-scale applications. However, despite these benefits, VAWTs face several challenges that hinder their widespread adoption and efficiency.

1. Efficiency and Power Output:

VAWTs generally have lower efficiency and power output compared to HAWTs. Maximizing the energy conversion efficiency of VAWTs is a crucial challenge to address.

2. Start-up and Cut-in Wind Speeds:

VAWTs often have higher cut-in wind speeds, making them less effective in areas with inconsistent or low wind speeds. Improving the start-up performance is essential to make VAWTs more versatile.

3. Aerodynamic Design:

The design of VAWT blades and rotor systems needs further optimization to enhance their aerodynamic performance, reduce drag, and increase energy capture.

4. Structural Integrity:

Ensuring the structural integrity of VAWTs, especially in turbulent wind conditions, is critical to their reliability and safety. This involves addressing issues related to blade materials, fatigue, and durability.

5. Noise and Vibration:

VAWTs can produce more noise and vibration compared to HAWTs due to their unique design. Mitigating noise and vibration levels is important for both urban and rural installations to reduce environmental and social impacts.

Objectives

The primary objective of this project is to develop an advanced Vertical Axis Wind Turbine (VAWT) system that addresses the aforementioned challenges and maximizes its efficiency and reliability. This will involve the following key solutions:

1. Efficiency Enhancement:

Implement advanced blade designs, materials, and solar powered battery to improve the overall efficiency and power output up to 1kW.

2. Lower Cut-in Wind Speeds:

Develop innovative mechanisms to reduce the cut-in wind speed to 3 m/s and rated wind speed to 12 m/s, allowing the VAWT to harness energy even in low-wind regions.

3. Aerodynamic Optimization:

Utilize computational simulations and wind tunnel testing to optimize the aerodynamic performance of the VAWT, reducing drag and improving energy capture.

4. Structural Enhancements:

Investigate new materials and construction techniques to enhance the structural integrity and durability of VAWTs, especially in turbulent wind conditions.

5. Noise and Vibration Reduction:

Develop noise and vibration dampening technologies to minimize the environmental and social impact of VAWTs in various settings.

Proposed specifications

- Power source : Solar
- Output voltage : L-L \rightarrow 12V – 48V
- Output power : 1000W – 1100W
- Output current (Line current) : 48A – 12A.
- Assembly weight : 11 kg
- Rated wind speed : 12 m/s
- Cut in wind speed : 4 m/s
- Electromagnetic overspeed protection

Literature Review

The literature on Vertical Axis Wind Turbines (VAWTs) highlights several key limitations in current market offerings. Commercially available VAWTs tend to exhibit restricted power output, typically below 800 watts, hindering their capacity to meet the energy demands of various applications. Additionally, many of these VAWTs suffer from relatively high cut-in wind speeds, requiring stronger wind conditions for power generation and limiting their adaptability in areas with low or inconsistent wind speeds. Furthermore, a significant challenge arises from their dependence on external power sources for certain essential functions, even when wind power is available. This reliance compromises their energy efficiency and autonomy, affecting their overall practicality.

Moreover, it's worth noting that while some VAWT models can produce higher output wattages, they often come with prohibitively high price tags. This pricing disparity poses a substantial barrier to entry for potential adopters, restricting the accessibility of VAWTs for a broader array of applications. In tandem with these cost-related challenges, VAWTs may encounter issues with scalability, complex maintenance requirements, and operational limitations that collectively underscore the pressing need for innovative research and development to overcome these limitations. Addressing these challenges holds the potential to transform VAWTs into a more accessible and attractive renewable energy solution across various applications and geographic locations.

Here are a few examples of popular Vertical Axis Wind Turbines currently offered in the market.

- GV-300W Vertical Axis Wind Turbine



Figure 1: GV-300W Vertical Axis Wind Turbine

Specifications

Model	: GV – 300W
Manufacturer	: Greef New Energy Equipment Co., Ltd.
Voltage	: 12 V / 24 V
Output power	: 300W – 400W
Power source	: External
Start Wind Speed	: 6 m/s
Number of blades	: 3
Price	: \$798.00-9,998.00

- FLTXNY FR 400W VERTICAL WIND TURBINE



Specifications

Model	: FR- 400
Manufacturer	: Wuxi Flyt New Energy Technology Co.,Ltd.
Voltage	: 12 V / 24 V
Output power	: 400W
Power source	: Wind
Start Wind Speed	: 2 m/s
Number of blades	: 5
Price	: \$850.00

Figure 2: FLTXNY FR 400W

Proposed Architecture of the system

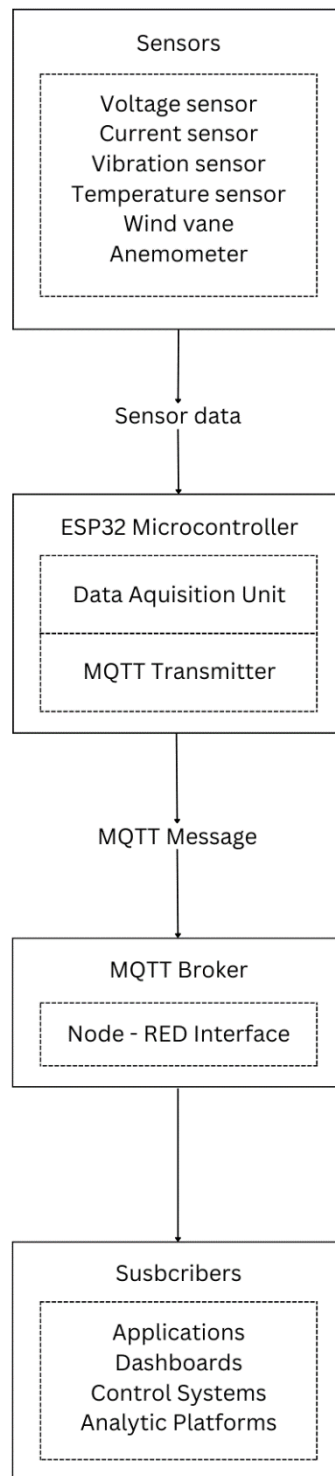


Figure 3: Top level view of the proposed system

System Components

1. ESP32 WROOM 32D Microcontroller

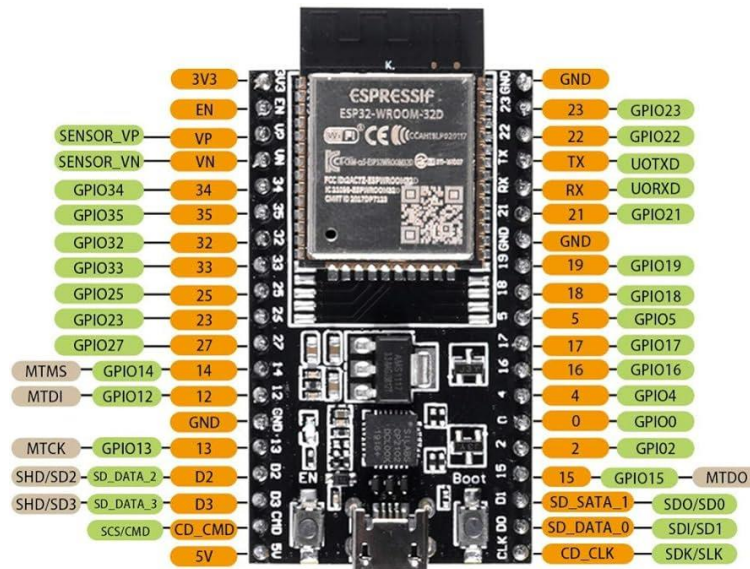


Figure 3: ESP32 WROOM 32D

The ESP32-WROOM-32D is a highly versatile and compact microcontroller module tailored for IoT and embedded applications. Powered by the robust ESP32 microcontroller, it boasts dual-core processing and high clock speeds, making it adept at handling complex tasks. What sets it apart is its comprehensive wireless connectivity, offering both Wi-Fi and Bluetooth capabilities for internet access and local communication. Despite its small form factor, this module provides a rich array of input/output (I/O) options, including GPIO, UART, SPI, I2C, and PWM pins, enabling easy integration with various sensors and components. It caters to diverse antenna needs, offering choices like PCB trace and external antennas. Additionally, it supports popular development environments like Arduino IDE, Micropython, and ESP-IDF for seamless programming, making it an excellent choice for IoT developers seeking a compact yet powerful solution. In essence, the ESP32-WROOM-32D combines the processing prowess of the ESP32 microcontroller with integrated Wi-Fi and Bluetooth capabilities, rendering it an ideal choice for creating connected and smart devices efficiently.

2. Wind vane



Figure 4: Wind vane

A wind vane, also known as a weathervane or wind indicator, is a tool used to measure wind direction. It typically consists of a flat or arrow-shaped plate mounted on a pivot, allowing it to freely rotate in the wind. The asymmetrical shape of the plate causes it to align with the wind's direction, and a horizontal arm points in that direction. This information is crucial in weather forecasting and hazard prediction, making wind vanes a common tool in weather stations.

3. Anemometer



Figure 5: Anemometer

An anemometer is a weather instrument used in meteorology, aviation, and agriculture to measure wind speed and direction. It typically features rotating cups or propellers that produce an electrical signal when wind passes over them, enabling the calculation of wind speed. Some anemometers also include a vane for wind direction measurement. These devices can be mechanical or electronic, with electronic versions being more accurate and reliable due to sensor-based measurements. Anemometers are often employed alongside other weather instruments like barometers and thermometers to provide comprehensive weather data.

4. Current sensor

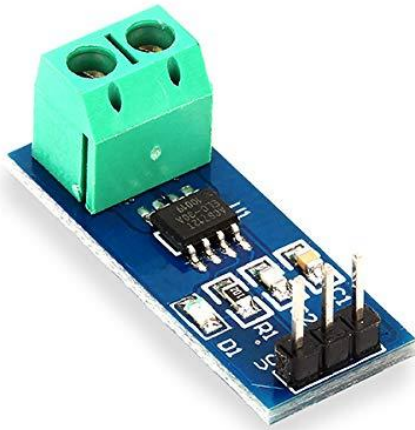


Figure 6: Current sensor

A current sensor is a crucial device used to detect and measure electric current within a circuit. Its applications range from monitoring electrical system performance to safeguarding equipment from damage due to excessive current and controlling the operation of electrical devices. Current sensors come in various types, including hall effect sensors, shunt resistors, and transformer-based sensors. Hall effect sensors detect the magnetic field generated by current flow and convert it into a measurable electrical signal, while shunt resistors gauge current by measuring voltage drops.

Transformer-based sensors utilize a magnetic core to measure current, inducing a voltage in the core that mirrors the current's magnitude. These sensors find common use in power distribution systems, motor control systems, and battery management systems, enabling the prevention of equipment damage by identifying overcurrent situations and triggering protective actions like circuit breakers or fuses. Additionally, they aid in monitoring and controlling electrical device operation, ensuring safety and efficiency.

5. Voltage sensor

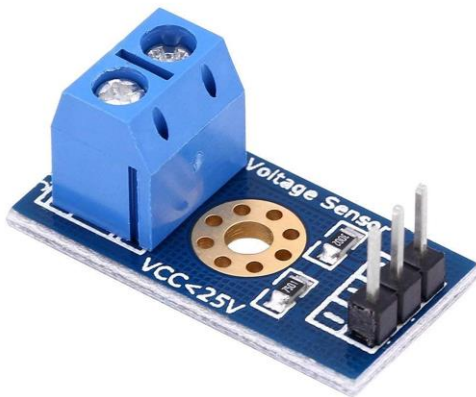


Figure 7: Voltage sensor

A voltage sensor is a vital device for measuring voltage differences between two points within an electrical circuit, serving to monitor system performance and safeguard equipment from overvoltage damage. Available in various types, including resistive, capacitive, and transformer-based sensors, these sensors employ different mechanisms for voltage measurement. Resistive sensors utilize voltage divider circuits, capacitive sensors employ capacitors, and transformer-based sensors rely on voltage transformers.

Voltage sensors have widespread applications in power distribution systems, battery management systems, and electronic control systems, playing a crucial role in detecting overvoltage conditions and initiating protective actions like circuit breakers or fuses. They also contribute to system monitoring, ensuring safe and efficient operation of electrical systems such as power supplies and batteries.

6. Temperature sensor



Figure 8: Temperature sensor

A temperature sensor is a versatile device that detects and converts temperature into an electrical signal, finding widespread applications in industrial processes, heating and cooling systems, automotive engines, and medical equipment. Various types of temperature sensors exist, including thermocouples, resistance temperature detectors (RTDs), thermistors, and infrared sensors, each employing distinct principles for temperature measurement. Thermocouples rely on the Seebeck effect to generate a voltage proportional to temperature differences. RTDs use metal wires like platinum or nickel to alter resistance with temperature changes, while thermistors use semiconductor materials to achieve the

same effect. Infrared sensors, on the other hand, gauge temperature by detecting infrared radiation emitted by objects. Temperature sensors are indispensable for maintaining precise temperature control in industrial processes, ensuring comfortable building temperatures in HVAC systems, and monitoring body temperature in medical devices, including the regulation of equipment like incubators and surgical instruments.

7. Vibration sensor

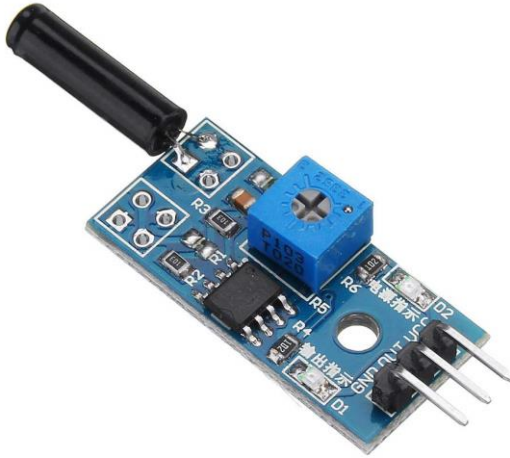


Figure 9: Vibration sensor

A vibration sensor is a versatile device employed for detecting and measuring vibrations in mechanical systems, playing a crucial role in monitoring machine performance and diagnosing mechanical issues like unbalance, misalignment, and bearing wear. These sensors also find applications in detecting seismic activity and ensuring the structural integrity of buildings and bridges. Vibration sensors come in various types, including piezoelectric sensors for high-frequency applications, accelerometers that convert vibration into measurable electrical signals, and proximity sensors using magnetic or eddy current technology to monitor changes in distance, particularly in rotating machinery.

They have widespread use in industrial and manufacturing sectors, including machinery, transportation, and power generation, where they are vital for performance monitoring, predicting and preventing mechanical failures, and averting costly downtime and equipment damage. Additionally, in structural engineering, vibration sensors are indispensable for assessing the health of buildings and bridges, as well as identifying and diagnosing potential structural concerns.

8. Solar panel



Figure 10: Solar panel

Solar panels, also known as photovoltaic (PV) panels, are devices designed to capture sunlight and convert it into electricity. They consist of multiple solar cells made of semiconductor materials, such as silicon, which generate direct current (DC) electricity when exposed to sunlight. Solar panels are widely used in renewable energy systems, including residential and commercial solar power installations, as well as in off-grid applications like remote power generation and spacecraft. They play a crucial role in harnessing clean and sustainable energy from the sun, making them a key component in efforts to reduce reliance on fossil fuels and combat climate change.

Block diagram of components

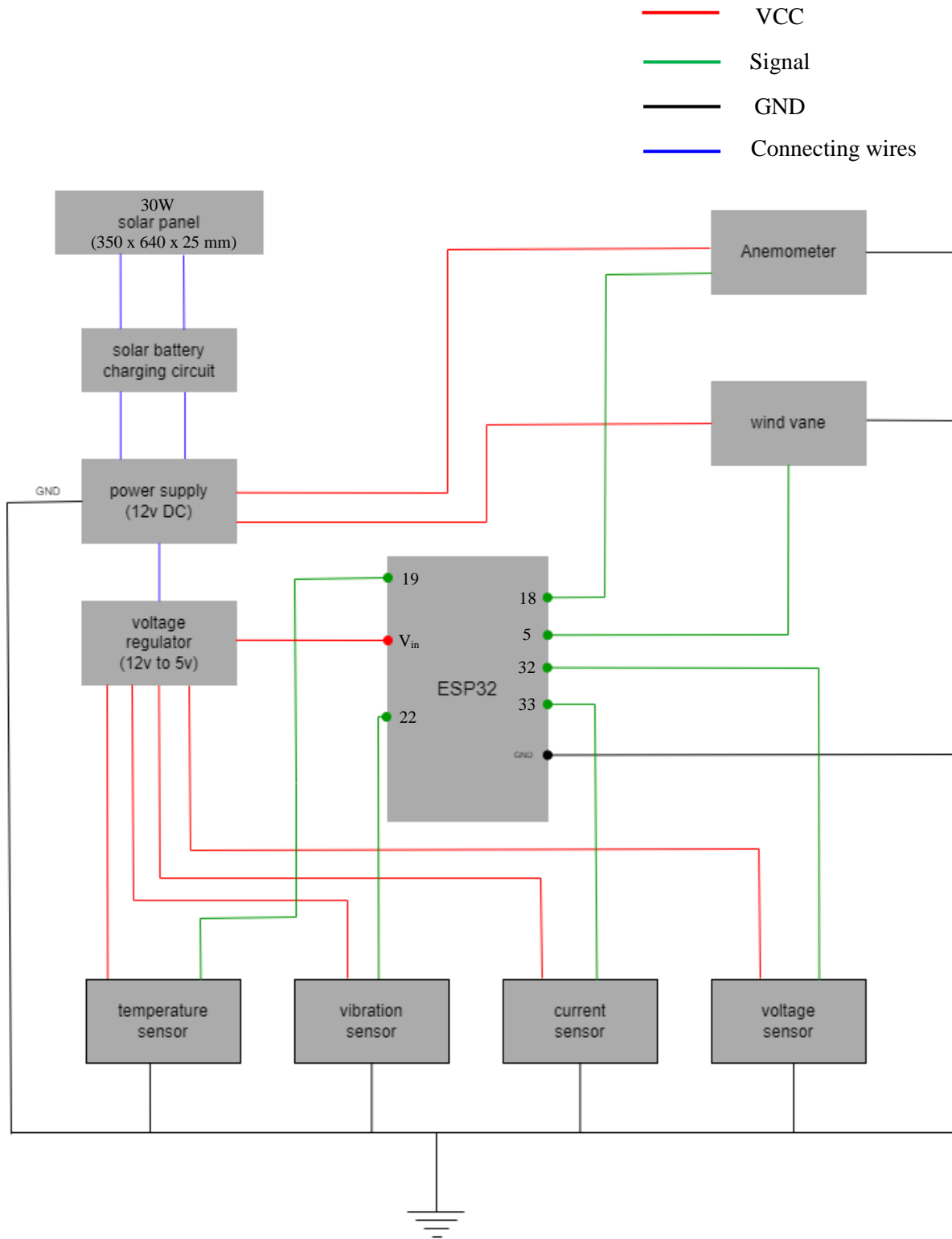


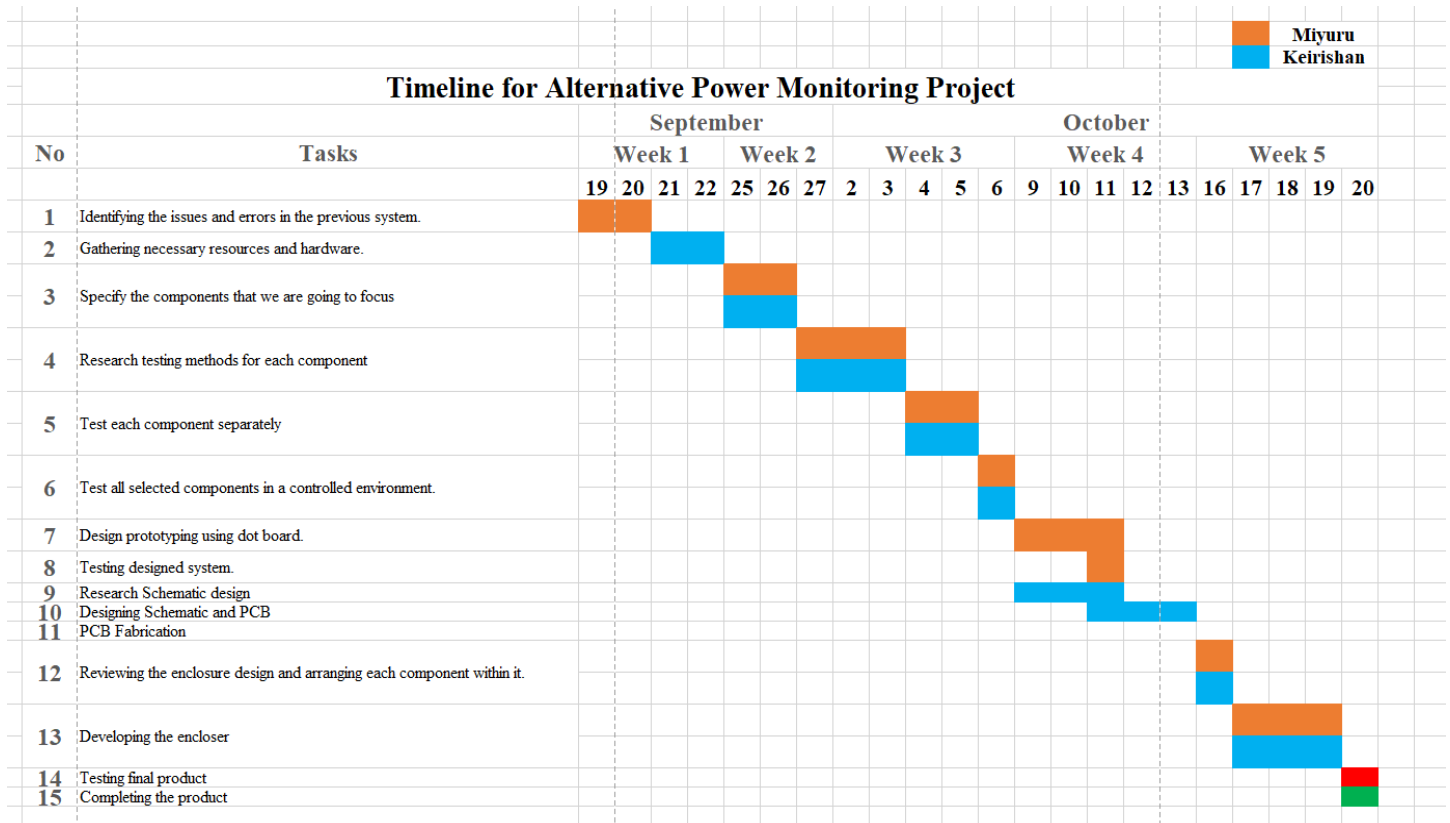
Figure 11: Block diagram of components

Sensor Information

Sensor name	Operating conditions (Temperature and humid range)	Interface	Output voltage	Supply power
1. Anemometer	T: -30°C to 80°C H: 0-100% RH	Analog	0.4V-2V	12V to 24V
2. Wind vane	T: -20°C to 60°C	Analog	0V-5V	5V to 12V
3. Temperature sensor	T: -55°C to 125°C	Digital	0.5V-2.5V	3.0V to 5.5V
4. Voltage sensor	T: -40°C to 60°C	Analog	0V-5V	3.3V to 5V
5. Current sensor	T: -40°C to 85°C	Analog	0V-2.5V	Input voltage: +5V
6. ESP32-WROOM-32D	T: -40°C to 125°C H: 10%-90%	-	-	Input voltage: +5V
7. Vibration sensor	T: -40°C to 85°C	Digital	-	3.3V to 5V

Table 1: Sensor information

Project Timeline



Conclusion

In concluding this Vertical Axis Wind Turbine (VAWT) project proposal, we underscore the significance of harnessing wind energy through innovative and sustainable means. VAWTs, with their unique advantages such as adaptability to low wind speeds and turbulent conditions, hold immense promise as a renewable energy source for a range of applications. However, this endeavor is not without its challenges, and our proposed project seeks to address these issues comprehensively.

Throughout the proposal, we have identified key challenges including limited power output, high cut-in wind speeds, external power dependency, and cost barriers for high-output VAWTs. By setting clear objectives and delineating solutions, we aim to overcome these obstacles and contribute to the advancement of VAWT technology.

Our objectives encompass enhancing efficiency, reducing cut-in wind speeds, optimizing aerodynamics, bolstering structural integrity, and mitigating environmental impact. By achieving these objectives, we aim to develop a more efficient, accessible, and eco-friendly VAWT system.

The collaboration between sensors, the ESP32 microcontroller, MQTT communication, and Node-RED interface forms a robust data ecosystem that facilitates real-time monitoring, analysis, and control. This comprehensive system architecture ensures that VAWT-generated data can be harnessed effectively for various applications and paves the way for a sustainable energy future.

In closing, this VAWT project embodies our commitment to advancing renewable energy solutions and addressing the complex challenges that surround them. We envision a future where VAWTs play a pivotal role in harnessing clean energy, contributing to environmental sustainability, and meeting the growing demand for renewable power sources. With concerted efforts and innovative solutions, we are poised to make this vision a reality, fostering a greener and more sustainable world for generations to come.
