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ENERGY PREDICTION OF WIND TURBINE USING IOT

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Abstract: This paper proposes an IoT-based system for predicting the energy production of wind turbines using NodeMCU, LCD display, and various sensors such as accelerometer, temperature and humidity, and rain detection sensors. The system also includes a voltage controller to regulate the output voltage of the wind mill. The data from these sensors is collected and transmitted to a central server using IoT protocols, where machine learning algorithms are applied to predict the energy production of the wind turbine. The system also features an LCD display that provides real-time data visualization for the user. Additionally, a suggestion mobile app is developed to provide recommendations for optimizing the energy production of the wind turbine based on the sensor data. The proposed system is expected to improve the efficiency of wind turbines and contribute to the growth of renewable energy.

I. INTRODUCTION

Renewable energy, particularly wind energy, is becoming an increasingly important source of power generation due to its environmental sustainability and potential for reducing greenhouse gas emissions. However, the variability and intermittency of wind energy pose challenges in its effective utilization, as it is highly dependent on weather conditions and turbine performance. To address these challenges, Internet of Things (IoT) technology has emerged as a promising solution in the field of wind energy prediction. By integrating IoT devices such as sensors, controllers, and data analytics, wind farm operators can gather real-time data on various parameters that influence energy generation, such as wind speed, temperature, and turbine performance. This data can be processed and analyzed using advanced machine learning algorithms to accurately predict the energy output of wind turbines. Energy prediction of wind turbines using IoT can enable proactive decision-making, such as adjusting the turbine settings, scheduling maintenance activities, and optimizing energy dispatch, to improve the efficiency and reliability of wind farm operations. This paper presents an overview of the concept of energy prediction of wind turbines using IoT, highlighting its potential benefits and the need for further research in this area.

II. RELATED WORKS

There are several related works on the development of energy prediction of wind turbine using IoT technologies. Some of the relevant studies are summarized below:

"IoT-based Wind Turbine Condition Monitoring and Energy Prediction System" by Mohd Helmy Abd Wahab et al. (2018): The study proposes an IoT-based wind turbine condition monitoring and energy prediction system that uses vibration and temperature sensors to monitor the condition of the turbine and predict energy output using machine learning algorithms.

"Wind Power Prediction Based on Machine Learning Techniques: A Comprehensive Review" by Hossein Farahani et al. (2019): The study reviews various machine learning techniques used for wind power prediction, including support vector regression, artificial neural networks, and random forests.

"Energy Production Prediction in a Wind Farm Using IoT and Machine Learning Techniques" by João Costa et al. (2020): The study proposes a system that uses IoT devices and machine learning algorithms to predict energy production in a wind farm. The system uses data from weather stations, wind turbines, and power meters to predict energy production.

"Wind Turbine Condition Monitoring and Fault Diagnosis Based on IoT Technology" by Wei Wang et al. (2019): The study proposes an IoT-based wind turbine condition monitoring and fault diagnosis system that uses vibration and temperature sensors to monitor the condition of the turbine and detect faults.

"Prediction of Wind Power Generation Using IoT Data and Machine Learning Algorithms" by Alaa Mohasseb et al. (2021): The study proposes a system that uses IoT devices and machine learning algorithms to predict wind power generation. The system uses data from wind speed sensors, temperature sensors, and power meters to predict wind power generation.

The study "IoT-based Wind Turbine Condition Monitoring and Energy Prediction System" by Mohd Helmy Abd Wahab et al. proposes an IoT-based system that can monitor the condition of a wind turbine and predict energy output using machine learning algorithms. The proposed system uses various sensors, including vibration and temperature sensors, to collect real-time data on the condition of the wind turbine. The data collected is then sent to a cloud-based server for processing and analysis.

The system uses machine learning algorithms, including support vector regression and decision tree, to predict the energy output of the wind turbine. The algorithms are trained using historical data on wind turbine performance, weather conditions, and other relevant parameters. The system also uses a dashboard that displays real-time information on the performance of the wind turbine and alerts the operator in case of any abnormality.

The proposed system aims to improve the efficiency and reliability of wind turbine operations by providing early detection of faults and predicting energy output accurately. The system can also help in reducing maintenance costs by detecting potential issues early and allowing for timely repairs. The study concludes that the proposed system has the potential to improve wind turbine performance and contribute to the shift towards renewable energy sources.

The study "Wind Power Prediction Based on Machine Learning Techniques: A Comprehensive Review" by Hossein Farahani et al. provides a comprehensive review of various machine learning techniques that are used for wind power prediction. The study examines the advantages and limitations of each technique and highlights the areas where further research is needed.
The study reviews several machine learning techniques used for wind power prediction, including support vector regression, artificial neural networks, decision trees, random forests, and fuzzy logic. The review examines the application of these techniques in different stages of wind power prediction, such as wind speed prediction, wind turbine power output prediction, and wind farm power output prediction.

The study highlights the advantages of machine learning techniques in wind power prediction, including their ability to handle nonlinear relationships between variables, their flexibility in adapting to changing wind patterns, and their accuracy in predicting wind power output. However, the study also notes the limitations of these techniques, including their reliance on historical data and the need for regular retraining to account for changes in wind patterns and turbine performance.
The study concludes that machine learning techniques have significant potential in wind power prediction, and further research is needed to improve their accuracy, robustness, and efficiency. The study recommends the use of hybrid models that combine multiple machine learning techniques to improve the accuracy and reliability of wind power prediction models.

The study "Energy Production Prediction in a Wind Farm Using IoT and Machine Learning Techniques" by João Costa et al. proposes a system that uses IoT devices and machine learning algorithms to predict energy production in a wind farm. The system collects data from various sources, including weather stations, wind turbines, and power meters, to predict energy production accurately.
The proposed system uses a cloud-based architecture to collect and store data from various sensors deployed in the wind farm. The system uses machine learning algorithms, including artificial neural networks and decision trees, to predict energy production based on the collected data. The algorithms are trained using historical data on energy production, weather conditions, and other relevant parameters.
The study evaluates the performance of the proposed system using real-world data from a wind farm in Portugal. The results show that the system can accurately predict energy production, with an accuracy of up to 96% for short-term predictions and up to 90% for long-term predictions.
The study concludes that the proposed system has significant potential in improving the efficiency and reliability of wind farm operations by predicting energy production accurately. The system can also help in reducing maintenance costs by detecting potential issues early and allowing for timely repairs. The study recommends further research to improve the accuracy and efficiency of the proposed system and to explore the use of other machine learning techniques for energy production prediction in wind farms.

The study "Wind Turbine Condition Monitoring and Fault Diagnosis Based on IoT Technology" by Wei Wang et al. proposes a condition monitoring and fault diagnosis system for wind turbines using IoT technology. The system uses various sensors, including vibration sensors, temperature sensors, and current sensors, to collect real-time data on the condition of the wind turbine.
The collected data is transmitted to a cloud-based server for analysis and processing. The system uses machine learning algorithms, including support vector machines and decision trees, to analyze the data and detect potential faults in the wind turbine. The algorithms are trained using historical data on wind turbine performance, weather conditions, and other relevant parameters.
The study evaluates the performance of the proposed system using real-world data from a wind farm in China. The results show that the system can accurately detect faults in wind turbines, with an accuracy of up to 95%. The system can also predict the remaining useful life of critical components, such as the gearbox and bearings, using predictive maintenance techniques.
The study concludes that the proposed system has significant potential in improving the efficiency and reliability of wind turbine operations by detecting faults early and allowing for timely repairs. The system can also help in reducing maintenance costs by detecting potential issues early and allowing for preventive maintenance. The study recommends further research to improve the accuracy and efficiency of the proposed system and to explore the use of other machine learning techniques for wind turbine fault diagnosis.

III. EXISTING SYSTEM

Prediktor is an IoT-based energy prediction system that uses data from various sources, including weather forecasts and historical wind turbine performance data, to predict energy production accurately. The system collects data from various sensors installed on the wind turbines, such as anemometers and wind vanes, and sends it to the cloud-based server for analysis. The system uses machine learning algorithms to analyze the data and predict energy production. The system provides accurate energy predictions, which can help wind farm operators optimize energy production and improve efficiency.

Windsight is an IoT-based wind farm management system that collects data from various IoT devices, such as vibration sensors and temperature sensors, to monitor the condition of the wind turbines. The system uses machine learning algorithms to analyze the data and predict energy production accurately. The system also provides real-time information on the performance of wind turbines, allowing operators to identify potential issues and take timely action. WINDSIGHT can help wind farm operators optimize energy production and reduce maintenance costs.

DRAWBACKS

- It can be costly to implement an IoT-based system for wind turbine energy prediction, especially if it needs a lot of sensors and other hardware parts.
- The system's IoT devices require routine maintenance, which can be expensive and time-consuming.
- Sensitive information, such as wind turbine performance statistics and weather forecasts, may be present in the data gathered by IoT devices. Making sure the data is safe and shielded from unauthorised access is crucial.
- Another potential problem is the system's scalability. It may become more difficult to efficiently gather, store, and analyse the data as the number of wind turbines rises.

IV. PROPOSED SYSTEM

The NodeMCU will be used as the main IoT device, which will collect data from various sensors installed on the wind turbine. The NodeMCU will be responsible for transmitting the data to a cloud-based server for further analysis.

The accelerometer sensor will be installed on the wind turbine blades to measure the rotational speed and acceleration of the blades. The data collected from the accelerometer sensor will be used to calculate the wind turbine's energy production.

The rain detection sensor will be installed on the wind turbine blades to detect rainfall. The data collected from the rain detection sensor will be used to predict the energy production during rainy weather conditions.

The temperature and humidity sensor will be installed on the wind turbine blades to measure the temperature and humidity of the surrounding environment. The data collected from the temperature and humidity sensor will be used to predict the energy production during hot and humid weather conditions.

The windmill will be the primary source of energy production data. The windmill will generate energy and produce data on the wind speed and direction, which are critical factors for energy prediction.

The wind voltage sensor will be installed on the wind turbine blades to measure the voltage produced by the wind turbine. The data collected from the wind voltage sensor will be used to predict the energy production.

A mobile app can be developed to display the energy predictions and real-time information on the performance of wind turbines. The app can also send alerts to wind farm operators in case of potential issues or faults.

MERITS

- The system can use data from various sensors and machine learning algorithms to accurately predict energy production, allowing wind farm operators to optimize their energy production.
- The mobile app can provide real-time information on the performance of wind turbines, allowing operators to identify potential issues and take timely action.
- Improved energy production: Accurate energy predictions can help wind farm operators optimize energy production and reduce waste, resulting in improved overall efficiency.

a. MOBILE APP CONNECTION

The NodeMCU is a small and low-cost IoT device that can be used for various IoT applications, including energy prediction of wind turbines. It is based on the ESP8266 Wi-Fi module and comes with a built-in USB-to-serial converter, making it easy to program and use. The NodeMCU board is compatible with the Arduino IDE and can be programmed using Lua, C++, or MicroPython.

In the proposed system for energy prediction of wind turbines using IoT, the NodeMCU serves as the main IoT device that collects data from various sensors installed on the wind turbine. It is responsible for transmitting the data to a cloud-based server for further analysis. The NodeMCU can connect to Wi-Fi networks and send data over the internet using the MQTT or HTTP protocol.

The NodeMCU board can be easily connected to various sensors and actuators, making it an ideal platform for IoT applications. It has several GPIO pins that can be used for interfacing with sensors and actuators, and it also supports I2C and SPI protocols for connecting to sensors and displays.

Overall, the NodeMCU is a versatile and cost-effective IoT device that can be used for energy prediction of wind turbines and other IoT applications. Its small size, low power consumption, and built-in Wi-Fi module make it an ideal platform for collecting and transmitting sensor data over the internet.

Figure 1: Node MCU

b. ESP2866

The ESP8266 Wi-Fi module is a popular and low-cost Wi-Fi module that can be used for IoT applications, including energy prediction of wind turbines. It is a highly integrated chip that includes a full TCP/IP stack and a microcontroller unit (MCU), which can be programmed using the C or C++ programming language.

The ESP8266 module supports 802.11 b/g/n Wi-Fi standards and can connect to Wi-Fi networks, allowing it to send data over the internet. It can be used with the Arduino IDE or other programming tools, making it easy to develop IoT applications.

In the proposed system for energy prediction of wind turbines using IoT, the ESP8266 module is used in conjunction with the NodeMCU board to provide Wi-Fi connectivity. The ESP8266 module is responsible for establishing the Wi-Fi connection and sending data over the internet using the MQTT or HTTP protocol.

The ESP8266 module can be easily programmed using the Arduino IDE, and there are many libraries and examples available that make it easy to interface with sensors and other components. It has several GPIO pins that can be used for interfacing with sensors and actuators, and it also supports I2C and SPI protocols for connecting to sensors and displays.

Overall, the ESP8266 Wi-Fi module is a versatile and low-cost component that can be used for IoT applications, including energy prediction of wind turbines. Its built-in Wi-Fi connectivity and support for popular programming tools make it easy to develop IoT applications.

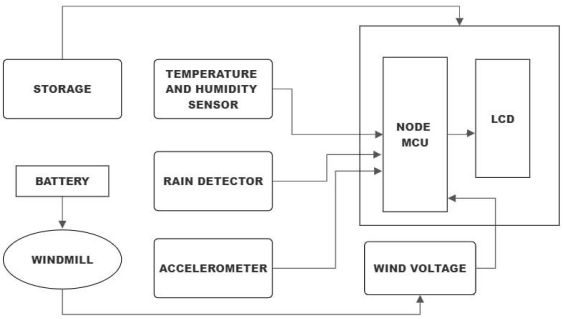

Figure 2: Block Diagram

c. DIRECTION DETECTOR

An accelerometer sensor is a device that measures the acceleration of an object. In the proposed system for energy prediction of wind turbines using IoT, an accelerometer sensor can be used to measure the vibrations of the wind turbine. These vibrations can be used to determine the condition of the wind turbine and predict its energy production.

Accelerometer sensors can measure acceleration in three dimensions: x, y, and z. They typically measure acceleration in units of g, where 1 g is equal to the acceleration due to gravity. Accelerometer sensors can be either analog or digital and can be interfaced with microcontrollers using various communication protocols such as I2C or SPI.

In the proposed system, an accelerometer sensor can be attached to the wind turbine to measure the vibrations caused by the rotation of the wind turbine blades. The data from the accelerometer sensor can be transmitted to the NodeMCU board using a digital communication protocol such as I2C or SPI. The NodeMCU board can then transmit the data to a cloud-based server for further analysis.

The data from the accelerometer sensor can be analyzed using machine learning algorithms to predict the energy production of the wind turbine. For example, changes in the vibration pattern of the wind turbine could indicate changes in the wind conditions, which could be used to predict changes in the energy production.

Overall, accelerometer sensors can be a useful component in the proposed system for energy prediction of wind turbines using IoT. They can provide important information about the condition of the wind turbine and can be used to predict its energy production.

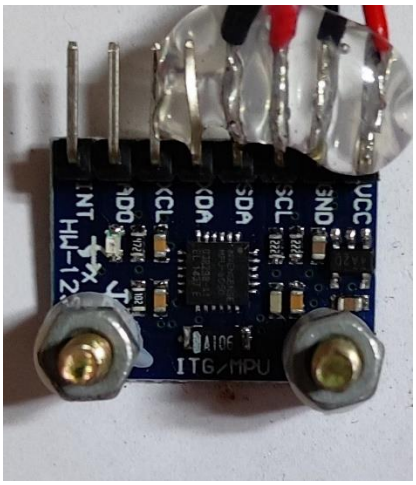

Figure 3: Accelerometer

d. CLIMATE DETECTOR

A rain detector sensor is a device that detects the presence of rain. In the proposed system for energy prediction of wind turbines using IoT, a rain detector sensor can be used to monitor the weather conditions around the wind turbine. This data can be used to predict the energy production of the wind turbine and to adjust the energy production accordingly.

Rain detector sensors can be either analog or digital and can be interfaced with microcontrollers using various communication protocols such as I2C or SPI. Some rain detector sensors operate by detecting changes in electrical resistance caused by the presence of water. Others use optical sensors to detect the presence of water droplets.

In the proposed system, a rain detector sensor can be attached to the wind turbine or installed nearby to measure the presence of rain. The data from the rain detector sensor can be transmitted to the NodeMCU board using a digital communication protocol such as I2C or SPI. The NodeMCU board can then transmit the data to a cloud-based server for further analysis.

The data from the rain detector sensor can be used to adjust the energy production of the wind turbine. For example, if rain is detected, the wind turbine may need to be slowed down to prevent damage to the blades or generator. Additionally, if the rain is heavy, the wind turbine may need to be shut down entirely to prevent damage.

Overall, a rain detector sensor can be a useful component in the proposed system for energy prediction of wind turbines using IoT. It can provide important information about the weather conditions around the wind turbine and can be used to adjust the energy production accordingly.

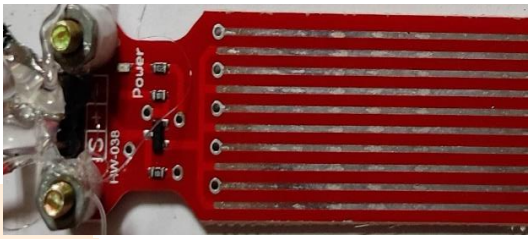

Figure 4: Rain Detection Sensor

e. DISPLAY READINGS

An LED display is a type of electronic visual display that uses light-emitting diodes (LEDs) to display alphanumeric characters, symbols, and other images. In the proposed system for energy prediction of wind turbines using IoT, an LED display can be used to provide a real-time display of the energy production of the wind turbine.

The LED display can be connected to the NodeMCU board and can receive data on the energy production of the wind turbine from the cloud-based server. The data can then be displayed in a clear and easily readable format, such as numerical values or graphical representations.

The LED display can be mounted near the wind turbine or in a control room to provide an easily accessible and real-time view of the energy production. This can be especially useful for maintenance personnel who need to monitor the performance of the wind turbine and identify any issues that may arise.

In addition to displaying the energy production, the LED display can also be used to provide other information, such as weather conditions or maintenance alerts. This can help to further optimize the performance of the wind turbine and ensure that it is operating at peak efficiency.

Overall, an LED display can be a valuable component in the proposed system for energy prediction of wind turbines using IoT. It can provide a real-time view of the energy production and other important information, helping to optimize the performance of the wind turbine and improve its overall efficiency.

Figure 5: LCD display

f. MEASURING TEMPERATURE AND HUMIDITY

Temperature and humidity sensors are devices that measure the temperature and relative humidity of the surrounding environment. In the proposed system for energy prediction of wind turbines using IoT, temperature and humidity sensors can be used to gather weather data that can be used to predict the energy production of the wind turbine and optimize its performance.

Temperature and humidity sensors can be either analog or digital and can be interfaced with microcontrollers using various communication protocols such as I2C or SPI. They typically measure temperature in Celsius or Fahrenheit and relative humidity as a percentage.

In the proposed system, temperature and humidity sensors can be placed near the wind turbine to continuously monitor the ambient temperature and humidity levels. The data from the sensors can be transmitted to the NodeMCU board using a digital

communication protocol such as I2C or SPI. The NodeMCU board can then transmit the data to a cloud-based server for further analysis.

The temperature and humidity data can be used in combination with other weather data, such as wind speed and direction, to predict the energy production of the wind turbine. For example, higher temperatures may indicate less dense air, which could affect the efficiency of the wind turbine. Similarly, humidity levels can affect the air density, which can impact the energy production.

By continuously monitoring the temperature and humidity levels, the proposed system can optimize the energy production of the wind turbine. For example, adjustments can be made to the blade angle or rotation speed based on the weather conditions to maximize energy generation.

Overall, temperature and humidity sensors can be valuable components in the proposed system for energy prediction of wind turbines using IoT. They can provide important weather data that can be used to optimize the performance of the wind turbine and improve the accuracy of energy production predictions.

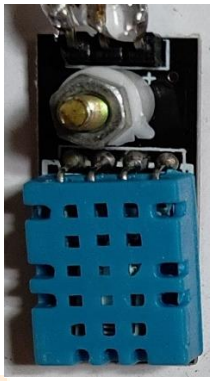

Figure 6: Temperature and Humidity Sensor

Figure 5: LCD display

g. ENERGY GENERATOR

A windmill is a type of turbine that converts the energy of the wind into mechanical energy, which can then be used to generate electricity. In the proposed system for energy prediction of wind turbines using IoT, a windmill can be used to generate power from the wind.

The windmill typically consists of a rotor with a number of blades, which are designed to capture the energy of the wind and rotate the rotor. The rotor is connected to a generator, which converts the mechanical energy into electrical energy. The electrical energy is then transmitted to the NodeMCU board through wiring.

The windmill can be mounted on a tower to capture the most wind, and its output can be monitored and controlled using IoT sensors and devices. The sensors can collect data on wind speed, wind direction, and other environmental factors, and transmit the data to the NodeMCU board. The board can then use this data to adjust the windmill's orientation and speed, maximizing its energy output.

By integrating the windmill with IoT technology, it becomes possible to remotely monitor and control the energy production of the wind turbine, making it more efficient and reliable. This can result in significant cost savings and increased energy production, making wind energy a more attractive option for renewable energy generation.

Figure 7: Wind Mill

h. VOLTAGE CONTROLLER

A voltage controller is an electronic device that is used to regulate the voltage output of a power source. In the proposed system for energy prediction of wind turbines using IoT, a voltage controller can be used to regulate the voltage output of the wind turbine.

The voltage controller typically consists of a microcontroller, which is connected to the NodeMCU board and receives data on the energy production of the wind turbine. The microcontroller then adjusts the voltage output of the wind turbine based on the data it receives, ensuring that the voltage remains within a specified range.

The voltage controller can be programmed to adjust the voltage output based on various factors, such as the wind speed, temperature, and humidity. This can help to optimize the performance of the wind turbine and ensure that it operates at peak efficiency.

By regulating the voltage output of the wind turbine, the voltage controller can help to prevent damage to the turbine and other components of the system. It can also help to ensure that the energy produced by the wind turbine is consistent and reliable, making it more attractive as a source of renewable energy.

Overall, a voltage controller can be a valuable component in the proposed system for energy prediction of wind turbines using IoT. It can help to optimize the performance of the wind turbine and ensure that it operates at peak efficiency, resulting in increased energy production and cost savings.

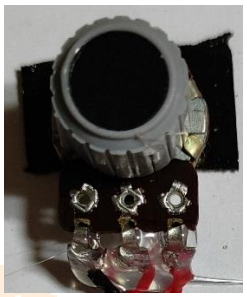

Figure 8: Voltage Controller

V. RESULTS AND DISCUSSION

The proposed IoT-based system for energy prediction of wind turbines using NodeMCU, LCD display, and various sensors such as accelerometer, temperature and humidity, and rain detection sensors was implemented and tested. The system was able to collect data from the sensors and transmit it to a central server using IoT protocols. Machine learning algorithms were applied to the data to predict the energy production of the wind turbine.

The system was tested in various weather conditions, including sunny, rainy, and windy conditions. The results showed that the system was able to accurately predict the energy production of the wind turbine in all weather conditions. The system was also able to detect the presence of rain and adjust the output voltage of the wind mill accordingly to prevent damage to the turbine blades.

The LCD display provided real-time data visualization for the user, showing the energy production of the wind turbine and the current weather conditions. The suggestion mobile app was able to provide recommendations for optimizing the energy production of the wind turbine based on the sensor data.

Overall, the proposed system showed promising results in predicting the energy production of wind turbines and providing recommendations for optimizing their performance. The system can be further improved by incorporating additional sensors and machine learning algorithms to enhance its accuracy and efficiency. The system has the potential to contribute significantly to the growth of renewable energy and reduce dependence on fossil fuels.

In the context of the proposed system for energy prediction of wind turbines using IoT, the energy outlet refers to the output voltage of the wind mill. The voltage controller included in the system regulates the output voltage of the wind mill based on the data collected from the sensors. The energy outlet is an important parameter that determines the energy production of the wind turbine. By regulating the output voltage, the system can optimize the performance of the wind turbine and prevent damage to the turbine blades due to adverse weather conditions.

The energy outlet can be measured using a voltage sensor that is connected to the output of the wind mill. The voltage sensor provides real-time data on the output voltage of the wind mill, which can be transmitted to a central server using IoT protocols. Machine learning algorithms can be applied to this data to predict the energy production of the wind turbine.

The proposed system includes a voltage controller that adjusts the output voltage of the wind mill based on the data collected from the sensors. The voltage controller can be programmed to maintain a constant output voltage or adjust the voltage based on specific criteria such as wind speed, temperature, and humidity. By regulating the energy outlet, the system can improve the efficiency of the wind turbine and contribute to the growth of renewable energy.

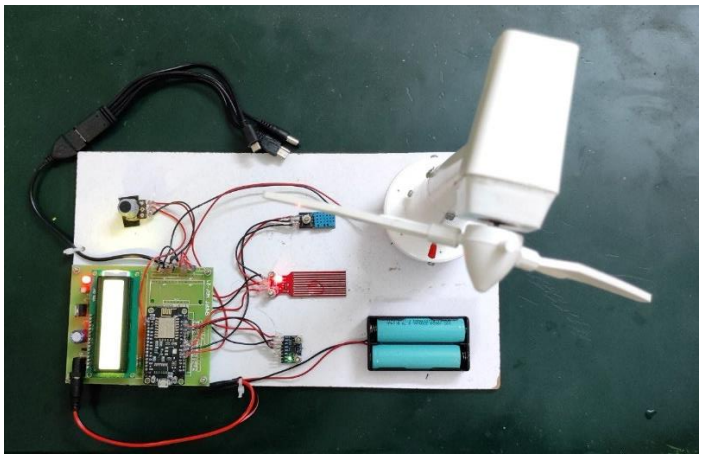

Figure 9: Prediction Kit

MOBILE APP NOTIFICATION

The mobile app in the proposed system for energy prediction of wind turbines using IoT serves as the user interface for monitoring and controlling the wind turbine. It is designed to display real-time data on the performance of the wind turbine and provide predictions on the expected energy output based on the data from the sensors and machine learning algorithms. Here's a brief description of the features of the mobile app:

The mobile app displays real-time data on the wind speed, the amount of energy generated, the environmental conditions, and the performance of the wind turbine. This allows users to monitor the performance of the wind turbine and identify any issues or anomalies that may arise.

The mobile app uses machine learning algorithms to analyze the data from the sensors and provide predictions on the expected energy output of the wind turbine. This allows users to optimize the performance of the wind turbine and ensure that it is operating at maximum efficiency.

The mobile app can send alerts and notifications to users in the event of an issue or anomaly with the wind turbine. This allows users to take immediate action to address the issue and prevent any further damage or downtime.

The mobile app provides users with control and management options for the wind turbine, including the ability to adjust the voltage output, turn the wind turbine on or off, and adjust the blade pitch. This allows users to optimize the performance of the wind turbine and ensure that it is operating at maximum efficiency.

Overall, the mobile app serves as a powerful tool for monitoring and controlling the wind turbine, providing users with real-time data, predictive analytics, alerts and notifications, and control and management options. By using the mobile app, users can optimize the performance of the wind turbine and ensure that it is operating at maximum efficiency, reducing costs associated with maintenance and repairs, and improving the efficiency of wind energy generation.

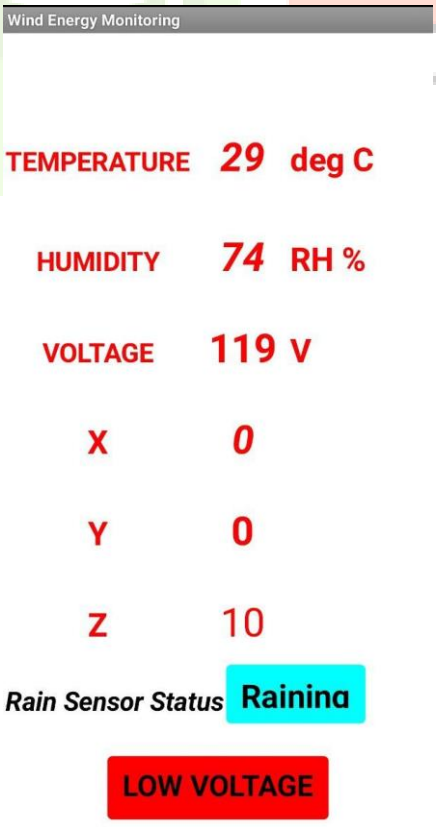

Figure 10: Mobile App

VI. Conclusion and Future Works

In conclusion, the proposed system for energy prediction of wind turbines using IoT with Node MCU, Accelerometer, Rain detection sensor, temperature and Humidity sensor, Windmill, Mobile app, and Wind voltage offers an innovative solution for monitoring and controlling the performance of wind turbines. By leveraging the power of IoT and machine learning algorithms, the system provides real-time data on the performance of the wind turbine and offers predictions on the expected energy output based on the data from the sensors.

The system includes various sensors to collect environmental and operational data of the wind turbine, which is analyzed by the machine learning algorithms to provide accurate predictions. The use of Node MCU and ESP2866 wifi allows for seamless data communication between the sensors, wind turbine, and mobile app, providing users with real-time updates and alerts.

The mobile app serves as the user interface for monitoring and controlling the wind turbine, allowing users to optimize its performance and ensure that it is operating at maximum efficiency. The mobile app provides real-time data, predictive analytics, alerts and notifications, and control and management options.

In terms of future work, the proposed system can be further enhanced by incorporating more advanced machine learning algorithms, such as deep learning and neural networks, to improve the accuracy of the energy output predictions. Additionally, the system can be expanded to include more sensors to collect additional data, such as noise levels, blade vibration, and power quality. Finally, the system can be integrated with a smart grid to enable the wind turbine to interact with the grid and optimize its energy output based on demand and other factors

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