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# Performance Analysis of Tulip Turbine at Different Angles Using IOT

Dr Anand S N<sup>1</sup>, Fritha Cardoza<sup>2</sup>, Nihal Ramesh Salian<sup>3</sup>, S Vaibhav Yogeesh<sup>4</sup>, Vaishnavi Shenoy<sup>5</sup>

Professor & HOD Aeronautical Department, Department of Aeronautical Engineering, Mangalore Institute of Technology & Engineering, Mangalore, India<sup>1</sup>

U.G Student, Department of Aeronautical Engineering, Mangalore Institute of Technology & Engineering, Mangalore, India<sup>2</sup>

U.G Student, Department of Aeronautical Engineering, Mangalore Institute of Technology & Engineering, Mangalore, India<sup>3</sup>

U.G Student, Department of Aeronautical Engineering, Mangalore Institute of Technology & Engineering, Mangalore, India<sup>4</sup>

U.G Student, Department of Aeronautical Engineering, Mangalore Institute of Technology & Engineering, Mangalore, India<sup>5</sup>

**ABSTRACT:** Recent times have seen a dramatic increase in the utilization of renewable energy sources to meet the enormous demand for consumption, bringing wind turbines into picture. Since majority of the wind turbines are remotely situated, which can be monitored through IoT rather than conventional approaches by using electronic devices like sensors and microcontrollers which can produce more precise findings. The purpose of the study is to look at how a turbine's direction will affect both its performance and energy output. In this research "Performance analysis of tulip turbine at different angles using IoT", the data obtained through technology by the sensors, turbine performance and its behaviour can be monitored and predicted. The analysis was carried out by collecting data from sensors installed on the turbine and transmitting them to an IoT platform for processing and analysis. The obtained output would help us to recognize the further enhancement for higher efficiency and give scope for improvements and also for the predictive maintenance of the system.

**KEYWORDS:** Renewable Energy, IoT, Different Angles, Efficiency .

## I. INTRODUCTION

A wind turbine is a device that converts the kinetic energy of wind into electrical energy. Wind turbines are an increasingly important source of intermittent renewable energy, and are used in many countries to lower energy costs and reduce reliance on fossil fuels.

To meet the requirements of energy necessity, wind energy is utilized as the substitute wellspring of energy. To utilize wind energy adequately, proper maintenance of wind plants are required. At some point shortcoming happens in windmills and it turns into a troublesome errand to reconfigure it so we need a decent method to do it. The Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

IoT based windmill parameter monitoring system is a remote monitoring and remote-control system for windmills. It helps to monitor some internal and external parameters and control the operation of windmills from a distance. It uses sensors to detect the condition around the windmill and a wireless network to send data to a central server. The central server can then generate reports on the condition of the windmill and send it back to remote locations. The data collected can be analysed to determine the efficiency of the windmill which can also help in predicting any potential problems that might arise, thereby helping in maintaining a healthy windmill. Moreover, the live information from the sensors is shown straight forwardly on a dashboard for distant checking. The control experts can get to this dashboard, and some other activities, whenever required, can be taken. The information can appear on hourly, day by day, week after week, or month-to-month premise. It is important for windmills to be monitored because they are expensive pieces of machinery that produce energy for electricity. If not monitored, they could break down and need repairs which would cost a lot more money than if they were monitored. The benefits of using IoT in windmill parameter

monitoring system includes remote monitoring, reduced operating costs, increased efficiency, improved safety and reduced downtime for maintenance work. Also monitoring and comparing the actual performance outcome of the machine with the expected outcome can help the management to understand the reason for the gap using the data collected from the machine.

The Tulip Turbine is a form of VAWT with the potential for great efficiency and little maintenance. However, the best orientation for Tulip Turbine is not yet known. In this study, we describe a performance analysis of a Tulip Turbine at two orientations 45 degrees and 75 degrees utilising IoT (Internet of Things) technology. The study's goal is to find the ideal orientation for the Tulip Turbine and to provide insights for enhancing the design of VAWTs. The introduction of IoT technology enabled us to measure the turbine's power output in real-time and analyse the data in a more efficient and precise manner. The outcomes of our tests could provide useful insights for the wind energy industry and for the development of renewable energy sources. By evaluating the sensor data, we hope to determine the most efficient orientation for the Tulip Turbine and provide insights for future VAWT research and development. The findings of this study could aid in the creation of more efficient and sustainable wind turbines, as well as the development of renewable energy sources. We can help minimise our dependency on non-renewable energy sources and alleviate the consequences of climate change by harnessing the power of wind energy.

IoT data can be analyzed at almost real time speed. In addition of that, certain actions can be taken based on the analyzed data. The objective of the project is to develop a system "IoT based Windmill monitoring system" to collect the data required to monitor a windmill and using that data to determine its maintenance schedule and automate it. The data is used to gather many other useful information.

### 1.1 PROBLEM STATEMENT

- Wind Turbines are one of the top rising sources of power generation in the world today. So the need of proper operation and maintenance is mandatory for providing reliable and cost efficient green energy.
- Wind Turbines are more prone to fault and maintenance of these windmills at remote location is a huge task. Therefore, it requires a novel technique to measure and sense important parameters. To monitor the wind turbine parameters for premature detection of faults and failures so as to reduce downtime and increase the productivity.
- Designs already being used have significant drawbacks.

### 1.2 OBJECTIVE OF WORK

- Study and analysis of tulip turbine at different angular positions.
- Improvement of the design for efficient production of electricity.
- Development of prototype of the wind turbine.
- Behaviour of the turbine in different conditions at remote location.

## II. RELATED WORK

Ali Naci Celik, Mustafa Kemal [1] reviewed a detailed monthly wind energy production is estimated using the Weibull-representative wind data for a total of 96 months, from 5 different locations in the world. The wind data in relative frequency format is obtained from these calculated Weibull parameters. Halder, Sourabh and G. Sivakumar [2] reviewed a detailed paper on Embedded based remote monitoring station for live streaming of temperature and humidity. In the paper they gave a detailed information on Weather monitoring and that it is important to collect information of temporal dynamics of weather changes. Vishal Kumar Singh, Dr Mallikarjun B,C, Rishav, Uttam Kumar Ray [3] reviewed a research paper on an IoT-based windmill monitoring system in which a windmill prototype is built and the necessary parameters of the wind turbine are detected using sensors. The Internet of Things has been designed to monitor the various components of a wind turbine and provide real-time data that can be accessed from any location. Barik Lalbihari [5] reviewed a detailed paper on IoT based temperature and humidity controlling using Arduino and Raspberry Pi. In the paper he has given a detailed information about the system. It employs Arduino with Raspberry Pi, a sensor device, and Wi-Fi module. The experimental results show the live temperature and humidity of the surroundings and the soil moisture of any plant using. D.J. Willis et.al. [14] in their research paper the reviewed the design and manufacture of wind turbine blades, towers/foundations, and nacelles Wind Farm Development includes offshore installation/siting, flow characterization, and loads/waves/wind characterization, as well as Wind Farm Operations, which includes controls, power production, wind farms, sensing, diagnostics, testing, structural health monitoring, reliability, energy storage, the grid, and power transmission.

### III. METHODOLOGY

- A model of wind turbine is designed by using Autodesk Fusion 360.
- To study and determine the aerodynamic characteristics of the wind turbine by numerical method, the commercial software ANSYS-FLUENT is used.
- Develop the prototype of the wind turbine by considering all aerodynamic parameters.
- Analysis and comparison of numerical results with experimental data.

#### 3.1 IOT SYSTEMS

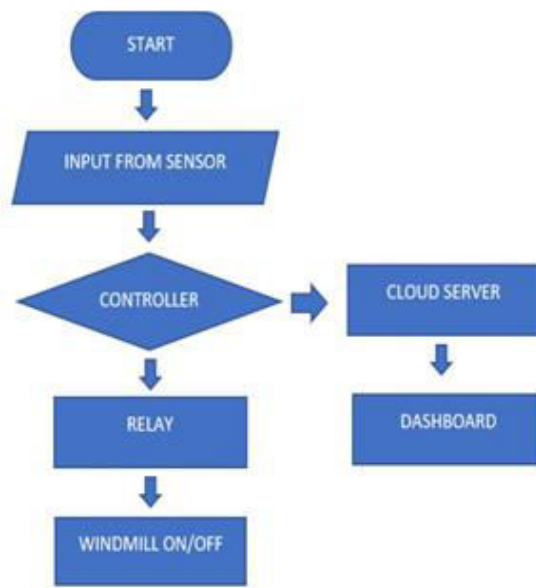


Figure 3.1.1 Flowchart of IoT System

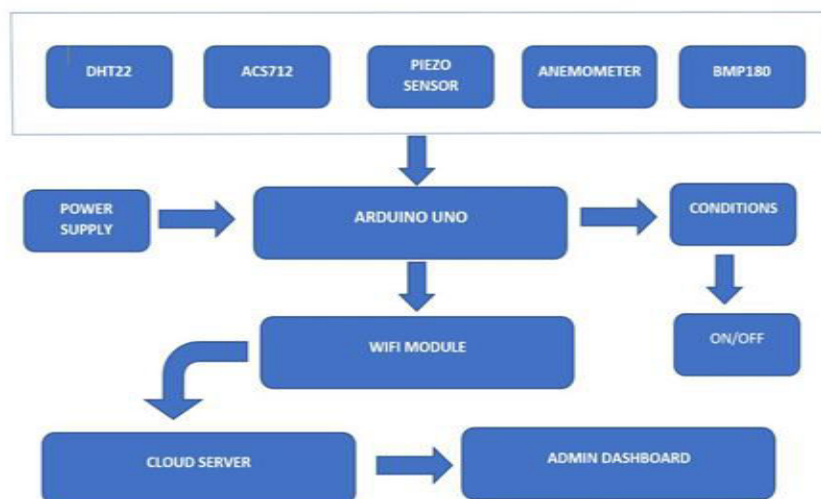


Figure 3.1.2 Block Diagram of IoT System

ESP8266 LAN module acts as a protocol shopper, and it will send the knowledge to ThingSpeak server. ThingSpeak is the best IoT platform used for data collection and storage purposes. Another unique feature of ThingSpeak is the data analysis and comparison module. Comparison between two different days can be accomplished using ThingSpeak



platform. Through Thingspeak, the user will be able to know about the status of the wind turbine and counter measures can be taken after the keen observation of the parameters of the wind.

### 3.2 CAD MODEL AND DESIGN SPECIFICATIONS

A literature review was conducted in order to develop the Problem Statement for designing a wind turbine model using Fusion 360 and using the commercial software ANSYS- FLUENT the aerodynamic characteristics of the wind turbine were determined. In order to develop a wind turbine prototype, all aerodynamic parameters were considered. Then, the results, discussions, and outcomes were analyzed and compared with experimental data.

The design of the turbine was done considering efficiency of power generation and was numerically calculated using ANSYS-FLUENT and using the following parameters.

Sl. No.	Parameter	Reference Values
1	Area of Blade	2.134E+07 mm <sup>2</sup>
2	Height of Blade	0.4 m
3	Diameter of Shaft	0.025 m
4	Height of Setup	1.25 m

Table 1 Turbine Dimensions



Figure 3.2.1 Side View

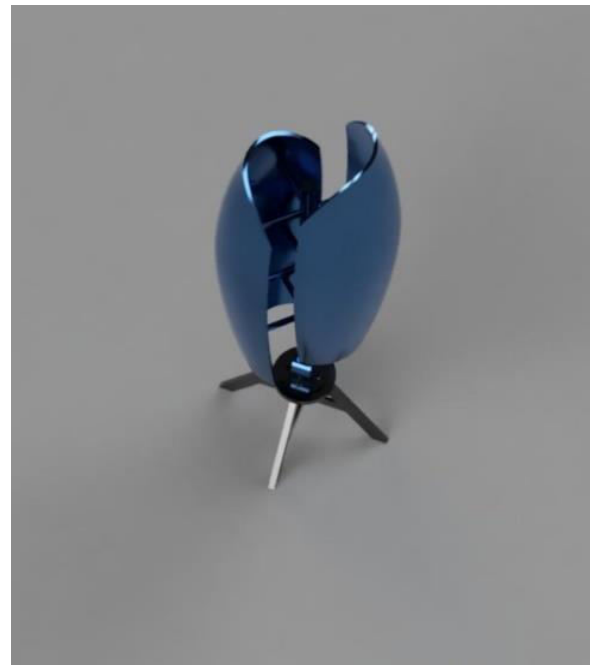


Figure 3.2.2 Top View

### 3.4 SIMULATION OF THE CIRCUIT

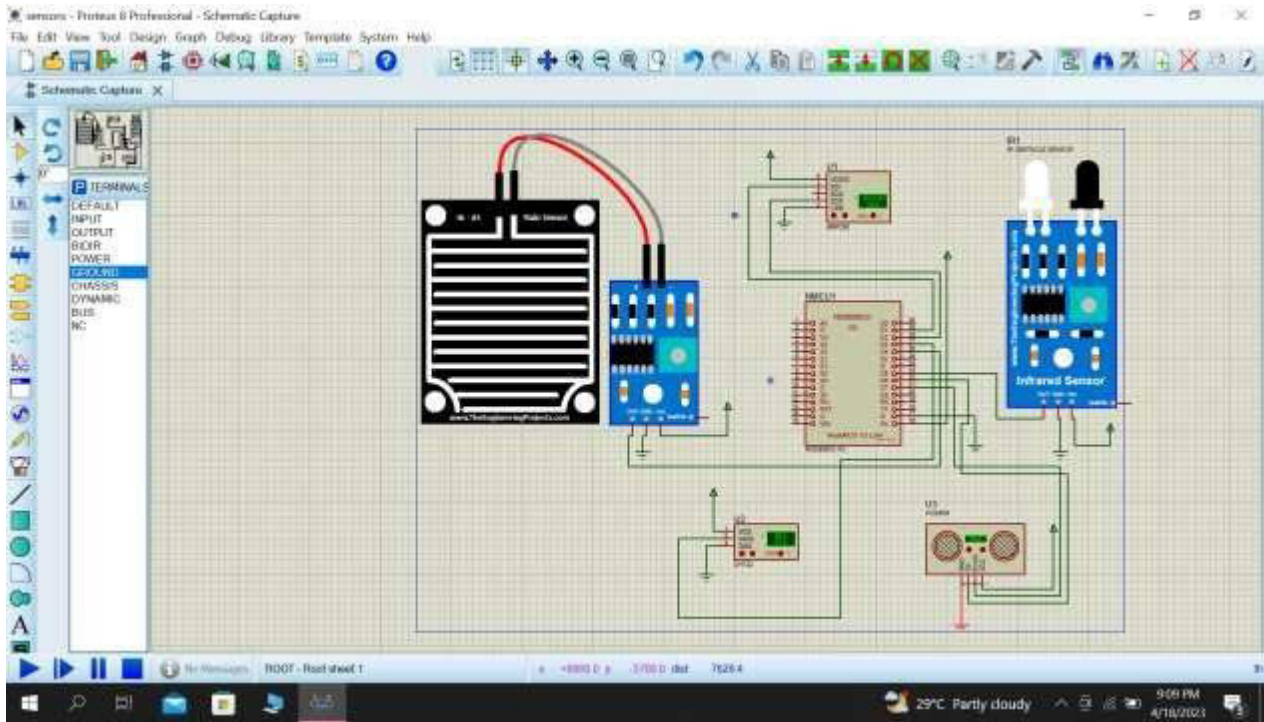


Figure 3.4.1 Simulation of Circuit

The simulation of the project using Proteus Design Suite 8.13 enables the testing and validation of the electronic circuit and embedded system before implementation. This ensures that any potential issues or errors can be identified and addressed before the actual implementation, leading to a more reliable and efficient system. The use of various sensors and the LCD display allows for the accurate monitoring and tracking of environmental conditions, making it an ideal choice for various applications such as weather monitoring, home automation, and industrial automation.

### 3.5 NUMERICAL ANALYSIS

The aerodynamic characteristics of the Wind turbine were calculated using the commercial software ANSYS-FLUENT. During the analysis, the lift coefficient ( $C_L$ ) graph, drag coefficient ( $C_D$ ) graph and velocity graph were obtained at various level. The following flow conditions were selected as initial boundary conditions for CFD computation:

**Velocity Magnitude**  $V = 27.78 \text{ m/s} \Rightarrow 100 \text{ kmph}$ , **Air density**  $\rho = 1.225 \text{ kg/m}^3$ , **Viscosity**  $\mu = 1.789 \times 10^{-5} \text{ kg/ms}$

Sl. No.	Parameters	Reference Values
1	Area A ( $m^2$ )	0.9897416 $m^2$
2	Density $\rho$ ( $kg/m^3$ )	1.225 $kg/m^3$
3	Viscosity $\mu$ ( $kg/ms$ )	1.789e-5 $kg/ms$

Table 2 Turbine Geometric Parameters

Analysis at 90 °

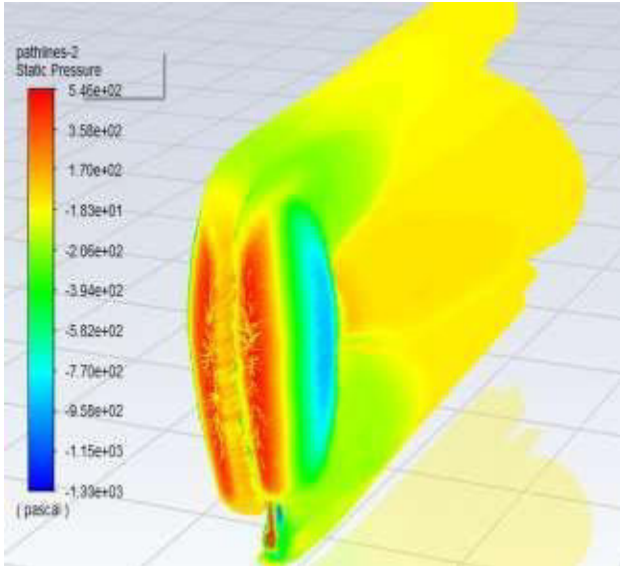


Figure 3.5.1 Total Static Pressure Distribution

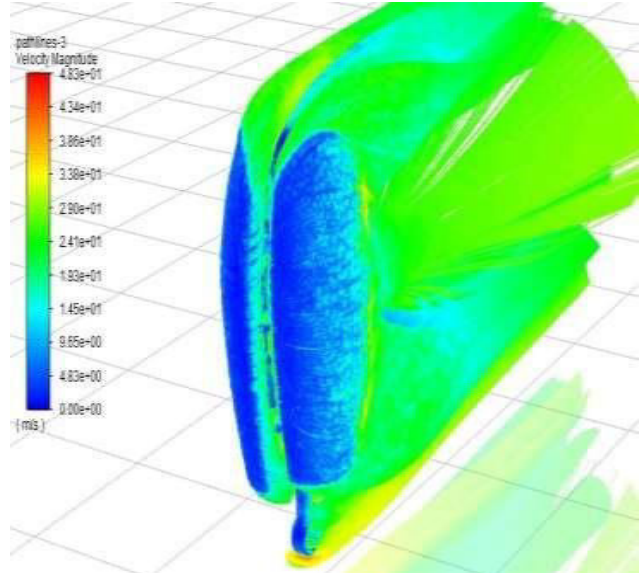


Figure 3.5.2 Velocity Vector Profile

Analysis at 45 °

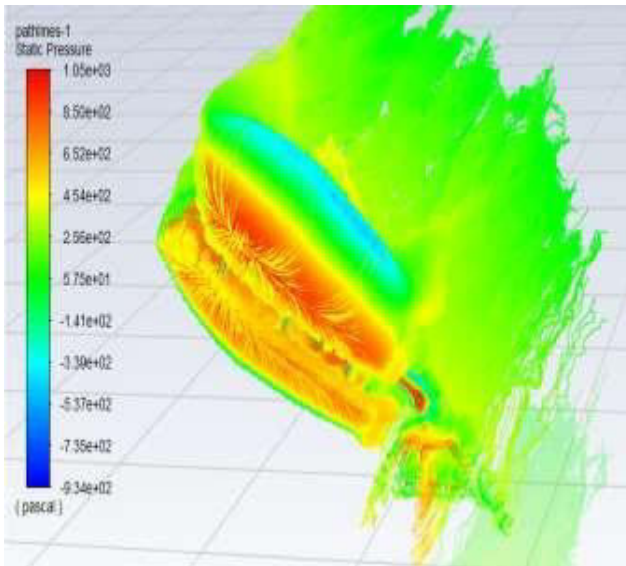


Figure 3.5.3 Total Static Pressure Distribution at 45°

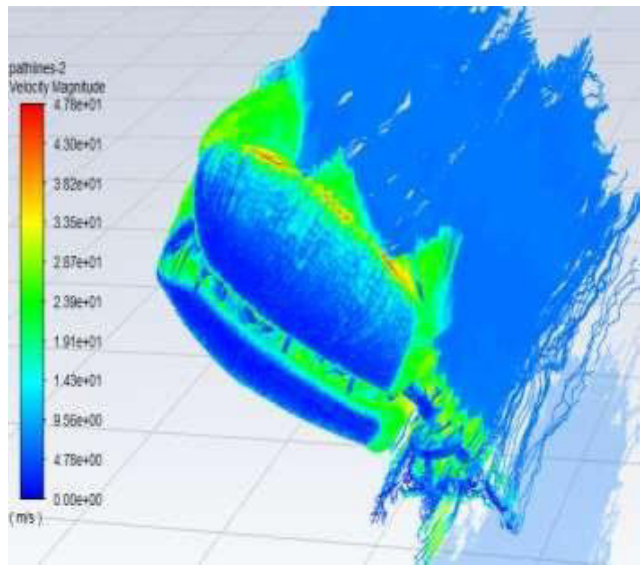


Figure 3.5.4 Velocity Vector Profile at 45°



Analysis at 75 °

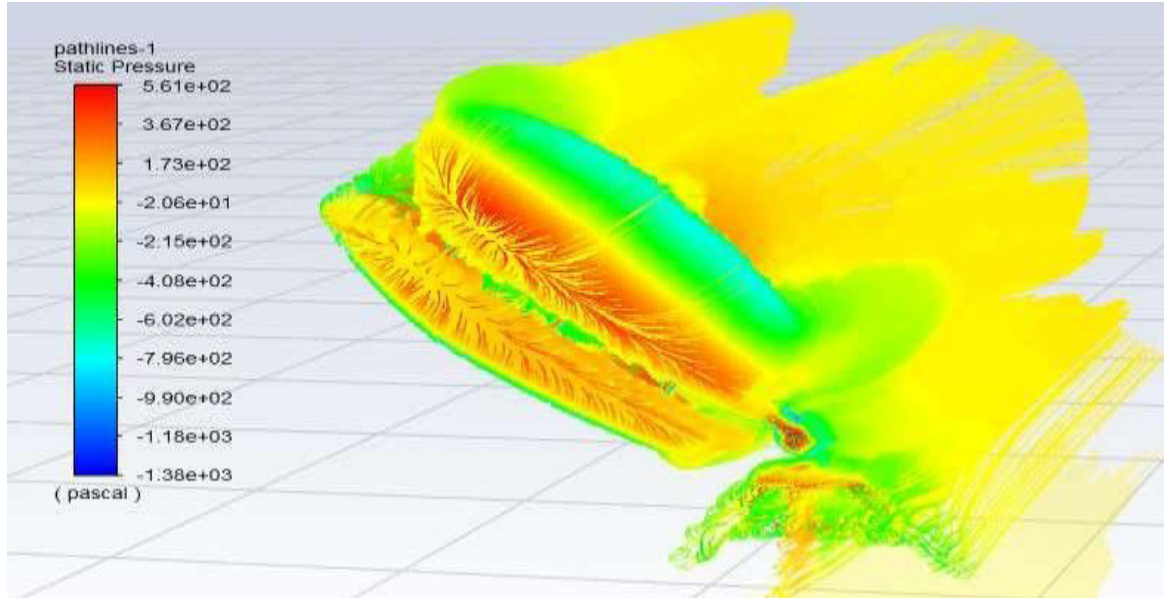


Fig 3.5.5 Total Static Pressure Distribution at 75° angle of inclination

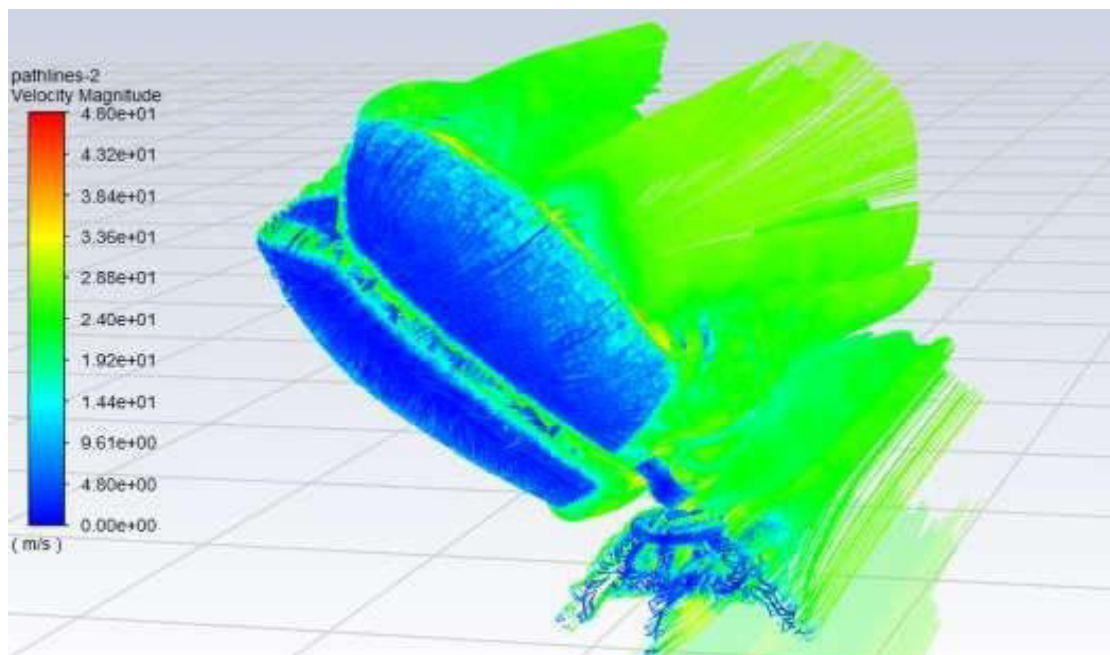


Fig 3.5.6 Velocity Vector Profile at 75° angle of inclination



Graphs

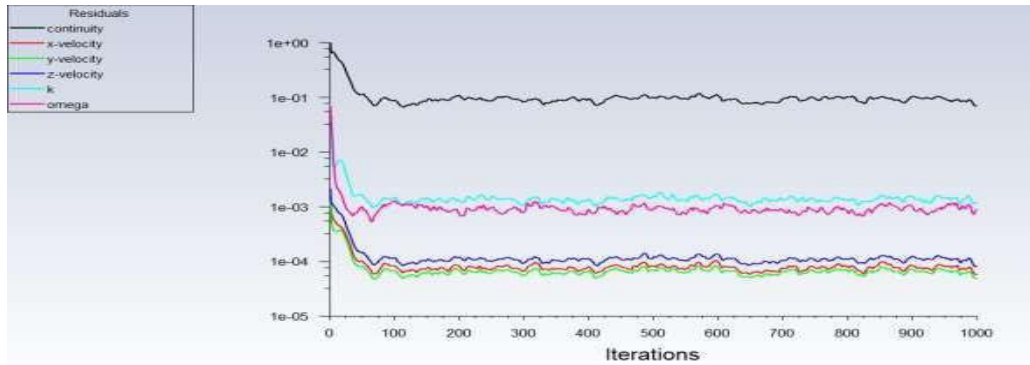


Figure 3.5.7 Velocity Variation Graph

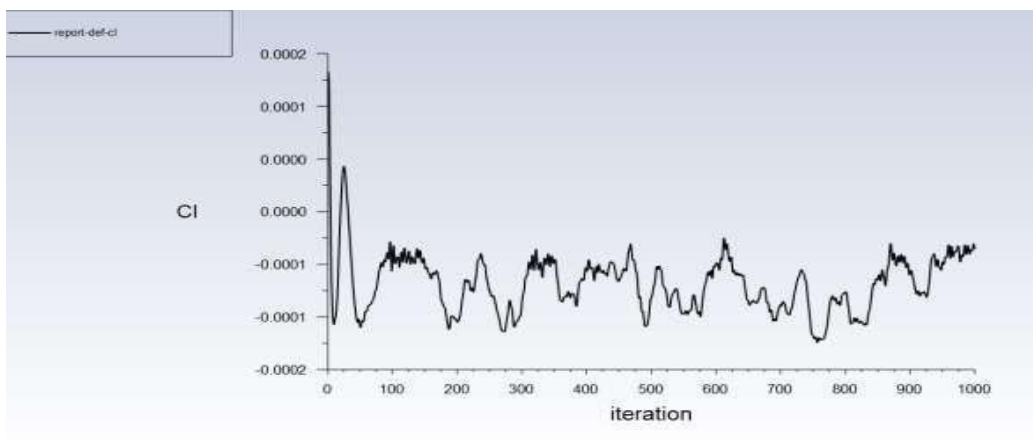


Figure 3.5.8 Lift Variation Graph

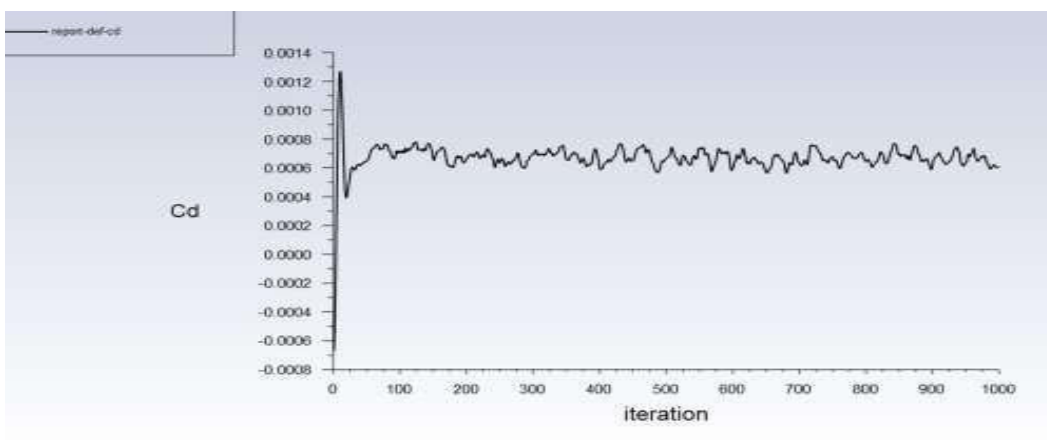


Figure 3.5.9 Drag Variation Graph

### 3.6 FORMULAS

- Sweep Area Of Turbine  $A = D \times H$
- Wind Power  $P_{wind} = 0.5 \times \rho \times v^3 \times A$
- Efficiency of turbine  $\mu = (1 - k_m) \times (1 - k_e) \times (1 - k_{e'}) \times (1 - k_t) \times (1 - k_w) \times C_p$
- Output Power  $P_{output} = \mu \times P_{wind}$
- Tip Speed Ratio  $\tilde{\tau} = \frac{P_{output}}{RPM} \times \frac{30}{\pi}$

### 3.7 PROTOTYPE FABRICATION AND ASSEMBLY

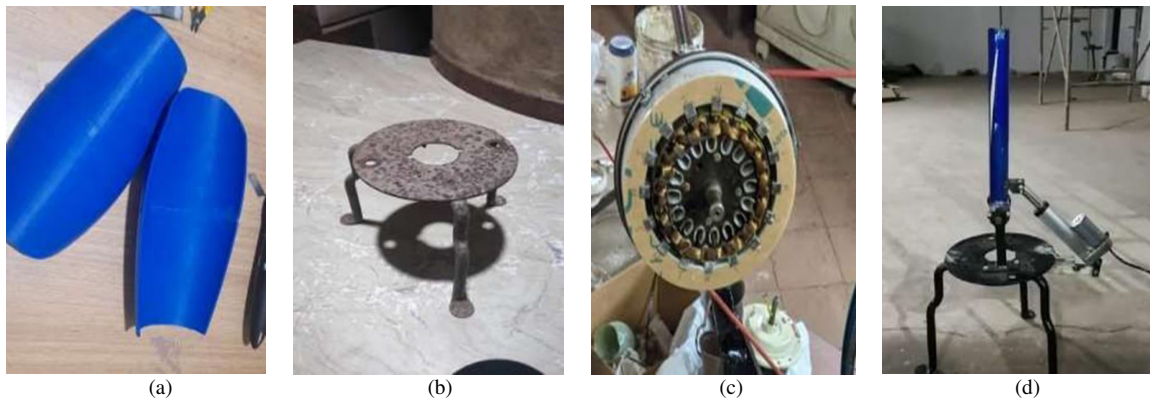


Figure 3.7.1 (a) 3D Printed PLA Blade (b) Stand (c) Motor with Neodymium Magnets (d) Linear Actuator mounted to Shaft

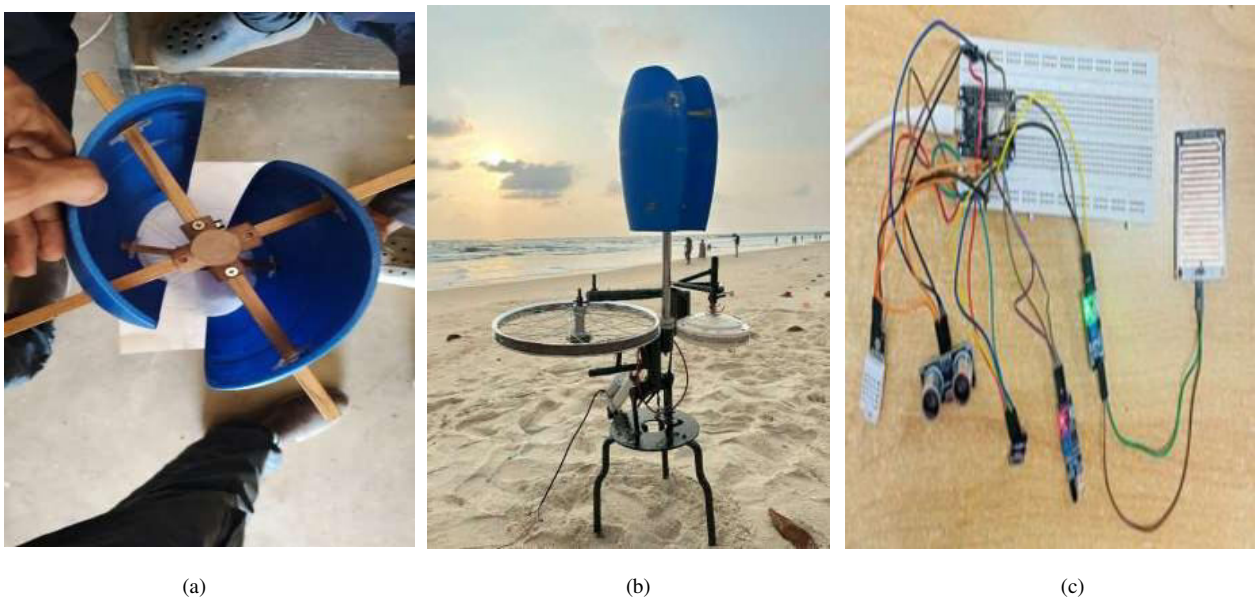


Figure 3.7.2 (a) & (b) Final model of the Tulip Turbine (c) Sensors connected to Arduino UNO

IV. EXPERIMENTAL RESULTS

The tulip turbine was tested at different angles at different times of the day (morning, afternoon, and evening). It was run for about 4 to 5 minutes at a 90 degree angle and its values were noted and calculated, as well as the power generated. Similarly, the test was repeated for 45 and 75 degrees, and the results were recorded and tabulated. For these values, a graphical representation was created to demonstrate the comparison.



Figure 4.1.: Turbine Testing at various orientations

The results from the sensors using IOT Technology and the graphs are shown below:

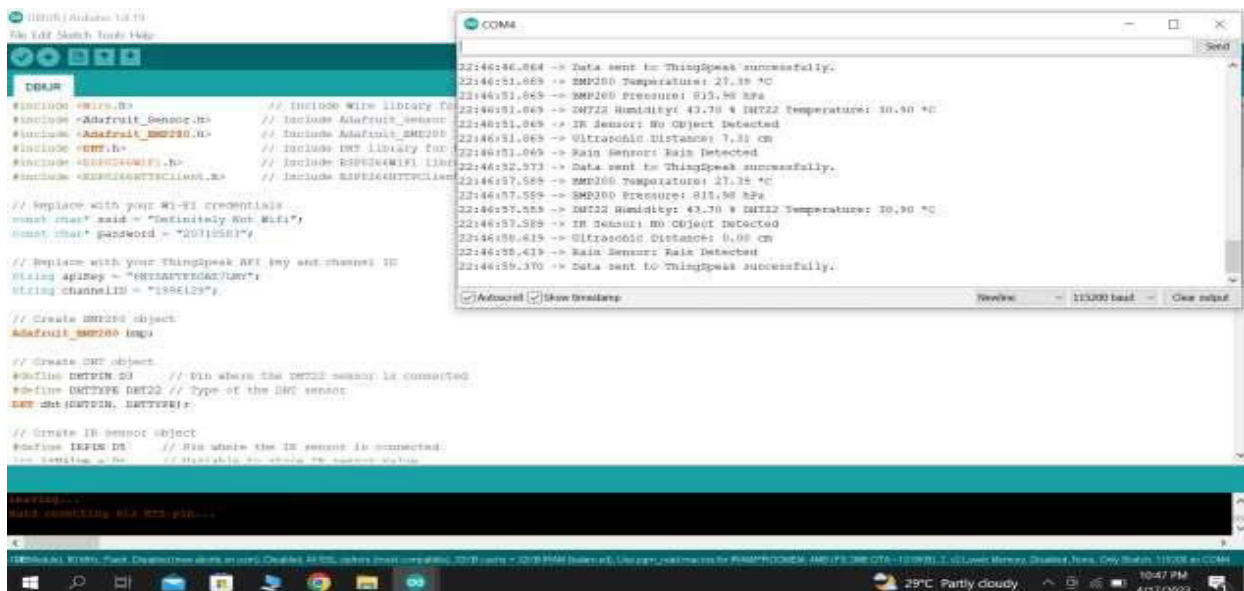


Figure 4.2: Arduino Uno IDE Output

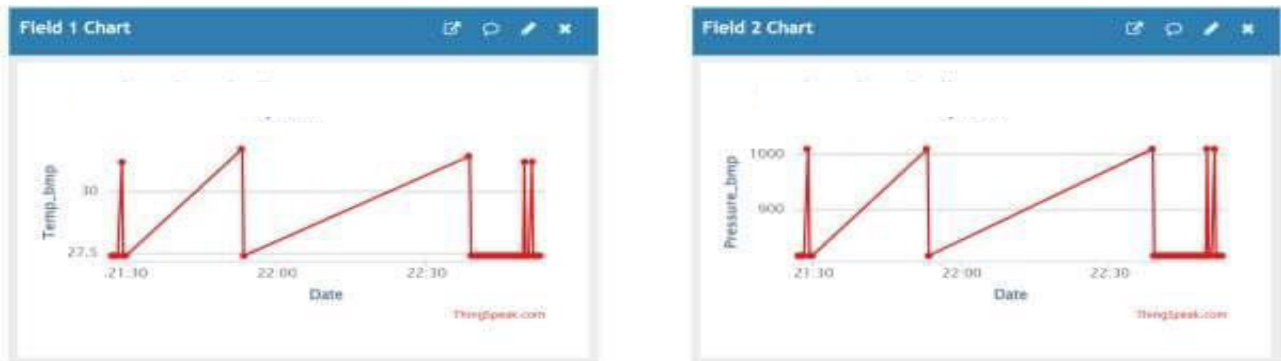


Figure 4.3 Outputs from BMP in ThingSpeak



Figure 4.4 Outputs from DHT22 in ThingSpeak

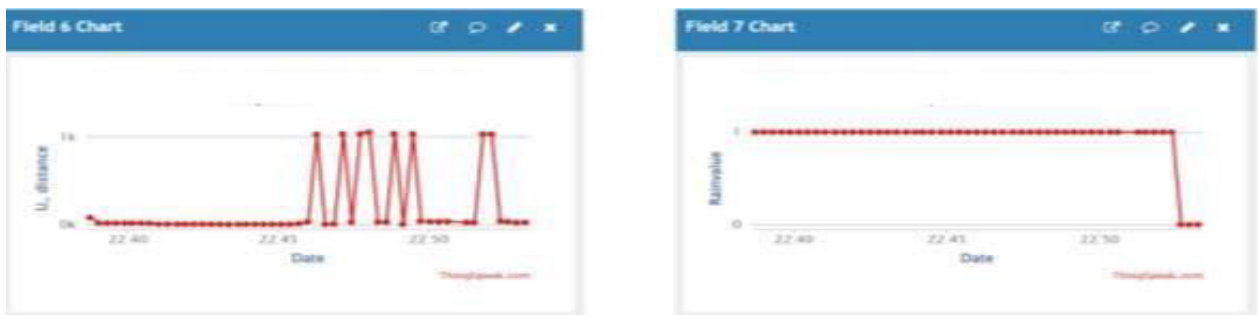


Figure 4.5 Outputs from Ultrasonic sensor and YL83 in ThingSpeak



Figure 4.6 Outputs from IR sensor in ThingSpeak



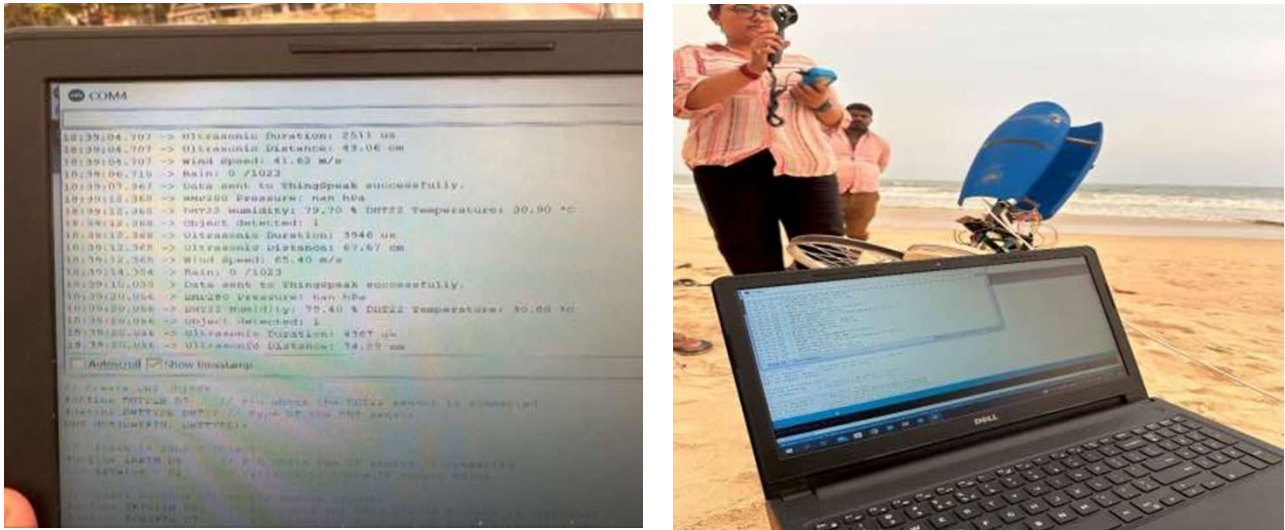


Figure 4.7 Outputs obtained in Dashboard

Time	Angle (degree)	Average Wind Speed (m/s)	Power Generated (W)
7:10	90	3.42	24
7:15	75	3.3	21
7:20	45	3.1	19
12:30	90	2.76	18
12:35	75	2.65	16
12:40	45	2.2	13
18:00	90	5.2	28
18:05	75	4.3	25
18:10	45	4.7	21

Table 3 Tabulation of conducted tests

There are 9 experimental trials have been done and the average power generated was 22W.

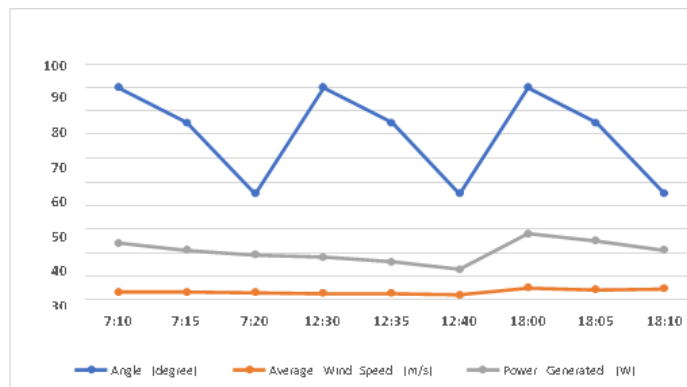


Figure 4.8 Graphical Representation of different variable parameter

## V. CONCLUSION

In this research work, an effort has been made to achieve the set of objectives, the IOT sensors were integrated to the model for obtaining real time technical parameters and to monitor turbine working conditions along with real data acquisition which enables its remote monitoring. As per the real time test conducted for the application in beach location, it was determined that the starting speed required to rotate the prototype developed was 1.5 m/s and gives approximately 16-20 RPM of the wheel for an average wind speed of 3.2 m/s. Analysis and observation of turbine at angles of 90<sup>0</sup>, 75<sup>0</sup> and 45<sup>0</sup> were carried out in both simulation as well as real time test, bringing to the observation that the prototype shows prominent rotations and tapping higher energies from 90<sup>0</sup>, 75<sup>0</sup> and 45<sup>0</sup> exhibiting no discernible rotation when inclined to the wind direction. For the 9 trials conducted, the average power generated was 22W and the real time data from the sensors were tapped on the dashboard using IoT technology for successful embedding of technology for preventive maintenance & efficient utilization.

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