

DEVELOPMENT OF VERTICAL AXIS WIND TURBINE PROTOTYPE AS FUTURE RENEWABLE ENERGY SOURCE

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechatronics

By

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of JENITH RAJA K (Reg. No. 40090013) and TEJA SHIVA SAI KUMAR PEDDINTI (Reg. No. 40090034) who carried out the project entitled "**DEVELOPMENT OF VERTICAL AXIS WIND TURBINE PROTOTYPE AS FUTURE RENEWABLE ENERGY SOURCE**" under our supervision from November 2023 to April 2024.

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We, JENITH RAJA K (40090013) and TEJA SHIVA SAI KUMAR PEDDINTI (40090034), hereby declare that the Project Report entitled “**DEVELOPMENT OF VERTICAL AXIS WIND TURBINE PROTOTYPE AS FUTURE RENEWABLE ENERGY SOURCE**” done by us under the guidance of **Dr. J. Senthilkumar, M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.

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ABSTRACT

A wind power plant with several benefits, notably as a renewable energy source, is the vertical axis wind turbine (VAWT). This study creates a VAWT and investigates its potential as a teaching tool via the lens of Science-Technology-Engineering-Art-Mathematics (STEAM) learning. For this study's experimental and interview types, a mixed-method embedded design was adopted. The findings of the study demonstrate a clear proportionality between the number of blades and wind speed and their effects on voltage, current strength, and power. VAWT can therefore be utilized as one of the STEAM-based learning projects.

Keywords – Vertical Axis Wind Turbine, STEAM, Learning, Renewable Energy

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Sea levels and pollutant levels have been rising daily. Thus, in an effort to lower energy costs and safeguard the environment, the use of renewable energy sources has increased globally. Wind turbines are made to produce electricity in order to get over this. An electrical device that produces power from wind energy is a wind turbine. There are several types, sizes, and shapes of these turbines to choose from. Thus, there are two different types of wind generators: wind turbines with vertical axis and horizontal axis wind turbines. This article provides an overview of the vertical axis wind turbine, or VAWT.

1.2 VERTICAL AXIS WIND TURBINE (VAWT)

The Vertical Axis Wind Turbine is a popular choice for residential use, providing renewable energy to homes. This turbine is made up of a rotor shaft that rotates vertically, along with two or three blades. Therefore, the turbine's movement is linked to the coins spinning on the edge. The turbine blades are wrapped around the shaft, while the generator is located at the bottom of the tower.

The operational principle of a wind turbine with a vertical axis involves the utilization of vertically oriented blades to rotate the turbine's rotors around a vertical shaft. They utilize wind power as a source of electricity generation. The generator utilizes the rotor, driven by wind, to transform mechanical energy into electrical energy. The components of a vertical axis wind turbine include the bearing, frame, blade support, shaft, and blade.

1.3 THE COMPONENTS OF VERTICAL AXIS WIND TURBINE

The Below is a block schematic of a vertical axis wind turbine. Any kind of load can use the energy that is produced as an output from this. In this instance, the load is the automatic lighting system. A Vertical Axis Wind Turbine (VAWT), gearbox, generator, battery, LED, and LDR circuit are all included in this block diagram.

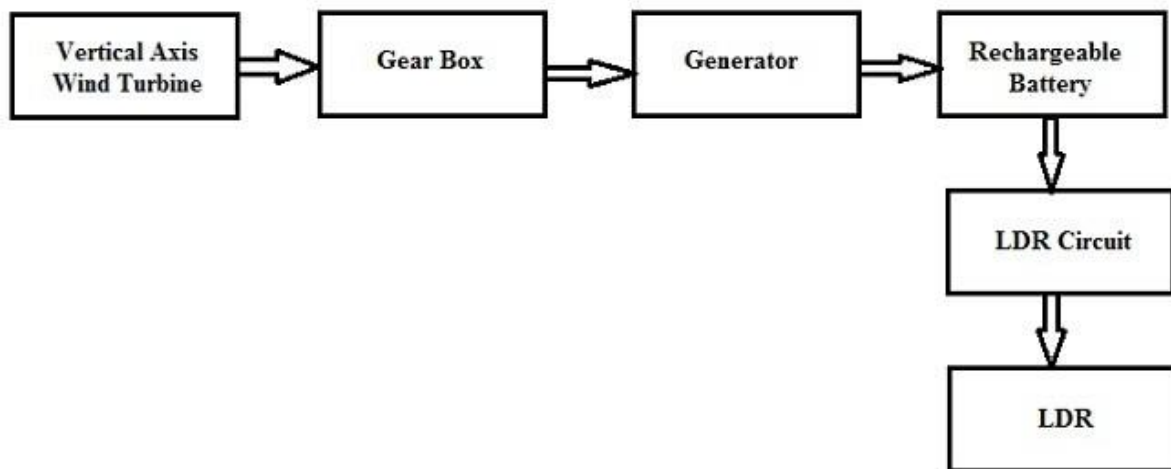


Fig.1.1 Circuit Diagram of VAWT

1.3.1 Gear Box

The main purpose of a gearbox in a wind turbine is to enhance the rotational speed between a low-speed and high-speed shafts that are connected by an electrical generator. Wind turbine gearboxes suffer from extreme cyclic loading due to random and unequal wind loads in the surrounding environment.

1.3.2 Generator

The conversion of mechanical energy to electrical energy is achieved by the wind turbine's generator. These generators are a little different from the generators used in electrical networks.

1.3.3 Rechargeable Battery

The electric energy generated by the wind turbine will be stored in a rechargeable battery.

1.3.4 LDR Circuit

The LDR circuit is used to turn ON/OFF the light.

1.4 VERTICAL AXIS WIND TURBINE WORKING

When the wind spins the turbine, this device operates. This lighting system makes use of the technology VAWT. The generator will receive this rotating turbine's mechanical input and produce electrical energy as its output. This turbine is installed on the highway road dividers. The turbine's wings are curled to capture wind from the two-way road, where the velocity of the vehicle causes the turbine to rotate. Depending on our needs, wind speed is used in several ways here.

A vertical axis wind turbine is connected to the gearbox, which is driven by gears. This gearbox is directly connected to the electric generating shaft. The turbine will spin when the wind is in motion. The gearbox in this system will amplify the internal rotations of the turbine and transfer them as a mechanical input to the generator. With this input, the generator will produce electrical energy, which will then be stored by the rechargeable battery.

In Thus, a turbine harnesses the velocity of the vehicle to generate and store electrical energy in the battery. The utilisation of the automated lighting system capitalises on the conserved energy. The LDR circuit utilises a resistor, transistor, battery, LED (light-emitting diode), and LDR (light-dependent resistor).

The transistor's emitter is electrically connected to the ground (GND), while the collector terminal is connected to the negative terminal of the light-emitting diode (LED). Here, the positive terminal of the resistor is connected to the LDR, while its negative end is directly attached to the voltage source.

The LDR will begin to detect light when the circuit is directly connected to the battery. LEDs will therefore automatically turn on as the light intensity decreases. Thus, automatic ON/OFF light systems can use this LDR circuit.

1.5 VERTICAL AXIS WIND TURBINE TYPES

There are two distinct categories of vertical axis wind turbines, namely the savonius wind turbine and the Darrieus wind turbine

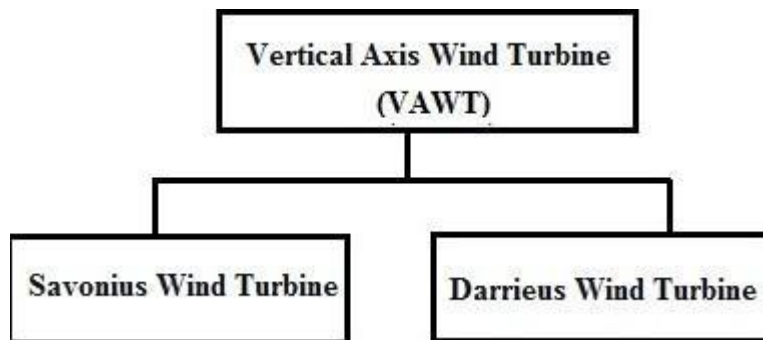


Fig.1.2: Types of VAWT

Savonius Wind Turbine

Savonius The Savonius wind turbine features a helical arrangement of blades encircling a vertical shaft. The turbine's solid wind-receiving zone is a crucial characteristic. The operation of these turbines is predominantly dependent on the flow resistance mechanism, whereby the rotation of the rotor is driven by the dynamic force exerted by the wind on the turbine blades.

The opposing the lateral aspect of the blades. encounters an aerodynamic resistance force simultaneously. This is similar to Our emotions airflow flowing from the other direction when we run or cycle. These turbines can so simply spin quickly to match the speed of the wind. For additional information about Savonius wind turbines, kindly click [this page](#).

Darrieus Wind Turbine

Georges Darrieus, a French inventor, is the source of the term Darrieus wind turbine. Another name for it is an egg-beater. The turbines in question possess elongated, curved wings that are interconnected at both the upper and lower ends of the rotor shaft.

These wind turbines generate rotation by harnessing the aerodynamic force of the lift. The wind will produce suction on the frontal surface of the wind turbine. as it flows around the structure, rotating the wings. Because to the design of their wings, these turbines, like Savonius turbines, do not encounter as much drag. These turbines will revolve more quickly than the wind once the revolution gets going.

1.5.1 Advantages

- Security for labour.
- Flexibility.
- They are able to produce power in any wind direction.
- Its ground-based arrangement of the gearbox, generator, and other components eliminates the need for a sturdy supporting tower.
- Its ground-based arrangement of the gearbox, generator, and other components eliminates the need for a sturdy supporting tower.
- These are less expensive to design than horizontal axis turbines.
- In contrast to other types, installation is simple.
- Since these are movable, we may easily go Moving from one location to another.
- To mitigate the risk to both humans and avian species, these are made with less speed blades.
- They function in all kind of weather, including stormy and mountainous settings.
- Where taller structures are prohibited, they are acceptable.
- They don't affect people in residential areas because of their basic operation.
- These turbines lessen maintenance costs.
- There are no mechanisms needed to run these turbines.
- The wind turbine can be used in areas where tall buildings are prohibited.
- These are the best for home energy sources, especially in cities, as they are quiet, cost-effective, and efficient.

1.5.2 Disadvantages

- Because of the drag that occurs in the blades during rotation, efficiency will be lower than with HAWT.
- Since these are connected on bases like buildings or the ground, they are exceedingly challenging to arrange on towers.
- Rotational efficiency is poor.
- reduced wind speed that is attainable.
- Component Deterioration.
- Low efficiency.
- Self-Starting mechanism.
- Because it is set up in an open space, certain animals or birds may stop it in its tracks.
- Because of the turbulent flow created by the air near the ground, they vibrate a lot.
- They Make noise pollution Applications

The applications of a vertical axis wind turbine include the following.

- Applicable to tiny wind projects
- Applied in domestic settings
- These turbines are utilised to produce electricity even in erratic weather patterns such as turbulence and high winds.

Thus, this is all about A comprehensive introduction to a Vertical axis wind turbine (VAWT). The vertical arrangement of the primary rotor shaft in this particular wind turbine configuration enables it to effectively capture wind from all directions. These turbines operate without needing yaw controls apart from the direction of the wind. These turbines were innovative designs and they have good features including quiet operation. These are smaller units, so we can easily locate them in commercial and residential areas. Here is a question for you, what is a Horizontal axis wind turbine?

1.6 PROJECT GOALS

Our need for energy is growing along with the use of technological devices. It is the duty of engineers to constantly research, develop, and enhance methods for producing green, renewable energy in order to lessen the adverse environmental effects that rising electricity use would have. Although other VAWT models have been developed in the past, industrial sites and rural villages will be the goal. Diesel generators are used to provide electricity to these mostly off-grid places.

1.7 DESIGN CONSIDERATION

The goal of creating a workable In Newfoundland and Labrador, as well as other places, the implementation of vertical-axis wind turbines is proposed for isolated towns and industrial locations. comparable conditions, has been taken up by MUN VAWT Design. The following constraints will be satisfied by the design:

Cooperate with diesel generators rather than substituting them

- Collaborate with diesel generators rather than swapping them out
- Design simplicity to lower production costs and maintenance concerns
- It can generate enough energy to cover fuel expenses
- Can be transported by boat or aeroplane to isolated locations

1.8 SCOPE OF THE PROJECT

MUN VAWT Design conducted study on airfoil structures, remote community and industrial site energy usage in Canada, weather data from Newfoundland and Labrador, and existing wind turbines before developing the turbine. SolidWorks models and computational fluid dynamics have been finished. To present the design and offer project updates, a website was made. The team utilised a Gantt chart and a project plan that had been approved by the Faculty of Engineering at Memorial University of Newfoundland to effectively monitor the progress of the project.

The following facets of the VAWT design were investigated during the project:

- Comprehensive structural analysis and design
 - Computational fluid dynamics is used to simulate aerodynamics in detail.
 - fundamental analysis of vibrations
 - Selection of multiple commercially available products
 - Engineering drawings and modelling of structural and mechanical parts
 - Financial evaluation
- The construction of a structural foundation and grid integration were not priorities for MUN VAWT construction.

1.9 BENEFITS OF VAWT DESIGN

When it comes to practicality, noise problems, and dependability Vertical-axis wind turbines (VAWTs) have greater performance compared to conventional wind turbines. Their ability to work from winds moving in any direction is their primary benefit.

As a result, a yaw system is not necessary to adjust the turbine blades' orientation in response to wind direction. The absence of a yaw system lowers the wind turbine's capital expenditures while increasing its dependability. [1] Second, because the drivetrain and generator are situated towards the bottom of the structure, VAWTs require less maintenance. Research in aeroacoustics has shown that the cyclic fluctuation in velocities of the VAWT blades causes an unstable flow, which reduces the sound that is radiated, which is another reason why VAWTs produce less noise than HAWTs. [2] Lastly, offshore situations are a good fit for VAWTs. The generator and gearbox, two pieces of heavy machinery used in VAWT power generating, are positioned beneath the rotor. These components can be positioned at or below sea level thanks to this arrangement, which also allows for a low center of gravity. This lowers the rotor's capital expenses and gives the supporting structure more stability. [1]

1.10 WEATHER DATA

Environment Canada provided historical weather information for the target area. An in-depth examination of information from Nain, Newfoundland, and

Labrador between September 2012 and September 2013 in order to ascertain average conditions and enable appropriate turbine sizing. To confirm that this data is normal, samples from other years and locations were compared with it. Located at an altitude of 7.6 metres above sea level, the Nain weather station records wind speed data. The wind gradient equation [3] was used to extrapolate the reported speeds up to At an elevation of 30 metres above sea level, a medium-sized turbine will probably be taller than this

Where α is the Hellman exponent that describes the wind gradient's shape h is the elevation, and V is the wind speed

A statistical examination of the wind data at an elevation of 7.6 m reveals The average velocity is 5.2 m/s, with a maximum velocity of 27.2 m/s. When adjusted for elevation of 30 metres, this translates to a maximum of 33 m/s and an average of 6.4 m/s [4].

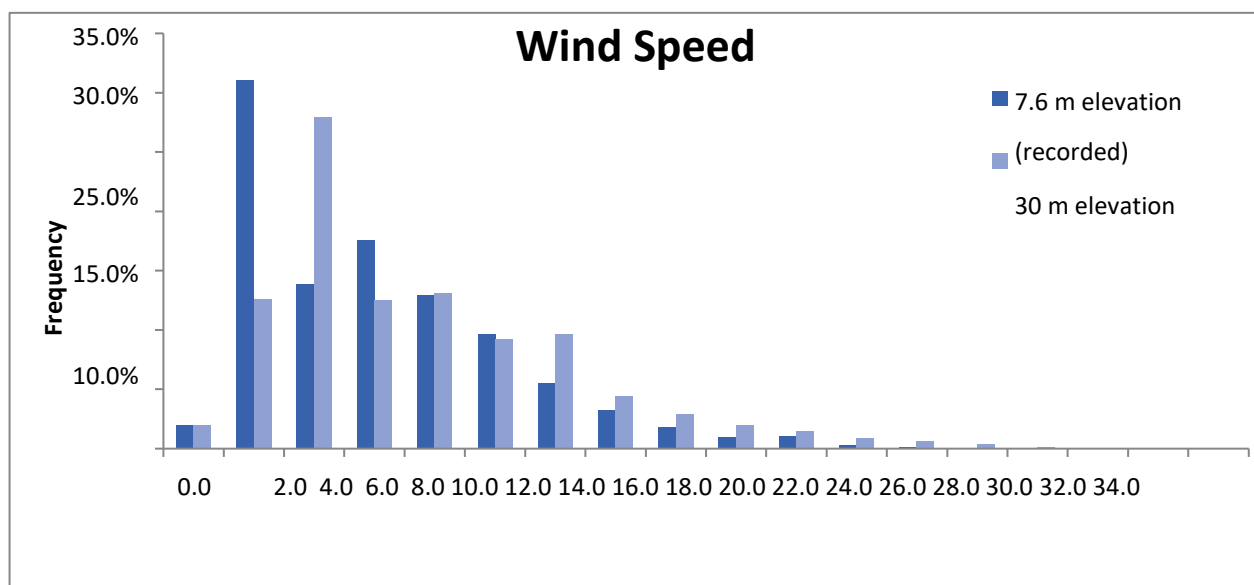


Figure 1.3: Wind speed data histogram for Nain, Labrador

Seasonal variations in Mean velocity are seen, with winter and autumn recording the highest speeds. This is helpful because those are the seasons when the target region's electricity demand is usually at its maximum. [5]

Table 1.1: Wind Speed Statistics

WIND SPEED STATISTICS										
Season	Year		Winter		Spring		Summer		Fall	
Elevation (metres)	7.6	30	7.6	30	7.6	30	7.6	30	7.6	30
Average Speed (m/s)	5.24	6.37	5.89	7.17	4.79	5.83	4.30	5.24	5.98	7.28
Median Speed (m/s)	4.17	5.07	5.28	6.42	4.17	5.07	3.61	4.39	5.28	6.42
Maximum Speed (m/s)	27.22	33.12	27.22	33.12	20.56	25.01	17.50	21.29	24.17	29.40

There were additional wind gust records available. Typically, the strongest gusts occur about 35 m/s, or 120 km/h.

1.10.1 Sizing

The sizing of VAWTs is determined by wind speed and power demand. In isolated settlements and industrial sites, A VAWT that produces power in conjunction with diesel generators is being developed by MUN VAWT Design. An average Research indicates that Canadian households consume 3.8kW of electricity in January and 1.4kW in August, while experiencing an average wind speed of 6.4 m/s at an elevation. of 30 metres. [4] [5] To make the turbine small enough for transportation, its capacity will be limited to 100kW. One turbine can provide enough electricity to power roughly 25 homes when it is operating at The highest capability for generating electricity and the consumption of power. This will use a renewable energy source to cut fuel use and fulfil the growing demand for electricity, even though it won't totally replace diesel generators.

The selection of the airfoil plays a crucial role in ensuring the optimal performance of a Darrieus turbine. The NACA symmetric series has been historically observed. used by several VAWTs, with the NACA 0018 being a common option. Beginning with the NACA 0018, Delft University

of Technology master's student 06-W-200 was developed by M. C. Claessens. The differences between the NACA 0018 and the DU 06- W- 200 airfoils are highlighted in the accompanying table. [7] airfoils.

Table 1.2: Technical Specifications for Various Configurations [6]

A comparison of technical specifications for different turbines

	H-rotor 1	H-rotor 2	Darrieus	HAWT (scaled)	HAWT
Rated power (kW)	500	500	500	500	600
Swept area (m ²)	850	850	955	1370	1520
Rated wind speed (m/s)	~13.5	~13.5	12.5	15	15
No. of blades	2	2	2	3	3
Tower height (m)	30	30	50	47	50
Turbine diameter (m)	35	35	34	42	44
Blade length (m)	24.3	24.3	54.5	18	19
Blade material	GRP	GRP	Aluminium	GRP	GRP
Yaw mechanism	No	No	No	Yes	Yes
Pitch or active stall mechanism	No	No	No	Yes	Yes
Gear box	Yes	No	Yes	Yes	Yes
Guy wires	No	No	Yes	No	No
Generator position	In tower	On ground	On ground	In nacelle	In nacelle
Rotation speed (rpm)	Constant, 13.6/20.4	Variable	Semi-variable, 28–38	Constant, 19/ 28	Constant, 18/ 27
Overall structure	Simple	Simple	Moderate	Complicated	Complicated
Mass blades only (t)	6	6	-	13	15
Mass turbine (t)	~24	~24	72.2	13	15
Mass nacelle (t)	~20	No nacelle	No nacelle	20	23
Mass tower (t)	153	32.8	No tower	36	42
Total weight above ground level (t)	197	56.8	72.2	68	80

1.10.2 Concept Selection

Based on previous research, a number The preliminary design took into account the choices of VAWT design. It was discovered that using current research instead of group brainstorming was preferable because the group had less Knowledge of VAWT design. The academic community has extensively studied the design of vertical-axis wind turbines. and industry research, which provided us with a solid basis for the composition of the group. Four categories were created from the overall design: solidity, airfoil type, VAWT configuration, and number of blades.

1.10.3 VAWT Configuration

The Darrieus and Savonius configurations are the two most prevalent forms of VAWTs. The Darrieus wind turbines employed aerofoils that generated lift around a rotating shaft, whereas the Savonius wind turbines employed drag-based "scoops" centred on a rotating axis. Because it was lighter and more efficient than the Savonius counterpart, the Darrieus configuration was chosen for the original design. There are several sub-configurations of the Darrieus wind turbine, These configurations encompass the full-Darrieus (or eggbeater), "H," and "V" designs.

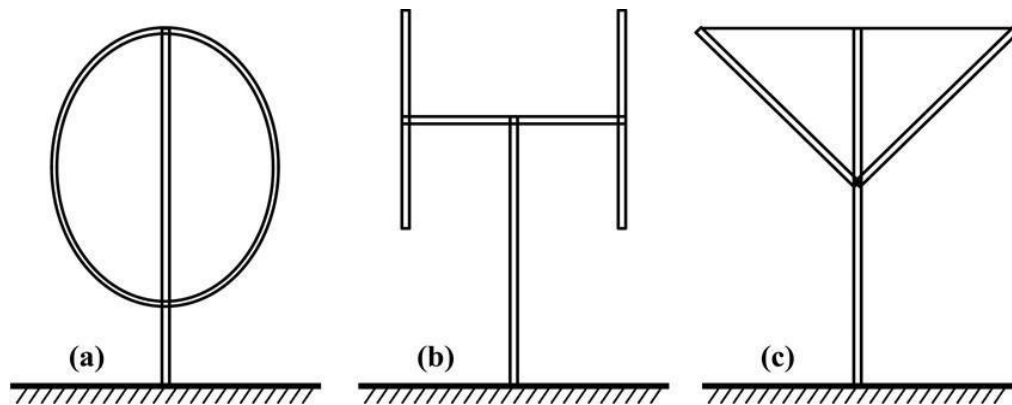


Fig 1.4: Configurations of Darrieus VAWT

The "H-Darrieus" configuration was chosen because it combines the simplicity of the "H" layout with the great efficiency of a Darrieus turbine.

1.10.4 Number of Blades

The stability, efficiency, and cost of a Darrieus-type VAWT are significantly impacted by the number of blades. Although 4-bladed variants were also taken into consideration, preliminary research indicated that 2- and 3-bladed layouts were the most prevalent . . 3-bladed VAWTs have the advantage of smaller tower, base, and bearing diameters, whereas 2-bladed VAWTs have cheaper capital costs due to their reduced material requirements. Thus rendering the expense of the second blade insignificant. The two-bladed VAWTs generate symmetric loadings that facilitate both the in-plane and out-of-plane vibration modes of the rotor. The

implementation of a three-bladed Variable Angle Wind Turbine (VAWT) minimises both in-plane and out-of-plane rotor vibration modes, hence enhancing rotor stability. In addition, the inclusion of a third blade serves to mitigate any potential noise and vibrations, hence enhancing the overall reliability of the rotor's torque production by lowering torque ripple.

CHAPTER 2

LITERATURE SURVEY

In order to achieve energy security and deal with Indonesia's upcoming environmental issues, renewable energy, or RE, is crucial. According to data from the Ministry of Energy and Mineral Resources in 2021, Indonesia has a massive 417.8-Gigawatt total potential for renewable energy [1]. The government hopes that by 2025, 23% of Indonesians will have completed them RE [2], [3].

On the other hand, the Covid-19 pandemic in 2020 made matters worse for the RE industry [4]. Furthermore, there has been no discernible improvement in Indonesia's growth in percentage terms for the number of RE. The fact that the mix only achieves 17.3% of the 23% target [6] and that only 10.4 GW of the 417.8 GW potential are actually realized [5] are clear indications of this. A potential for RE that can be fully utilized is wind energy [7].

There is enough wind speed in Indonesia, with an average speed between 3 and 6 m/s. In the Nusa Tenggara region, faster speeds are possible, ranging from 3.5 to 6.5 m/s. In contrast, the wind speeds in islands like Papua, Sulawesi, Java, Kalimantan, Sumatra, and Sulawesi range from 2.7 to 4.5 m/s [8]. Although the term "turbine" usually refers to designs from North America and Europe, the two continents with the greatest wind speeds (9–12 m/s). The relationship between wind speed and conditions indicates that there is great potential for the development of wind energy utilization.

Creating Wind power represents a viable approach for harnessing wind energy. The Horizontal Axis Wind Turbine (HAWT) is the most commonly utilised type of wind turbine. Nevertheless, the Vertical Axis Wind Turbine (VAWT) presents itself as a viable alternative for power generation owing to its numerous advantages. According to Sargolzaei [9], VAWT exhibits a moderate rotational speed but generates a substantial torque. VAWT has several benefits, including a straightforward design, a low tip speed ratio to prevent damage at high velocities, and wind turbine blades that move vertically, or parallel to the direction of the wind. As a result, a turbine-directional mechanism is not necessary because the turbine will respond to the direction of the

wind [10]. Additionally, Islam et al. [11] forecast that during the coming years, VAWT technology will allow for reduced production costs; non-spacious installations of VAWT just need space.

VAWT can be utilised not only to solve electrical energy needs but also to teach STEAM (Science, Technology, Engineering, Arts, and Mathematics). After being introduced to the issue of restricted electrical energy, students will use VAWT to identify alternative solutions based on advantages and possibilities. According to certain studies, STEAM-based education can help students become more adept at critical thinking [12], teamwork [13], and practical problem-solving [14].

Thus, the purpose of this research is to build a variable area wind turbine and examine how the quantity of propeller blades affects the electrical energy produced. The future of VAWT in STEAM education was also examined in this study. This study can help determine which VAWT, particularly in Indonesia, is most effective at producing electrical energy as NRE. The mixed-method design incorporates this study [15]. This study is divided into six phases, as Figure 1 illustrates. Preliminary research, conceptualization of the problem, instrument design, data collection, analysis, and conclusion are the phases.

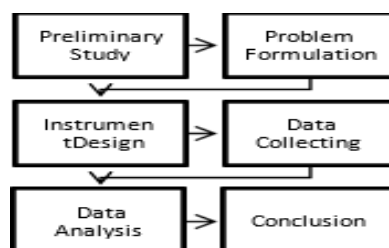


Figure 2.1. Research Stages [15]

To find any gaps, a preliminary study is now conducted between expectations and reality. The problem is then articulated using the gap analysis to determine a solution. Lastly, planning for the tools and VAWT to be manufactured is done during the instrument design phase. The VAWT design was adapted in accordance with STEAM learning objectives after being acquired from Horizon Educational. The VAWT's design can be



Figure 2.2. VAWT tool design [16]

The following is a description of the stages involved in designing and manufacturing this tool.

Stage of Preparation: At this point, the instruments and components of the VAWT are prepared. One Aluminium rotor and stator, four propellers, one LED base, lower and upper blade plates, a connecting cable, a multimeter, a blade plate lock, a fan, and one coil winding base are all included.

Stage of Assembly:

1. Placing the stator and rotor in the center of the installation.
2. Attaching a magnet to the blade plate underneath.
3. Installing different numbers of fan blades or propellers (2, 3, 4).
4. Putting the upper blade plate in place.
5. Attaching the multimeter to the connecting wires.

Step of Testing: Select between low, medium, and high fan speed settings.

Using an anemometer to measure the wind speed magnitude (0.1 resolution, 0.1 limits, accuracy $\pm 5\%$). examining the voltage measurements that the multimeter produced and their outcomes. Keep a record of the information gathered.

The stage after VAWT design (Figure 3) is data collection. Currently, testing of the VAWT tool is used to gather experimental data. In May and June of 2022, the test was held at Universitas Negeri Surabaya's (the State University of Surabaya) Basic Physics Laboratory. The following research factors are relevant to the conducted experiments:

Wind speed and the number of propeller blades are two manipulation variables. Two,

three, and four will control the VAWT's propeller count. Concurrently, the wind speed was changed for the low, medium, and high, three times -speed types.

The response variables are voltage and electrical current. The instrument generates and measures the mains voltage with a multimeter. The type of power plant, the distance between the fan and VAWT, and room temperature are examples of control factors. All of the components make up the VAWT type of power plant. During the trial, the air temperature was recorded as 25°C. They are currently 30 centimeters apart.

On the other hand, three undergraduate students studying physics education (IZ, HS, FN) had structured interviews conducted in order to gather qualitative data. The initial researcher's close friends helped select these three interview subjects in order to increase their willingness to participate in the interview process. Furthermore, three of them had personally witnessed the development and testing of VAWT by researchers. To find out how they felt about using VAWT in STEAM-based learning, interviews were done. Initially, movies on descriptions, materials and tools, design, and VAWT testing were shown to the interviewers. Lastly, three questions with indicators were presented to the interviewees: the tool's influence on students, its potential when applied to their learning, and their expectations for the future. Both quantitative and qualitative descriptive methods are used in data analysis. A statistical technique called quantitative descriptive analysis paints a picture or description of the subject of study depending on varying information gathered from a particular subject group [16]. The relationship between voltage, current intensity, and electrical power and the number of blades created is the data that is being analyzed in this instance.

VAWT in STEAM Learning

Through an exercise, the VAWT gives students a chance to feel and experience STEAM education in physics classes. The meaning of becoming a STEAM member was conveyed to the children through a few STEAM activities. The students "understood the essence of STEAM, the interconnection among science in energy, math inefficiency, technology, and engineering in tool construction by implementing the learning model of guided inquiry" [14]. Given the educational background of senior high school students, guided inquiry was selected as the learning approach. The primary theme of the inquiry is the shift from concrete to abstract thought processes.

Moreover, the following is an explanation of the findings from the interviews with the three respondents. The first query concerns VAWT's possible use in STEAM-based physics education. The purpose of this inquiry is to get pre-service physics instructors' opinions on the tool's potential for educational use.

"VAWT can be used in STEAM-based physics education, but it should be noted that students need to be familiar with the physics ideas covered in the tool, such as how mechanical energy is converted to electrical energy or how electrical efficiency is compared."- HV

Because VAWT offers precise and understandable physics knowledge, I believe it is excellent for use in physics education. Additionally, because students may observe VAWT's guiding principles firsthand, it can also have a good impact. IZ

"VAWT has the potential to be used in physics education because it helps students grasp the value of renewable energy sources for the planet and is extremely relevant to 21st-century skills." - FN

Because VAWT technologies may incorporate physics knowledge, it is evident that their general reasoning is excellent when used to physics learning. If investigated further, the angular velocity, classical mechanics, and other physics concepts that can be examined using VAWT

Rotational mechanics, electrical power, efficiency, energy, and Ohm's law. in keeping with research [15] that develops STEAM-based teaching that is applicable Regarding physics. In this context-based STEM Education Learning activity, the primary objective is to use physics and other academic subjects to design, build, or create

anything connected to solving energy-related problems with renewable energy sources.

The impact of using VAWT on students generally is the subject of the second question. This is their response.

"I believe VAWT can bring innovation to the study of physics." - HV

"I am very certain because using VAWT can bring novelty to learning and enhance motivation, abilities, and concept understanding."- IZ

"Obviously, I think that this tool has a positive impact on students because it already integrates Science, Technology, Engineering, Arts, and Math." - FN

HV and IZ claim that the use of VAWT in education is original and inventive, particularly in the field of physics. Because VAWT improves students' motivation, comprehension, and skills in a good way, it can boost the possibility of implementing it in STEAM instruction. Constructivism, a learning theory that holds that cognitive conflicts mark the beginning of the learning process, lends support to STEAM-based education. Lastly, information is acquired by pupils via contact with their surroundings and personal experience. Furthermore, according to some empirical research, STEAM education can enhance students' capacity for critical thinking, teamwork, practical problem-solving, and learning motivation. [16].

The primary economic foundation of every nation is energy. Obtaining energy sources is not simple. It is essential for any country to have a diverse range of energy sources in order to fulfil its basic requirements. Utilizing nature could help convert a variety of natural occurrences, Transforming solar, wind, ocean, and oil into valuable energy. Renewable energy refers to this type of energy.

"The most common definition is that renewable energy is from an energy resource that is replaced rapidly by a natural process, such as power generated from the sun or from the wind," Science Daily Research Newspaper has defended renewable energy. [16].

Recently, there has been a noticeable increase in the demand for renewable energy. According to an According to the study by the International Energy Agency, there was a notable rise in the proportion of power produced from renewable sources, with an increase from little over 13% in 2012 to 22% in the subsequent year. Moreover, it is anticipated that the aforementioned percentage will increase to 26% by the year

2020. [17].

The conventional power plants in Saudi Arabia primarily run on fuels that are harmful to the environment, such as oil or gas. According to Eco Spark, an environmental organisation [4], oil power stations are considered to be one of the main sources of pollution in the environment. The most important environmental effects of oil are mentioned below by the environmental charity EcoSpark: Oil produces greenhouse gas emissions and air pollution.

- Oil consumes a lot of water, pollutes the water, and releases heat into the atmosphere.
- Solid waste and toxic sludge are produced by oil.
- Oil extraction and refining have a detrimental effect on the environment.
- Oil transportation carries a high danger of environmental damage.
- One non-renewable source of electricity is oil.

Given their potential to lower environmental risks and improve lifestyle and health, renewable energy sources should be carefully considered in light of the above-described consequences on the environment.

Among Wind energy is considered to be one of the most prominent sources of energy. Wind energy refers to the process of transforming the kinetic energy of wind into mechanical energy. This energy drives the rotational motion of the blades, which in turn generates electricity. Our project is well-suited for wind power. The project aims to harness wind energy and generate electricity through the utilisation of Vertical Axis Wind Turbines (VAWT).

Wind turbines can be classified into two distinct types: Horizontal Axis Wind Turbines. (HAWT), which is utilised as a power plant and is more widely employed worldwide, is depicted in figure 2.1.

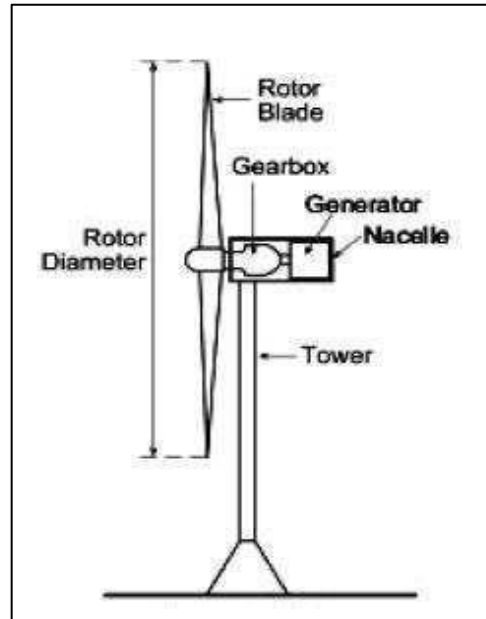


Figure 2.3 HAWT overview layout

<http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=15875&context=rtd>

These The most efficient wind turbines are those of this type. The benefits and drawbacks of horizontal versus vertical axis wind turbines have been discussed by Cole Gustafson of Dakota State University. He states, "Research studies evaluating wind turbine performance have shown that horizontal axis machines are more efficient than vertical axis machines." However, because horizontal wind turbines have a wider blade spread than vertical axis machines, they cannot be installed in tight locations. Additionally, some find it offensive that horizontal axis machines have a big blade area [5].

Figure 2.2 illustrates the VAWT, which are the alternative form of wind turbine. The most often used type of turbine for generating renewable energy at home is the VAWT.

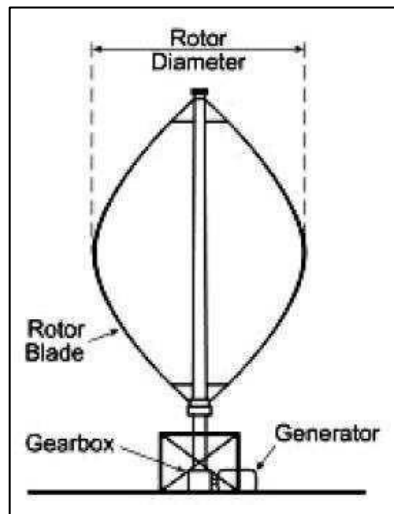


Figure 2.4 VAWT overview layout

Source: <http://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=15875&context=rtd>

VAWT is less commonly utilised in comparison to the Horizontal Axis Wind Turbine. The lesser effectiveness of VAWT compared to HAWT in terms of power plant generator efficiency is the reason behind this. However, VAWT is more effective when implemented on smaller settings, such as in residential yards, parks, and commercial establishments. Vertical axis turbines have the capability to harness wind energy from many directions, including the ability to generate electricity when wind flows from the upper to the lower regions. Due to their adaptability, vertical axis wind turbines are considered the optimal selection for deployments in scenarios characterised by unpredictable wind conditions or where public regulations prohibit the turbine from being positioned at a sufficient height to capitalise on a consistent wind. [6]. The HAWT vs. VAWT arrangement is shown in Figure 2.3.

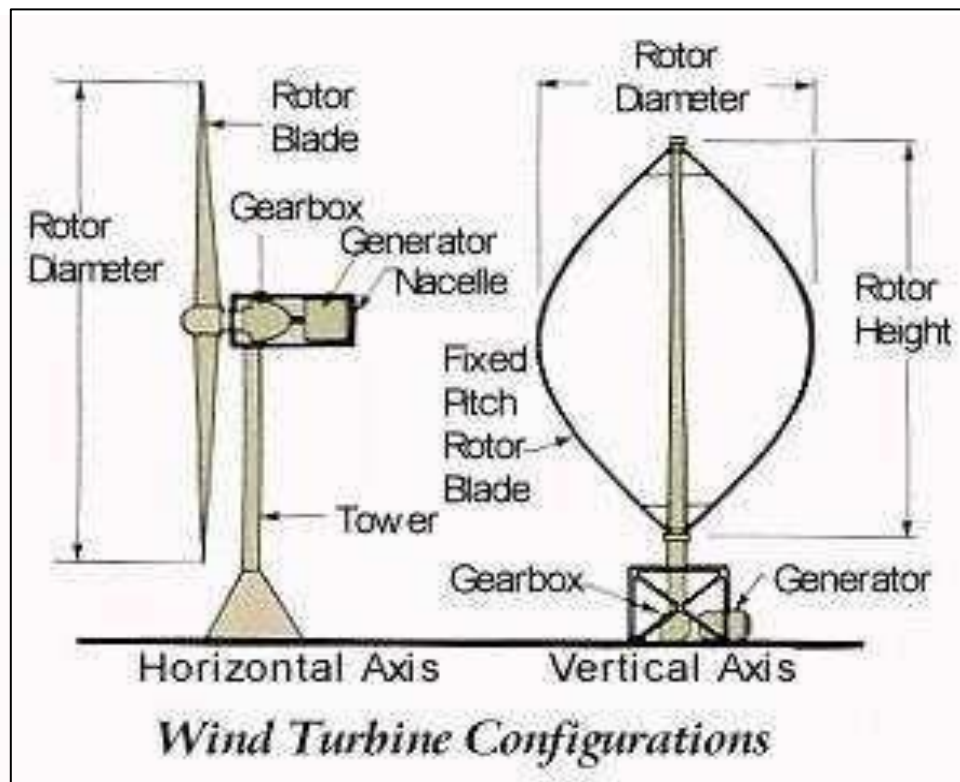


Fig. 2.5 Configuration of HAWT Vs VAWT

Source: <https://sci10sectionm.wordpress.com/2014/02>

PREVIOUS WORK

There are two types of vertical wind turbines. Our project focuses on the Savonius model as one type, while the Darrieus model is another option. The initial type resembles a half-gallon drum that has been split in half and is mounted on a revolving shaft. The second type is similar to an egg beater and is of a smaller size. Most wind turbines in use today are Savonius wind turbines.

You can find some information about these two models on the Renewable Energy UK website. In 1922, the Savonius type of vertical axis wind turbine (VAWT) generator was devised by Sigurd Johannes Savonius of Finland, after previous exploration of similar wind turbine designs. [17].

The Darrieus represents a specific variant of a vertical axis wind turbine (VAWT) generator. Contrary to the Savonius, the Darrieus wind turbine operates as a lift-type VAWT. Instead of using cups to collect wind and physically moving the turbine, a Darrieus turbine harnesses the lift forces generated by The wind interacts with

aerofoils, causing them to rotate. [18]

The research paper "DESIGN, ANALYSIS AND FABRICATION OF SAVONIUS VERTICAL AXIS WIND TURBINE" was released in the Engineering and Technology International Research Journal (IRJET). on June 2, 2015 [19].

The goal of this study dispute was to show how much more efficient The Savonius model performs differently in different wind conditions compared to the traditional horizontal axis wind turbine. It analysed different pieces of evidence indicating that, when the angle of attack is low, the lift force also plays a role in the overall torque. created. Therefore, rather than being a machine that is only drag-driven, the Savonius rotor can be described As a hybrid of a drag-driven and lift-driven device. It can exceed the C_p limit set for machines that are exclusively drag-driven.

According to the results of a few of these experiments, a vertical axis wind turbine can use free wind energy to generate very small amounts of power. When designing, household use is taken into account. Generally speaking, The Savonius model has the potential to provide a minimum of 10% of the required energy.

Additionally, the research indicates that this turbine is typically appropriate for heights of 8 to 10 metres above ground. due to the extremely low air velocity at ground level. And finally, reinforced glass fiber is a more expensive alternative to Aluminium alloy for turbine blade material despite having a higher degree of elasticity.

The blade angle was determined to be the most important aspect after the team conducted some brainstorming to determine what influences the turbine most significantly To optimise power output efficiency.

After considerable investigation, we locate a paper that addresses the turbine blade angle.

A study titled "EFFECT OF THE BLADE ARC ANGLE ON THE PERFORMANCE OF A SEVONIUS WIND TURBINE" was published in Advancements in Mechanical Engineering (AIME) [20].

This article focuses on choosing the optimal angle of the blade to boost the turbine's effectiveness. Investigating the impact of the blade arc angle on the efficiency of a traditional two-bladed Savonius wind turbine through a transient computational fluid dynamics method. The simulations utilised the Reynolds Averaged Navier-Stokes equations and the renormalization group turbulence model.

According to the article's findings, the turbine that achieves the highest power coefficient (c_p 0.2836) during the trial is equipped having a 160° angle of the blade

arc.

The author supplied Table 2.1, which demonstrates the superior power coefficient in various scenarios. The graph illustrates the dynamic torque coefficient of the blade at various blade arc angles.

Table 2.1 Calculating the maximum coefficient for various cases [20]

Case	Blade angle	$C_{P \max}$	C_P gain percentage (relative to case 4)
1	150	0.2687	2.67%
2	160	0.2836	8.37%
3	170	0.2835	8.33%
4	180	0.2617	0.00%
5	190	0.2521	−3.67%
6	200	0.2271	−13.22%

CHAPTER 3

AIM AND SCOPE

AIM

- One wind power plant that has several benefits the Vertical Axis Wind Turbine (VAWT) is especially intriguing as a potential renewable energy source. This study develops a VAWT and explores the educational possibilities of this tool within the framework of Science, Technology, Engineering, Art, and Mathematics (STEAM) learning. .
- An experimental and analytical form of mixed-method embedded design was employed in this study.
- The study's findings demonstrate a direct proportionality between wind speed and blade count and voltage, current intensity, and power.
- • VAWT can be used as a valuable tool for STEAM-based learning initiatives.

OBJECTIVES

- This project's primary goal The goal is to create and analyse a small-scale vertical axis wind turbine with an Arduino controller..
- The report begins with an overview of the history of wind turbines before delving deeper into a more thorough analysis of the primary variety of vertical axis wind turbines, outlining their features, benefits, drawbacks, and operational distinctions from horizontal axis wind turbines.

CHAPTER 4

MATERIALS AND METHODS

4.1 METHODOLOGY

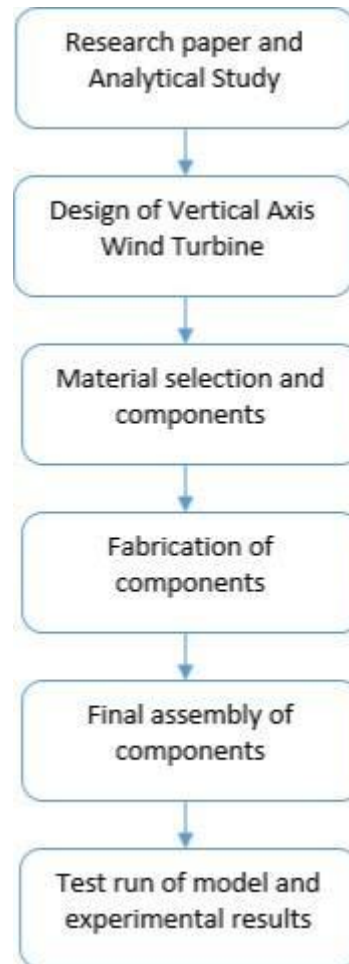


Fig.4.1 Methodology

4.2 COMPONENTS OF VERTICAL AXIS WIND TURBINE FOR PROPOSED PROJECT

The components of the full-scale Vertical Axis Wind Turbine include base plates, shaft, Aluminum blades, connectors, neodymium magnets, deflectors, gears, bearings, reciprocating pump, Arduino, solenoid valve, soil moisture sensor, jumper wires.

4.2.1 Base Plates

The two base plates are made of MS-steel and the structure stands approximately 3 feet high. The bottommost base plate has a diameter of around 48cm and the other has a diameter of around 40cm. By itself the bases will not support the torque and moments produced from our wind turbine, so three base extensions are provided to maintain stability.

4.2.2 Shaft

There are two shafts-Outer hollow shaft and inner solid shaft having diameters 1.5 cm and 1 cm respectively. It is made of Aluminium material and the shaft contains two ring magnets (10mm*20mm) at a distance of about 1.2-1.4 cm between them.

4.2.3 Blades

Following the selection of a profile, three blades made of aluminum flat plate with a thickness of 12 mm will be manufactured to precisely replicate the chosen airfoil. The machining process includes grinding the 12mm plate to 5-6 mm thickness. The blades are then twisted to the required angle by fixing one of the ends to a vice and using a wrench to achieve the required blade angle followed by cross cutting of extra portion.



Fig.4.2 Blades for VAWT

4.2.4 Blade Shaft Connectors

The six radial connecting arms are made of aluminum in order to keep the system lightweight and to reduce centrifugal, moment, and inertial forces. The blades can be mounted to the center mounts and, consequently, the center shaft using the connecting arms. Tig- welding is performed to keep the blades in-tact with the connectors.

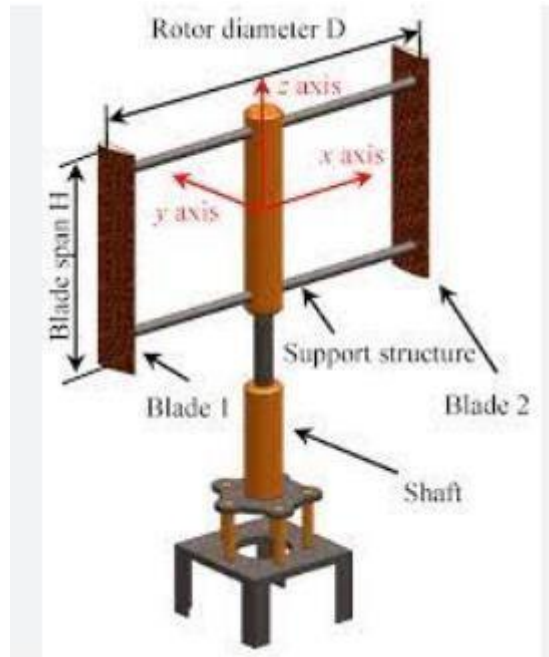


Fig.4.3 Blade Shaft Connectors

4.2.5 Neodymium Magnets

Eight neodymium magnets are provided on either side of the base plates. The neodymium magnets are installed to provide the extra torque and reduce the coefficient of friction. This concept is inspired by maglev magnetic train levitation of placing alternating like and unlike poled magnets to produce additional torque.

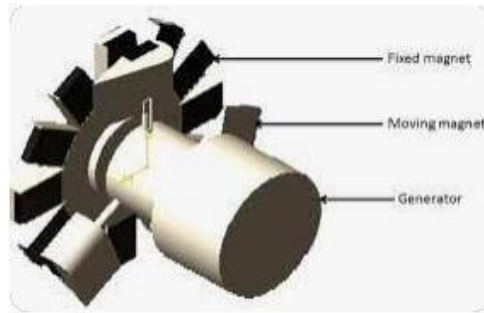


Fig.4.4 Neodymium Magnets

4.2.6 Deflectors

Two deflectors are used for self-starting Optimising the turbine's performance at low wind speeds. Sheet metal is made into a hemispherical shape. These deflectors are welded onto the main shaft.

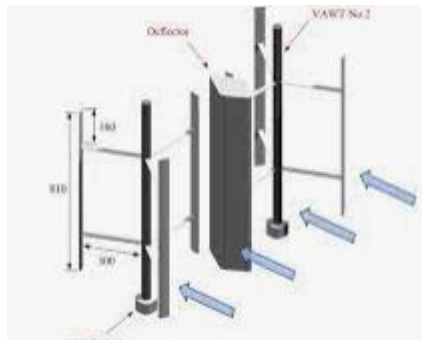


Fig.4.5 Deflectors

4.2.7 Generator

A generator is a device that is utilised to transform mechanical energy into electrical power which can be used in an external circuit. The specification of the generator used in our VWAT is 12V-500rpm.

4.2.8 Reciprocating Pump

A reciprocating pump is a form of positive displacement pump in which a certain amount of liquid is gathered in an enclosed volume and then pressured out to the proper location. At high pressures and modest flow volumes, reciprocating pumps work well.



Fig.4.6 Reciprocating Pump

4.2.9 Arduino

Arduino is an incredible open-source platform that allows for the creation of electronic prototypes and inventions. This includes an Integrated Development Environment (IDE) software running on your device that allows you to create and programme a physical circuit board by uploading computer code. Arduino boards have the ability to read inputs and convert them to outputs.

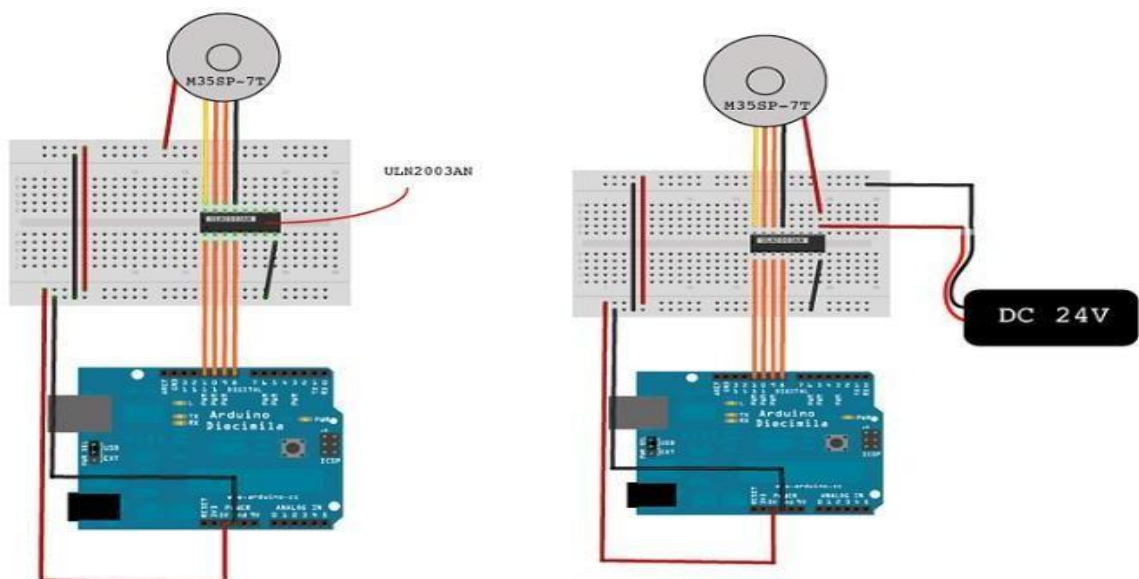


Fig.4.1: Arduino Board

4.2.10 Soil Moisture Sensor

One type of sensor commonly employed is the soil moisture sensor, which is utilised to assess the amount of water present in the soil. As the straight gravimetric aspect of soil moisture includes extraction, drying, as well as weighting of samples. Without specifically utilizing any other soil laws, such as the dielectric constant, electrical resistance, or changes in moisture content, these sensors compute the volumetric water content.

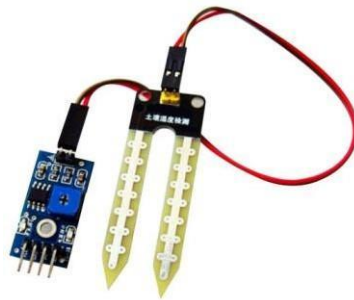


Fig.4.2 **Soil Moisture Sensor**

4.2.11 Solenoid Valve

A solenoid valve is a valve which is operated electromechanically. The valve includes a solenoid that consists of an electric coil in its centre, along with a movable ferromagnetic core. This tool is commonly known as the plunger. Rest assured place, a small orifice is closed off by the plunger. The electric current induces a magnetic field passing along the coil. There is force applied by the magnetic field at the plunger. The aperture opens after the plunger is pushed into the center of the coil. This is the fundamental idea behind how solenoid. The valve opens, and the liquid will flow in, by applying a voltage over the coil.



Fig.4.3 Solenoid Valve

CHAPTER 5

RESULT AND DISCUSSION

5.1 RESULT

Combining a vertical axis wind turbine (VAWT) with Arduino can create a small-scale wind energy generation system for educational purposes or low-power applications. The VAWT design uses blades that rotate on a vertical axis, making it omnidirectional unlike horizontal axis wind turbines (HAWTs) which need to face the wind. An Arduino board can be used to monitor the VAWT's performance. By connecting an anemometer (wind speed sensor) and the generator (electricity output) to the Arduino, you can measure wind speed and voltage generated. This setup allows you to track how much electricity is being produced at different wind speeds. You can even visualize the data on a computer screen or store it for further analysis. This information can help you optimize the VAWT design and understand its efficiency in harvesting wind energy.

Concept: VAWTs are wind turbines with a rotating shaft oriented vertically. They offer advantages like omnidirectional wind capture and simpler design compared to horizontal axis wind turbines (HAWTs). An Arduino can be used to measure wind speed through an anemometer, monitor the VAWT's rotation using a sensor like a hall effect sensor, and potentially control aspects like braking or battery charging based on these readings.

Components: You'll need the VAWT itself, which can be built from blades, a shaft, and support structure. An Arduino board is the heart of the data acquisition system. An anemometer measures wind speed, and a hall effect sensor or similar detects the turbine's rotation. Additional components might include a voltage regulator, battery, and potentially a motor driver for control purposes.

Functionality: The Arduino reads wind speed from the anemometer and rotation speed from the sensor. This data can be displayed on a connected LCD or uploaded to a computer for further analysis. You can program the Arduino to take actions based on the readings. For instance, it could activate a braking mechanism at high winds or manage battery charging based on generated power.

Applications: Data from the Arduino can help you optimize the VAWT's performance by understanding wind patterns and how they affect power generation. You can use this information to improve blade design or adjust the turbine's orientation. The Arduino's control capabilities can be used for safety features like braking or even active control systems to maximize power output at varying wind speeds.

5.2 DISCUSSION

The project focuses on the design, development, and testing of a prototype vertical axis wind turbine (VAWT) as a promising solution for harnessing renewable energy. Traditional horizontal axis wind turbines (HAWTs) dominate the wind energy sector, but VAWTs offer distinct advantages such as simpler construction, lower noise levels, and suitability for urban and decentralized settings.

The project begins with comprehensive research into VAWT technology and its potential applications, examining various designs and operational principles. Based on this research, a prototype is designed to optimize efficiency, reliability, and cost-effectiveness. Advanced materials and innovative engineering techniques are employed to enhance performance and durability.

Prototyping involves rigorous testing under simulated wind conditions to evaluate the turbine's power generation capabilities, efficiency, and stability. Data collected during testing is analyzed to identify areas for improvement and refinement in subsequent iterations.

Throughout the development process, attention is given to environmental impact, ensuring that the VAWT prototype aligns with sustainability goals. Consideration is also given to scalability and integration with existing energy infrastructure to facilitate widespread adoption.

CHAPTER 5

CONCLUSION

VAWT is a popular prototype used in STEAM teaching. There might be a way to overcome energy limitations with the assistance of this wind power station. The study aims to investigate the relationship between voltage, current strength, power, and the number of blades. In addition, there is a direct relationship between wind speed and electrical power. VAWT is an excellent choice for a project focused on STEAM-based learning since it fulfils all the necessary requirements for a well-rounded STEAM experience. This research indicates that it could be utilised as an alternative to STEAM instruction in high school, as well as a possible future renewable energy source..

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APPENDIX

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