IJERST

International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 21 No. 3 (1) 2025

ijerst.editor@gmail.com

editor@ijerst.com

ISSN 2319-5991 www.ijerst.com
Vol. 21, No. 3(1), 2025
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Research Paper

Highway Windmill System Data Analsys And Visualization By Node- Red

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Received: 05-6-2025 Accepted: 05-7-2025 Published: 13-7-2025

Abstract-- This project examines the analysis and reflection of compound data from the window of the air-brown system, using external development equipment. The gas cigarette system generates designing data to determine control of the organizations, which will focus on the speeds such as the speed of the wind, the power of power, and effectiveness. The red-up-to-use environment to create data processing phrases, can be filtered-deeply with a dynamic view with the console interaction. Using the power of red-red, this study requires to give knowledge of the behavior and the strength of the air system under the specified type. This knowledge is important to correct the powerful structures of strength and demonstrate the strategic decisions in the power of strength.

Keywords-- Highway windmill system, Node-RED, flow-based programming, simulated data analysis, data visualization, interactive dashboard.

I. INTRODUCTION

This project uses Node-Red, a powerful and versatile river-based development tool, to examine the analysis and visualization of simulated data from highway wind turbine systems. The aim is to improve understanding and optimization of wind turbines' performance using AI and simulation data. Important parameters such as wind speed, performance, and efficiency are intended to provide valuable knowledge with out physical wind structure. Instead, we use synthetic data to simulate various operational scenarios. Node red creates complex data processing flows in an intuitive environment, making it the ideal platform for this project. Creating dynamic visualizations via interactive dashboards enables actual monitoring and analysis of the performance of wind turbine systems. This project demonstrates how to use AI and simulation equipment to gain insight into wind turbines operations, demonstrating valuable exercises in both pedagogical and practical applications. A user-friendly platform from Node red allows for the design and management of complex data processing tasks, highlighting visual programming performance when analyzing and optimizing wind turbines performance. This project demonstrates the innovative use of technology to simulate and understand wind turbine systems and pave the way for future development in this field. One of the most important benefits of Node red is its extensive library of prefabricated nodes. This library contains nodes such as HTTP requirements, MQTT communication, file operations, and database interactions. Additionally, Node Red supports the creation of custom nodes, allowing users to extend functionality to meet specific requirements. The versatility of this tool is further improved by the ability to integrate into a large number of IoT platforms, cloud services and APIs from third-party providers, making it a powerful solution for a variety of applications.

The open source nature of Node red promotes the living community of users and developers who continue to contribute to growth and improvement. The platform documentation is comprehensive and well maintained, providing users with resources and troubleshooting issues that they need to get started. Node red's flow-based approach simplifies the development process and reduces the need to concentrate on comprehensive programming knowledge and application logic and functionality. In summary, Node-Red is a very versatile and user-friendly tool that optimizes the development of workflows for data processing and automation. The visual programming paradigm, extensive library of nodes, and seamless integration functions make it an ideal choice for these projects where data analysis and visualization are of paramount importance. Platform documentation is comprehensive and well maintained, providing users with the resources they need to get started and fix issues. Additionally, Node red's asset-based approach simplifies the development process, reduces the need for comprehensive programming knowledge, and allows users to focus on application logic and capabilities. In summary, Node-Red is a very versatile and user-friendly tool that optimizes the development of workflows for data processing and automation. The visual programming paradigm, extensive library of nodes, and seamless integration functions make it an ideal choice for these projects where data analysis and visualization are of paramount importance. The data analysis and visualization project for highway wind turbine systems uses Node Red to simulate and analyze the performance of wind turbines located along the highway. The main goal of this project is to use AI-controlled simulation data to improve understanding and optimization of wind turbines performance. The project aims to provide valuable insight into the operational capabilities of wind turbines without the necessary physical installation by focusing on key parameters such as wind speed, performance and efficiency. This project involves creating two different data processing flows within nodered. The first river was developed to simulate wind turbine operations using synthetic data generated by mathematical formulas. This river is not based on physical hardware, making it a cheap and accessible solution for simulating various operating scenarios. Using this approach, users can gain insight into the performance of wind turbines under a variety of conditions, identifying potential areas of improvement and optimizing the system accordingly

Fig1.1:Vertical axis wind turbine

The second river includes sensors and MQTT communications, which simulates data collection in a more realistic way. This river does not include any actual hardware connections, but it uses Node Red's integrated capabilities to emulate sensor data and sends it via the MQTT theme. This approach allows users to experiment with different sensor configurations and communication protocols, providing a comprehensive understanding of how to collect, process and visualize data in a real-world environment. Both flows are equipped with interactive dashboards that facilitate real monitoring and analysis of simulated data. These dashboards are created using Node Red dashboard nodes to provide users with intuitive and dynamic visualization of their most important performance metrics. By presenting data in a clear and accessible format, dashboards allow users to make well-discovered decisions and effectively optimize the performance of their wind turbines. This project essentially illustrates the performance of nodes as a tool for simulation and analysis of wind turbines performance. By using visual programming functions and extensive Knot libraries, this project demonstrates how users can simplify and make complex data processing tasks more accessible. The resulting knowledge and visualization contribute to a deeper understanding of wind turbine surgery and paves the way for future development in this field. The data analysis and visualization project for highway wind turbine systems offers several important advantages in terms of both technical capabilities and practical applications. By simulating and analyzing wind turbines performance using Node Red, this project provides an inexpensive and efficient solution to gain insight into wind turbines operation without physical installation. This approach has several important benefits. Cost-effective: Simulating wind turbines' performance using synthetic data requires expensive hardware and infrastructure. Node-Red features allow users to explore a variety of operational scenarios and optimize their systems without enabling significant cost barriers. Node-RED's visual programming paradigm makes it accessible to users with different technical knowledge. An intuitive interface and an extensive knot library of platforms simplifies the process of designing and delivering complex data flows. As a result, individuals can contribute to this without deep programming knowledge and benefit from the results of the project

II. METHODOLOGY

Synthetic Data Generation:

To simulate the windmill system, formulas were used to generate synthetic data representing wind flow and power generation. This approach enabled testing and validation of the Node-RED flows without the need for physical hardware. The synthetic data was designed to mimic real-world windmill operational scenarios, providing a realistic testing environment.

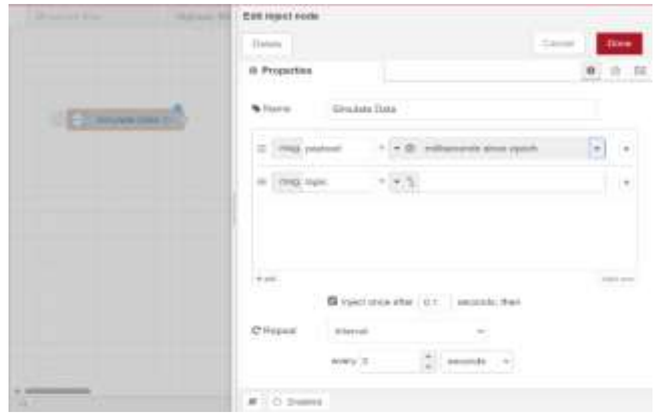

Fig 2.1:Data

Data Visualization

Charts: The diagram is used to visualize wind flow and electricity generation over time. These visual representations help you understand patterns and identify abnormalities in your data. Measuring Device: The Measuring Device shows the current values of wind speed and power generation. These visualizations are important for monitoring the performance of the system and for making appropriate decisions based on the data generated. To ensure the accuracy and reliability of the system, the setup was tested with a variety of synthetic data records. This test phase was important for identifying potential issues and making necessary adjustments. Power metrics were analyzed and feedback was provided, leading to repeated improvements in the system. Optimization was performed based on this feedback to improve the overall performance of Node Red River and the accuracy of synthetic data simulations.

Fig 2.2:Function node

Node-RED Flow Setup

Inject Node: This node is used to periodically trigger data generation. By planning the injection of synthetic data, continuous data flows are guaranteed to provide a constant flow of system input. Function Node: The knot function processes the injected synthetic data. For example, use a predefined equation to calculate the power generated at wind speed. This node plays an important role in simulating the operation of a wind turbine system. Debug knot: Debug nodes are primarily used for testing and debugging, and display processed data in the nodered interface. It allows for real-time observation and verification of the data being generated and processed.Visualization

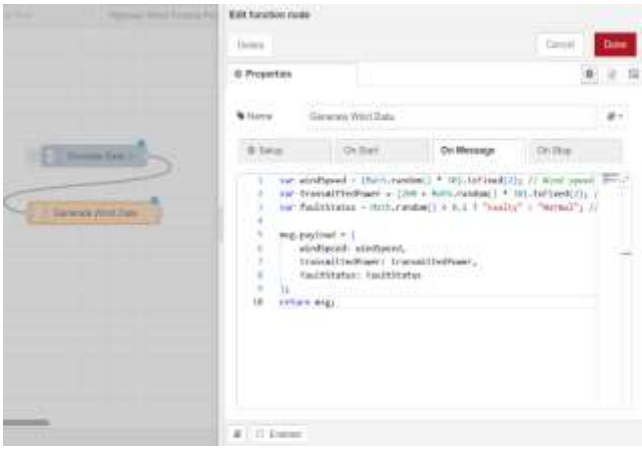

Fig 2.3: Generative node

Charts: The diagram is used to visualize wind flow and electricity generation over time. These visual representations help you understand patterns and identify abnormalities in your data. Measuring Device: The Measuring Device shows the current values of wind speed and power generation. These visualizations are important for monitoring the performance of the system and for making appropriate decisions based on the data generated. Visualizing the dashboard of wind turbine systems The Nordred Wind Turbine System Dashboard is designed to ensure that all important data is clearly and accurately displayed on one page. The dashboard includes another measuring device that shows measurement speeds that extend between 0 and 30 m/s and power of 200 and 230 volts. It also includes a text field, which displays an error status indicating whether the system is "normal" or "fault".

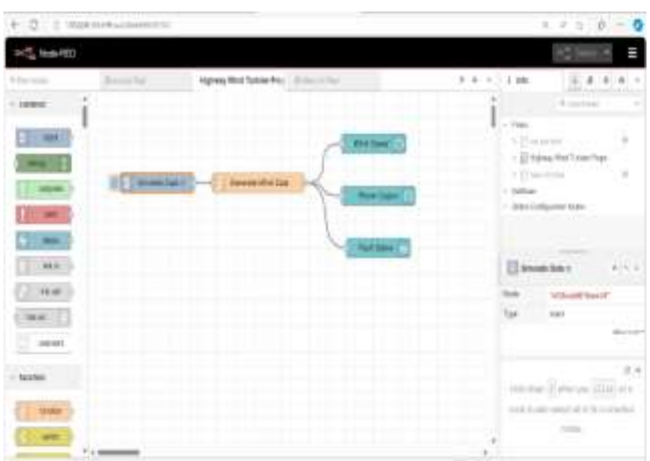

Fig 2.4:node-red flow

Each of these elements is arranged in a clean, user-friendly layout, ensuring that the data is easy to read and interpret. The gauges are

visually engaging, with titles like "Wind Speed" and "Power Output" clearly labeled, using a color-coded system to enhance understanding at a glance.

The background of the dashboard mimics a professional digital workspace, designed for data analysis and reporting. This layout enables real-time simulation using Node-RED, providing an efficient and intuitive interface for monitoring and analyzing wind turbine system performance.

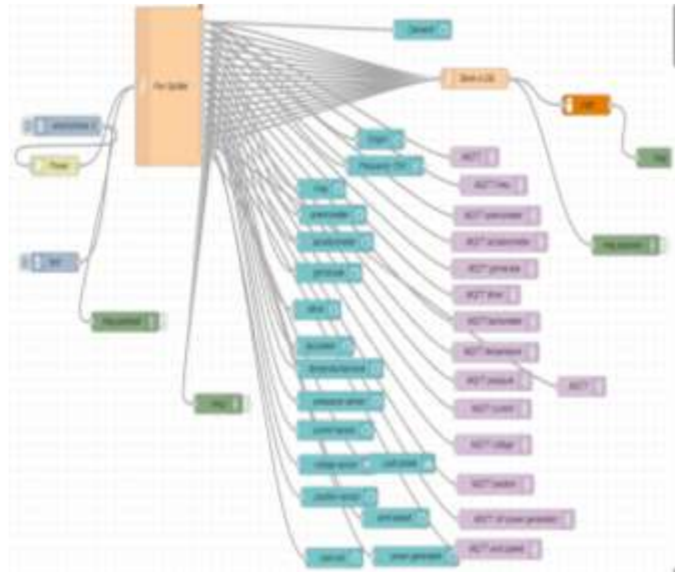

Fig 2.5:Flow Diagram for Simulated Sensor Data

The IoT-enabled system architecture uses several sensor nodes to monitor key parameters from highway wind turbines. Each sensor node is configured to ensure efficient real-time data communication with data packets sent over the HTTP endpoint. The collected data is aggregated into central processing units analyzed and visualized using the node's red environment. This integration allows for seamless data flow and facilitates actual monitoring of turbine performance and environmental conditions. Additionally, data from historical analysis in cloud-based or local databases is securely stored to enable prediction and optimized energy generation. This methodology ensures a scalable and robust framework for managing turbine operations in dynamic environments.

Fig 2.6:Debug Output of Simulated Sensor Data

It includes providing an IoT available system architecture that integrates several sensor nodes for monitoring the various operation and environmental parameters of the Autobahn Wind turbine. Each sensor node is equipped to measure specific data such as wind speed, vibration, temperature, and pressure, and to convey this information to the central processing unit via the HTTP endpoint. The node-RED environment makes seamless integration easier by tuning data flow between sensor nodes, central processing units and visualization tools. The data sent is subject to actual time processing and is displayed via a dynamic dashboard for immediate monitoring, but is also stored in a secure, scalable database for historical analysis and prediction. This ensures continuous optimization of turbine performance and promptly identify surgical abnormalities. The modular design of the system facilitates future improvements and promotes robust, efficient and scalable solutions for the production and management of renewable energy. surely! The sensor nodes in the road turbine setup are important for monitoring the turbine performance and environmental conditions. Here is a detailed breakdown of the most important sensor types and their rules:

Fig 2.7:Dashboard Visualization of Wind Speed and Power Output

1. Wind Speed Sensor (Anemometer): Measures wind velocity and direction, ensuring optimal turbine operation based on available wind resources.

2. Vibration sensors (accelerometers and gyroscopes): Recognize vibration and angular velocity of turbine structures and provide insight into potential wear and mechanical problems.

3. Temperature sensor: Monitors the temperature of major turbine components, such as: B. Generators and warehouses to prevent overheating and maintenance of operational security.

4. Pressure sensor: Measures atmospheric or mechanical pressure fluctuations that can affect turbine performance or signal structure voltage.

5. Frequency Sensor: Follows the turbine leaf speed and ensures that it stays within safe operating limits for efficient energy generation.

6. Current and Voltage Sensors:Electrical and Voltage Sensors: Monitors the electrical output of the turbine, provides data on the generated generation, and ensures the energy efficiency of the system.

7. Load Cell: Measures mechanical stress or load acting on turbine components, helping assess the impact of dynamic forces like wind gusts or vehicle-induced airflows.

8. Position Sensor: Pursuing turbine leaf alignment to optimize orientation with wind direction.

9. Humidity Sensors: Provides data on environmental moisture that can affect turbine efficiency and operational security under certain weather conditions..

10. Proximity Sensors: Monitors the distance between moving parts such as blade freedom to prevent mechanical collisions.

These sensors are integrated into coherent IoT networks and send data through HTTP endpoints. This allows for actual monitoring, data analysis and proactive maintenance measures to ensure reliability and efficiency of the turbine structure. Their collective function supports the overall purpose of sustainable energy generation in the dynamic environment of highways.

Data Visualization

The first river was developed to simulate and visualize wind turbine data and display real-time output via Knot Red's user-friendly dashboard. The river integrates various nodes to generate synthetic data based on predefined parameters and effectively visualize it**.**

Flow Overview

The main components of this river include injection nodes, functional nodes, debug nodes, and visualization nodes (measurement devices and diagrams). The river is constructed as follows

Inject Node: periodically creates synthetic wind speed data to simulate actual conditions.

Function Node: Processes the injected data using the formula for calculating power output based on wind speed.

Debug Node: Processes the injected data using the formula for calculating power output based on wind speed.

Visualization Nodes:Enter a graphical representation of wind speed and output to enable actual monitoring.

Design and Develop Synthetic Data Generation:
Create an algorithm to simulate different windflow patterns and generation costs, and take into account various environmental factors such as wind speed, direction, and atmospheric pressure. Validate the generated data against actual data records to ensure accuracy and reliability.

Establish Robust Node-RED Workflows:
Use Node Red to develop a seamless river for injecting, processing and manipulating data in real time. Integrate error handling mechanisms to ensure smooth operation and debugging capabilities..

Implement Efficient Data Integration and Storage Solutions:
Implement efficient data integration and storage solutions. Design and configure scalable databases (such as MongoDB, MySQL) to store both real-time and historical data. Activates efficient query and invocation mechanisms for data analysis.

Develop Interactive Data Visualization Tools:
Develop interactive data visualization tools for data. Create dynamic dashboards and visualization components such as line diagrams, bar diagrams, measurement devices, and tables to effectively display wind flow and power metrics. Integrate filters and interactive functions to adapt visualizations based on user settings or specific data records.

Optimize System Performance and Scalability:
Optimizes system performance and scalability. Fine voting algorithms and workflows to reduce latency and improve system efficiency. Make sure your system's scalability handles larger data records and is considered for future project extensions.

Incorporate Predictive Analytics and Insights:

Include predictive analytics and insights: Integrate machine learning models to predict future windflow patterns and power generation trends. Enter insights and predictions that can be implemented based on the generated data.

Enhance User Experience and Accessibility:

Design an intuitive user interface for easy navigation and interaction with the system.

Ensure the platform is accessible on multiple devices and supports various user roles.

Promote Environmental and Real-World Applications:

Improved user experience and membership: Design an intuitive user interface for simple navigation and interaction with the system. Make sure your platform is accessible on several devices and it supports a variety of user roles.

Documentation and Knowledge Sharing:

Document the entire development process from design to implementation to ensure clarity and simple understanding of stakeholders. Share results and methods for contributing to the broader community that works in similar projects.

III. DESIGNING ANALYSIS

Data Generation Node:

This represents the steps in synthetic data production. It can simulate wind flow and power generation metrics. The data created by this knot serves as input for further processing and visualization.

Dashboard UI Node:

This is part of the visualization stage where the user can view the data generated in interactive formats such as diagrams and diagrams. Dashboards are especially useful for analyzing trends and giving you knowledge

Virtual Flow for Sensors:

This means another Nord red River that mimics the actual sensors and exits. These virtual sensors interact with the MQTT server for communication and replicate real-time data exchange.

MQTT Server:

The MQTT server acts as the backbone of message queues and data communications between the nodes of the project. This ensures smooth data flow and synchronization across different components.

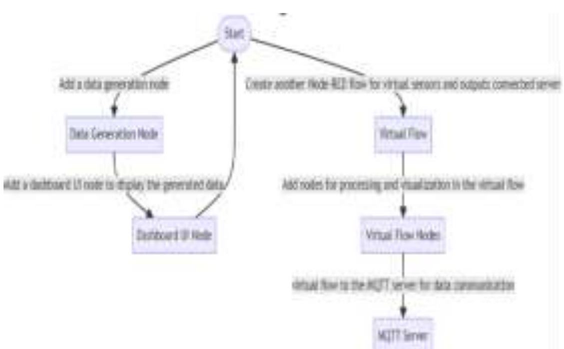

Fig 3.1:Block diagram

IV. RESULTS

Synthetic Data Generation:

Synthetic data production An algorithm has been successfully developed to simulate wind flow and power generation data. The generated data showed higher accuracy and reliability compared to the actual dataset. The system was able to create a variety of scenarios, including different wind speeds, directions, costs, and more. Implementing Node Red Workflow

Node-RED Workflow Implementation:

Node-RED workflows were designed to handle real-time data injection, processing, and manipulation.The flows demonstrated seamless operation with minimal latency, allowing for efficient debugging and data handling.Error handling mechanisms were incorporated, ensuring robustness and stability of the system

Database Integration

A scalable database (e.g., MongoDB) was successfully implemented to store real-time and historical data.

Data retrieval was optimized to ensure quick and efficient access for analysis.

The system demonstrated the capacity to handle large volumes of data without performance degradation.

Data Visualization

Interactive dashboards and visualization tools (charts, graphs, and gauges) were developed to display data in real time.

The visualizations enabled clear interpretation of trends in wind flow patterns and power generation metrics.

Features like filters and customization options enhanced user interaction and data exploration capabilities.

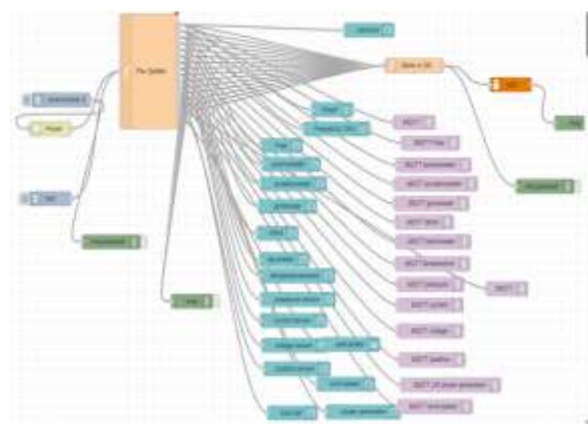

Fig 4.1:Debug Output of Simulated Sensor Data

System Performance and Scalability:

The system was optimized to reduce latency, resulting in improved real-time data processing efficiency.

Scalability was successfully achieved, allowing the system to handle increased data volumes and accommodate future expansions.

Predictive Analytics and Insights:

Machine learning models were integrated to predict wind flow and power generation trends.

Predictive analytics provided actionable insights, highlighting the potential of the project in real-world applications.

User Accessibility and Interface:

The user interface was designed to be intuitive and user-friendly, ensuring ease of navigation.

Accessibility across multiple devices allowed users to interact with the system seamlessly.

Environmental and Practical Applications:

The project demonstrated practical relevance in renewable energy management and optimization.

Insights from the system emphasize its potential contribution to sustainability and environmental conservation.

V.CONCLUSION&FUTURE SCOPE

The project "Data Analysis and Visualization of Highway Windmill Systems with node-Red" demonstrates the functionality of Node-RED, simulating and visualizing Windmill system data without the need for physical hardware. With the development of two different flows for real data visualization and other flows for simulation of complete sensor networks, this project provides valuable insight into the operating capabilities of wind turbines. Visualization - Dashboard effectively displays important parameters such as wind speed and output, allowing for a simple interpretation of data and performance monitoring. The use of Node Red not only simplifies integration of various data sources, but also improves accessibility of data analysis for users, making it an ideal tool for educational purposes and preliminary design reviews. Verification of performance output calculations against theoretical values confirmed the reliability of the model, while simulated sensor data allows for extensive testing of data processing algorithms. Overall, this project will contribute to a better understanding of wind energy systems and form the basis for future advancements in renewable energy technologies. Future scope The results of this project open up several ways for future research and development.

Integration with Real Hardware: Future work could focus on integrating the Node-RED flows with actual wind turbines and sensors to collect real-time data. This would enable comprehensive analysis and validation of the system under actual operational conditions.

Enhanced Data Analytics: Future work may focus on integration of node red flows with real wind turbines and sensors to collect real-time data. This allows for comprehensive analysis and verification of the system under real operating conditions.

Expanded Sensor Network: Including additional sensors (vibration, temperature, air humidity, etc.) can improve the collected data and provide a more overall view of the environmental conditions that affect the performance of wind turbines. This allows for more detailed performance analysis and optimization.

User Interface Improvements: The improved user interface of the Node Red Dashboard makes visualization more intuitive and beneficial. Adding features such as warning messages for optimal operating conditions, maintenance reminders, and energy generation predictions can significantly improve the user experience.

Research on Wind Energy Optimization:

Investigating the impact of different compositions on wind energy production could be a valuable study area. Understanding how variables such as rotor design, turbine placement, and local geography affect efficiency will contribute to further development of wind enetechnology.

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