International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6s
DOI: https://doi.org/10.17762/ijritcc.v11i6s.6950
***Article Received**: 27 March 2023 **Revised**: 15 May 2023 **Accepted**: 24 May 2023*

A Complete Design of Smart Wind Farm Enriched with Novel Anemometer

K. Revathi[1], T. Tamilselvi[2], W. Gracy Theresa [3], M. Dhivya[4]
[1]Department of Computer Science and Engineering,
Panimalar Engineering College,
Chennai, India - 600123
neyadharshini@gmail.com
[2]Department of Computer Science and Engineering,
Panimalar Engineering College,
Chennai, India - 600123
tamilselvime@gmail.com
[3]Department of Computer Science and Engineering,
Panimalar Engineering College,
Chennai, India - 600123
gracypit19@gmail.com
[4]Department of Computer Science and Engineering,
Panimalar Engineering College,
Chennai, India - 600123
dhivyachweetu@gmail.com

Abstract— Renewable energy are endless and environment friendly sources of power production and also it is considered as the alternative of non- sustainable energy sources like coal, fossil fuels and nuclear power. Wind Energy is accounted as one of the fast depleting, pollution free energy source compared to hydro power and thermal power. Internet of Things (IoT), which is a wireless, self configuring network of sensors powered with communication facility promotes the facility of remote monitoring and control activities in smarter way without human intervention. Likewise machine learning is another technological giant offers accurate prediction over the voluminous data and imposes intelligence to the machines kept for operation. The primary objective is to develop an IoT based wind farm module that enables installed capacity identification, structural monitoring and scope for power generation in that locality.

Keywords- deep learning; internet of things (IoT); renewable energy sources; sustainability; wind power.

I. INTRODUCTION

In order to fulfill the growing energy demand, the renewable energy sources gained attention towards it. These are sustainable energy sources and facilitates an alternative solution other non-sustainable energy sources such as coal, fossil fuel and nuclear power. Among various sustainable energy elements like biomass, geothermal, hydro, solar and tidal, wind energy is accounted as one of the fast depleting, pollution free energy source [1]. Wind power energy association of America in its recent survey made by 2019, the wind energy is positioned first as because it's a no-emission energy source.

Our country ranked fourth in the highest wind power installed capacity. The government of India leverages tax and ready to waive few percentages in the total cost of new wind farm installation project. In general, wind farm installed with wind turbines converts the mechanical energy into an electrical energy. The size of the wind farm depends on the number of wind turbines and its coverage of distribution. There are two types of wind farms commonly known as onshore and offshore. The challenges associated with wind farm are,

- Identifying the potential location for installation
- Maintaining the equipment health of the wind mill
- Forecasting the energy production accurately

With the help of modern technologies, it is possible to address the above mentioned challenges related to wind park. The primary objective of the proposed work is to provide complete solution to wind park issues listed above.

According to the information observed from the Ministry of New and Renewable Energy, Government of India, our country is positioning fourth place in the highest wind installed capacity. The statistical report on 31st March 2019, India generated 35.6 GW and produced 52.66 billion units (BU) in the duration of 2017-2018. Tamil Nadu contributed 33799.65 MW power generations all over the India and it has the installed capacity in locations like Gudimangalam, Kayathar, Kanyakumari and Tripur. The government is continuously encouraging the projects in this streamline to effectively

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6s
DOI: https://doi.org/10.17762/ijritcc.v11i6s.6950
***Article Received**: 27 March 2023 **Revised**: 15 May 2023 **Accepted**: 24 May 2023*

identify potential areas for installation and boost up the accumulated power generation [2].

In order to serve the need for wind power generation in Tamil Nadu, the proposed system attempts to facilitate smart wind farm design which forecasts energy production by calculating the wind energy parameters such as its speed, direction including the turbine characteristics like blade and rotor specification. The proposed model also uses deep learning techniques to predict promising power generation capacity in that area in near future as short term as day wise. The characteristics of the smart wind farm design are as follows:

- Accuracy
- Access friendly
- Environment friendly
- Faster
- Reliable
- Secure

The article's remaining sections are organized as follows: The related research done in this field was examined in section 2. Additionally, the research gap and real-world applications are noted. The architecture of the IoT based wind farm is described in section 3. The deep learning classifier is further developed. Section 4 discusses the classifier's performance, and Section 5 concludes the study.

II. LITERATURE REVIEW

In this section, remarkable contributions made by various researchers in obtaining effective solutions to wind farm are detailed.

A. Related Work

Lina Alhmoud et al. [3] proposed an IoT application to improve the reliability issues related to wind turbines. He conducted literature survey to bring difference between IoT and cyber physical systems, to obtain the various hardware and software platforms for the successful implementation, also provided the scope for wind energy conversion system (WECS) in near future. In order to enable sustainable operation of the wind farm, it is necessary to maintain the reliability of the wind turbine. The proposed model developed an IoT device to monitor the quality of the turbines integrating fog computing with Thingspeak cloud service.

Mohammed Noor-A-Rahim et al. [4] contributed their significant effort in ensuring the reliability of wind turbine state by devising an IoT based communication framework. The framework attempted to facilitate reliable wireless connection exists between sensory network of turbines and control center using a fusion algorithm. Further it designed a repeat-accumulate mode of communication to ensure reliability.

Ersin Akyüz et al. [5] devised a cloud assisted IoT prototype to enable remote monitoring of wind turbines. The proposed work selected the wind speed, direction, voltage and battery current as its primary attributes and the acquired data are collected through a data logger designed for it. Furthermore Microsoft Azure which is a cloud platform availed the storage and analysis functions for the system. It utilized the Power BI software to project the results in a more appealing manner over mobile devices. Edison prabhu et al. [6] proposed IoT enabled fault diagnosis system for wind turbines by placing the relevant sensors over the blade, bearing, generator and rotor to assess its healthiness.

Fran lizza et al. [7] designed an IoT based remote monitoring solution to assess the status of the wind turbines. The proposed model utilized the universal asynchronous receiver/transmitter (UART) to bridge between IoT device and control relay. The significant efforts for an IoT based wind mill monitoring to diagnosis the fault are captured [8-12].

Stanly Wilson and Kirubanand [13] addressed the data collection strategies for wind turbine management. The IoT based energy management system for wind employing microgrids was inherently investigated in [14-16]. The significance of wind power system and study on optimizing the power is conducted in [17 & 18].

Kalvagadda Lohit Reddy et al. [20] implemented IoT based wind energy management system with fuzzy logic. Muhammad Shahzad Nazir et al. [21] explored the existing anemometers and it technological characteristics and discussed the scope for ANN based techniques in wind power prediction in his article. It revealed that ANN based approaches were estimated to contribute 38% in forecasting operations, 29% in fault diagnosis, 23% in control activities and 10% in designing forums.

Tayeb Brahimi [22] developed a power prediction module for WECS. In this work, artificial neural network (ANN) algorithms were used to estimate the power generation based on the meteorological data from the Kingdom of Saudi Arabia. When comparing the test results with other artificial intelligence techniques like support vector machines (SVM), random tree and random forest, random tree outperformed the ANN based mechanisms.

Fei Chen et al. [23] designed a sensor fault diagnostic and control system in order to maximize the capacity of power generation in WECS. His work investigated the applicability of deep learning techniques in arriving accurate prediction. The simulation results of this model proved with higher accuracy and efficiency in terms of response time.

Dr. A. K. Parvathy from Hindustan Institute of Technology and Science contributed significant effort in obtaining real time energy management mechanisms deployed under smart home environment through optimizing the cluster of prosumers.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6s
DOI: https://doi.org/10.17762/ijritcc.v11i6s.6950
Article Received: 27 March 2023 Revised: 15 May 2023 Accepted: 24 May 2023

B. Research Objectives

The primary objectives are as follows:

1. To build smart wind farm module employing appropriate sensors as IoT edge devices
2. To predict and monitor the health of the installed wind turbine remotely
3. To enable short term wind power prediction over the data observed with IoT module empowering with deep learning mechanisms.

III. PROPOSED SYSTEM

The modules for implementing the suggested system are broken down and covered in more detail below.

A. Obtaining a novel design of anemometer

The proposed system is to promote the power of existing WECS by regular monitoring of the wind turbines and predicting the power generation in advance with the help of a promising design of anemometer with low energy consumption. The popular anemometers in market and proposed as prototypes along with its characteristics are presented as table 1 as below.

TABLE I. TECHNOLOGICAL CHARACTERISTIC'S OF EXISTING ANEMOMETERS

Anemometer	Wind Speed	Wind Direction	Range (m/s)	Standard
Cup type	Yes	No	4-75	Yes
Wind Vane	No	Yes	0-360	Yes
Hot Wire	Yes	No	0-200	No
Pressure Sphere	Yes	Yes	50-200	Not on Market

With the influence obtained from existing efforts towards anemometer design, the proposed work decided to design a novel compact sensor which measures the both wind speed and direction together. To attain speed and direction of the wind with ultra-low level energy consumption, a 6-axis accelerator or gyroscope is elected and the same encapsulated within a spherical surface. Thus the novel anemometer determines the wind speed based on the accelerations of the sensor surface. The predominant components of the proposed anemometer are BMI270 IMU accelerator, a 3D printed spherical sensor case, the mounting structure and the same is projected as Figure 1.

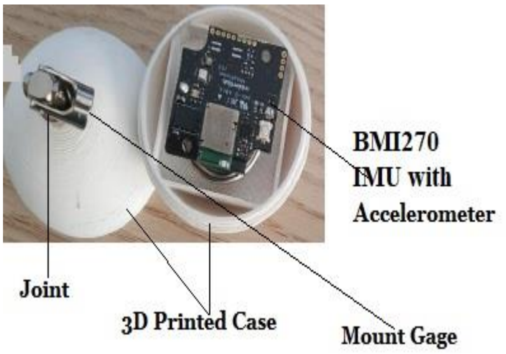

Figure 1. Cut-through view of novel anemometer.

In connection with wind speed calculation, the wind force applied over the sensor is to be determined. The wind speed can be calculated by measuring the wind force exerted on the sensor case and the formula to obtain the same is given as equation1.

$$F(t) = \frac{1}{2}\mu\rho A V(t)^2 \quad (1)$$

Where F(t) – Wind force; A- Area of the contact surface; μ – geometry shape of the surface; ρ – Density of the air which is a constant value 1.226 kg/m; V(t) – Speed of wind with time. Further the expressions with respect to forces over the degree of freedom (DOF) of the surfaces are expressed as equations 2 and 3 respectively.

$$F_x(t) = F(t)\cos(\theta(t)) \quad (2)$$

$$F_y(t) = F(t)\sin(\theta(t)) \quad (3)$$

The effect of accelerations over the DOF of sensor surface is portrayed as figure 2 and the relevant notations to capture the change of accelerations as equations 4 and 5 respectively.

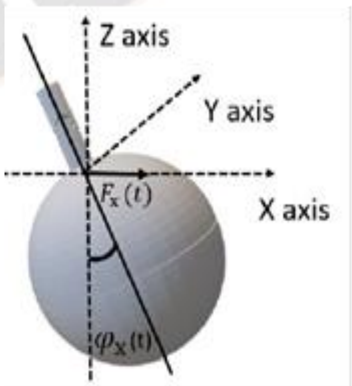

Figure 2. Wind speed analysis with x-axis of the sensor surface.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6s
DOI: https://doi.org/10.17762/ijritcc.v11i6s.6950
***Article Received**: 27 March 2023 **Revised**: 15 May 2023 **Accepted**: 24 May 2023*

Finally, the wind speed calculation ascertaining the above mentioned contribution is given as equations (6) and (7) as follows.

$$V(t)^2\cos(\theta(t)) = \frac{2}{\mu\rho\, Al_1\cos\left(\sin^{-1}\left(\frac{Ax(t)}{g}\right)\right)}\left[I\frac{d^2\left(\sin^{-1}\left(\frac{Ax(t)}{g}\right)\right)}{dt^2} + ml_2A_x(t)\right] \quad (6)$$

$$V(t)^2\sin(\theta(t)) = \frac{2}{\mu\rho\, Al_2\cos\left(\sin^{-1}\left(\frac{Ay(t)}{g}\right)\right)}\left[I\frac{d^2\left(\sin^{-1}\left(\frac{Ay(t)}{g}\right)\right)}{dt^2} + ml_2A_y(t)\right] \quad (7)$$

B. Developing a IoT prototype for smart wind farm

An IoT based prototype for the proposed WECS is illustrated as Figure 3.

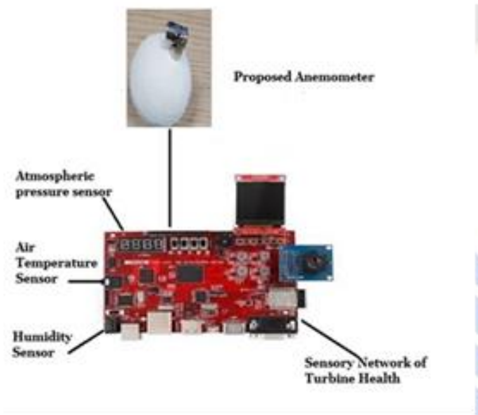

Figure 3. The proposed IoT prototype for wind farm.

It is designed by carefully deriving the significant attributes contributing the real time monitoring and power generation module of the wind farm. The proposed prototype enriched with the compact anemometer developed in this previous module for determining the wind speed and direction effectively instead of deploying relevant sensor available in the commercial market. Simply by integrating all the sensors, establishing a communication among the same for data exchange enables the working prototype of the proposed smart wind farm.

C. Accommodating deep learning practices

The previous attempts clearly envisioned that in the process of predicting wind power, the ANN based approaches were utilized. The deep learning algorithms like convolutional neural network (ConvNets / CNN) gained attention recently because of its efficiency in mapping historical and time series data within a minimal execution time period. The steps in CNN proposed for predicting wind power is depicted as Figure 4.

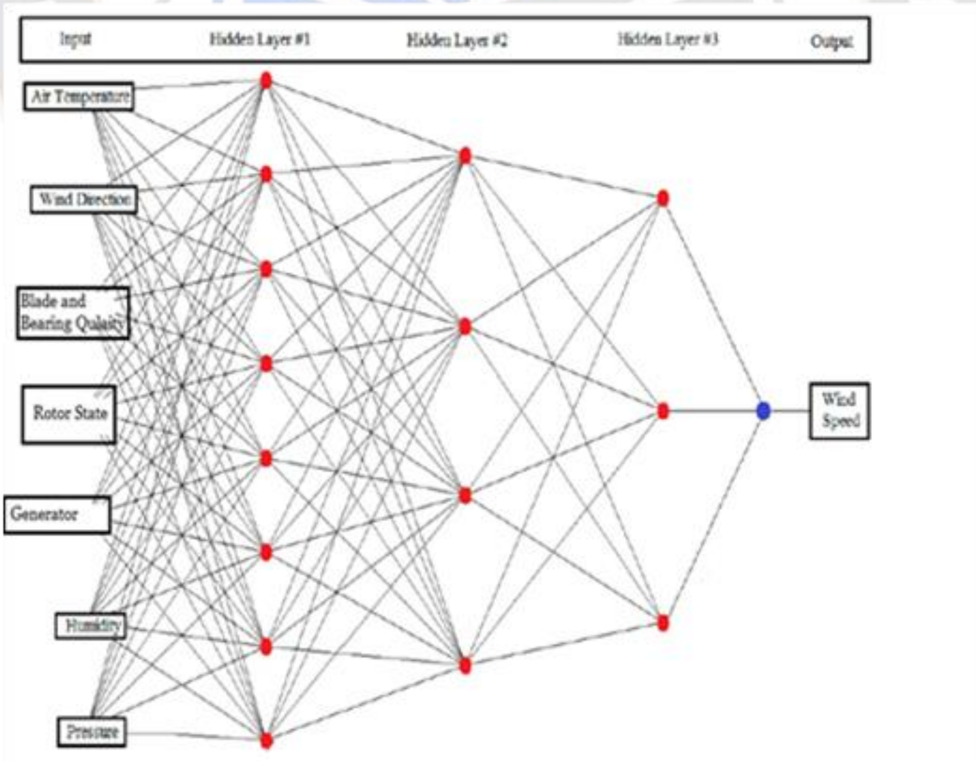

Figure 4. Steps in CNN for forecasting wind power.

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6s
DOI: https://doi.org/10.17762/ijritcc.v11i6s.6950
***Article Received**: 27 March 2023 **Revised**: 15 May 2023 **Accepted**: 24 May 2023*

Furthermore to improve the performance the cuckoo optimization algorithm is applied herewith. The Cuckoo Search Algorithm (CSA) has been used in various areas to optimise the solution in accordance with the statistical data. Image processing, pattern recognition, software testing, data mining, cyber security, cloud computing, Internet of Things, etc. are some of the main areas where CSA implements.

A recently created meta-heuristic optimization approach called Cuckoo Search is employed to resolve optimization issues. This meta-heuristic algorithm, which draws inspiration from nature, is based on Levy flights random walks and the brood parasitism of some cuckoo species. The process flow of cuckoo optimization is presented as Table 2.

TABLE II. ALGORITHMIC STEPS IN CUCKOO OPTIMIZATION

1:	Initialize habitats of cuckoo by assigning random values to profit function
2:	Dedicate some eggs to each cuckoo
3:	Estimate ELR for each cuckoo as in Equation (8)
4:	Let cuckoos to lay eggs within the ELR limit
5:	Kill those eggs that are recognized by host birds
6:	Let eggs hatch and chicks grow
7:	Evaluate the habitat of each newly grown cuckoo
8:	Limit cuckoos' maximum number in environment and kill those who live in worst habitats
9:	Cluster cuckoos and find best group and select goal habitat
10:	Let new cuckoo population immigrate toward goal habitat
11:	If condition is satisfied stop, else go to step 2

To obtain the egg laying radius (ELR) which is ration of the total number of eggs laid and number of eggs available at present scenario, first set the maximum and minimum limit of egg laying capacity of the cuckoo like Var_{max} and Var_{min} respectively with α - a numeric value used to adjust the maximum limit of ELR. The mathematical notation to calculate the ELR is expressed as equation 8.

$$ELR = \alpha \times \frac{Number\,of\,current\,cuckoo's\,eggs}{Total\,number\,of\,eggs} \times (Var_{Max} - Var_{Min}) \quad (8)$$

IV. RESULTS AND DIXCUSSION

This portion goes into great detail about the execution environment, significant performance measures that demonstrate the effectiveness of the proposed deep learning model, and the assessment results.

A. Execution Platform

The performance of the proposed deep learning model is assessed using the Tensor Flow 2.0 execution environment. It was developed as an open source by Google. Developers have favored it as a solution because it is so easily available. The system requirements to conduct deep learning experiments in the Tensor Flow environment are outlined in Table 3.

TABLE III. SYSTEM REQUIREMENTS

Software Requirements	Hardware Requirements
Microsoft Visual C++ Redistributable pip 19.0 Python 3.5 Raspbian 19.0 Windows 10	Central Processing Unit (CPU) : Intel Core i7-2.9Ghz Graphics Processing Unit (GPU) : NVIDIA GTX 1050 Ti with 4 GB RAM

B. Performance Measures and Evaluation Results

The performance metrics used to observe the proposed CNN with cuckoo optimization are root mean square error (RMSE) and mean absolute error (MAE) and the same determined by accounting actual wind speed V_i^{act} and predicted speed V_i^{pred}, also are represented as equations 9 and 10.

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left(V_i^{act} - V_i^{pred}\right)^2}. \quad (9)$$

$$MAE = \frac{1}{N} \sum_{i=1}^{N} \left|V_i^{act} - V_i^{pred}\right| \quad (10)$$

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 6s
DOI: https://doi.org/10.17762/ijritcc.v11i6s.6950
Article Received: 27 March 2023 Revised: 15 May 2023 Accepted: 24 May 2023

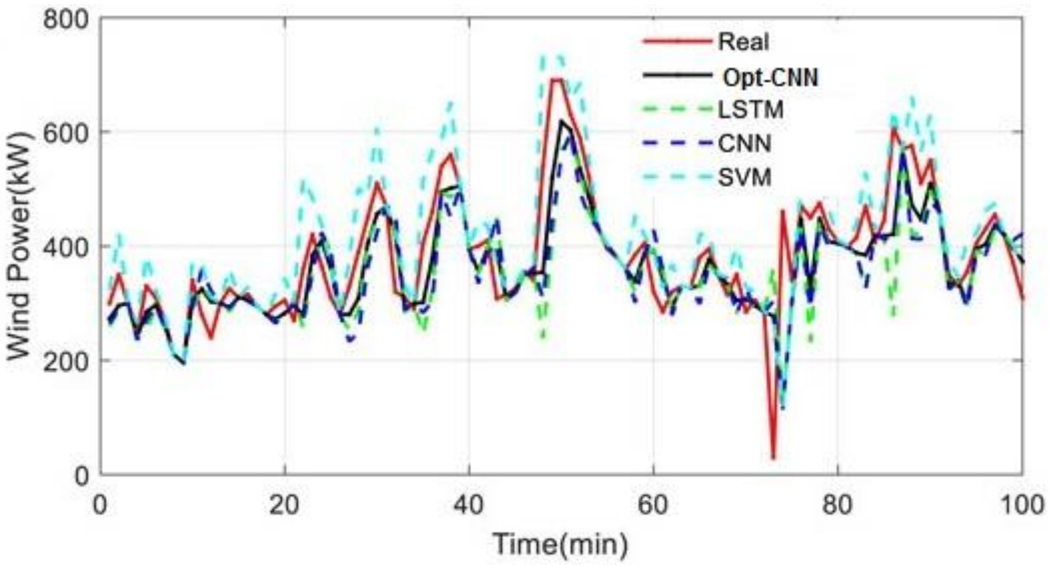

Figure 5. Comparative analysis of wind energy prediction against proposed deep model.

The proposed model (CNN with Cuckoo Optimization) is evaluated against important machine learning techniques such as CNN, LSTM, and SVM. The major objective is to assess how close the model's predictions come to the actual values that were observed. As a result, a high RMSE is "bad" and a low RMSE is "excellent". The difference between the observed and anticipated values is represented by the residual in the formula. The mean squared error (MSE) is the sum of all squared residuals. The measure is then reset to the scale of the response variable by taking the RMSE's square root. The most accurate graphic representation of the many techniques used to estimate the classifier for wind energy prediction is shown in Figure 5. It is clear that the proposed model is meant to yield better results than existing methods utilized for comparative analysis. The findings make it abundantly evident that the proposed deep model (Opt-CNN) was judged to have a relatively small error rate, one that ranges from 0.3 to 0.5 at best.

V. CONCLUSION

Without relying on conventional fuel technology, wind power has a significant potential to provide green energy. In order to prolong the lifespan of their electro-mechanical elements, wind turbines require routine, proactive maintenance. In this work IoT prototype for smart wind farm is discussed. Moreover, a novel anemometer design and its efficacy are elaborated. After completing the required pre-processing activities, such as cleaning, noise removal, and feature extraction, the selected dataset is ready for classification. In order to wind energy, a deep learning system an optimized CNN is then applied to the data. It lists a 98.72% accuracy rate. The model's predicted error rate is discovered to be less than 0.5, indicating that it is a "good" model.

For further deep learning model realization over the beneficiaries, a mobile application can be created.

ACKNOWLEDGMENT

There are no funding sources.

AUTHORS CONTRIBUTION

Author 1: Ideation, Drafting and Experimentation
Author 2: Drafting and Supervision
Author 3: Experimentation and Supervision
Author 4: Drafting

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

[1] J. Charles Rajesh Kumar and Majid, M. A., "Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities", Energy, Sustainability and Society, vol.10, no.2, pp.1-36, January 2020, https://doi.org/10.1186/s13705-019-0232-1.

[2] PIB- Delhi, "Year End Review – 2022", Ministry of New and Renewable Energy, https://pib.gov.in/PressReleasePage.aspx?PRID=1885147, Published on 20 Dec 2022.

[3] Lina Alhmoud and Hussein Al-Zoubi, "IoT Applications in Wind Energy Conversion Systems", Open Eng, vol.9, pp. 490-499, Nov 2019, https://doi.org/10.1515/eng-2019-0061.

[4] Md. Noor-A-Rahim, M. O. Khyam, Xinde Li and Dirk Pesch, "Sensor Fusion and State Estimation of IoT Enabled Wind

Energy Conversion System", sensors-MDPI Journal, vol.19, no.1566, pp.1-13, Apr 2019, https://doi.org/10.3390/s19071566.

[5] Ersin Akyüz and Batın Demircan,"IoT and Cloud Based Remote Monitoring of Wind Turbine", Celal Bayar University Journal of Science, vol.15, no.4, pp. 337-342, Dec 2019, DOI:10.18466/cbayarfbe.540812.

[6] K. Edison Prabhu and A. N. Sanoofar, "Implementation of IOT for Real Time Monitoring and Fault Diagnosis of Wind Turbine", International Journal of Recent Trends in Engineering & Research, pp.288-292, April 2018, doi 10.23883/ijrter.conf.02180328.055.ksmlf .

[7] M. Fran Lizza, S. Anitha and R. Raj Mohan, "IoT Based Wind Turbine Monitoring, Fault Diagnosis and Control Using UART", vol. 3, no. 8, pp. 72-79, April 2017.

[8] S. K. Reddy, S. Kumar and V. K Gupta, "IoT-Based Framework for the Management of Wind Farms and Microgrids", IEEE Access, vol. 9, pp. 12947–12958, 2021.

[9] Long Zhao, Yuhao Zhou, Igor Matsuo, S K. Korkua and Wei-Jen Lee, "The Design of a Holistic IoT-Based Monitoring System for a Wind Turbine", In Proc. of 55th Industrial and Commercial Power Systems Technical Conference (I&CPS), Calgary, AB, Canada, 2019, pp. 1-7, doi: 10.1109/ICPS.2019.8733375.

[10] M. R. Hema, K. N. Harshitha, G. Swathi and S. A. Sumiya Taj, "Remote Monitoring and Diagnosis System For Wind Turbine Using IOT", Journal of Emerging Technologies and Innovative Research (JETIR), vol. 5, no. 5, pp. 49-51, May 2018.

[11] Y. Li, J.Qian, W. Wang and X. Yuan, "Optimal Power Management of Wind Turbine Microgrid Using IoT-Based Control", Int. J. Electr. Power Energy Syst., vol. 130, no. 107001, 2021.

[12] Vishal Kumar Singh, B. C. Mallikarjun, Rishav and , "IOT based Windmill Monitoring System", International Journal of Engineering Research & Technology (IJERT) , vol. 6, no. 13, pp.1-4, 2018.

[13] Stanly Wilson and V.B. Kirubanand, "Wind Turbine Data Collection using IoT", International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 9, no. 2, pp. 3563-3566, Dec 2019, DOI: 10.35940/ijitee.B6331.129219.

[14] J. Zhang and X. Zhang, "IoT-Based Energy Management System for Wind Energy Microgrid", Int. J. Energy Power Eng., vol. 8, pp. 36–44, 2019.

[15] Shengqing Li , Srikanta Patnaik and Jianqi Li, "IoT-Based Technologies for Wind Energy Microgrids Management and Control", electronics, vol. 12, no.1540, pp. 1-7, March 2023, https://doi.org/10.3390/ electronics12071540.

[16] Dipta Voumick, Prince Deb and Mohammad Monirujjaman Khan, "Operation and Control of Microgrids Using IoT (Internet of Things)",Journal of Software Engineering and Applications, vol. 4, no. 8, pp. 418-441, Aug 2021, DOI: 10.4236/jsea.2021.148025.

[17] Michael Lanre Adekanbi, "Optimization and digitization of wind farms using internet of things: A review", International Journal of Energy Research, pp. 1-7, May 2021, DOI: 10.1002/er.6942.

[18] FenZhou XupingTu and QingdongWang, "Research on offshore wind power system based on Internet of Things technology", International Journal of Low-Carbon Technologies, vol. 17, pp. 645-650, April 2022, https://doi.org/10.1093/ijlct/ctac049.

[19] Nugroho, R. ., Ruliyanta, & Nugroho, E. R. . (2023). Directional Flat Panel Antenna Design for Analog to Digital TV Broadcast Transition in Indonesia. International Journal of Intelligent Systems and Applications in Engineering, 11(1), 63–69. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2444.

[20] Jéssica Alice A. Silva, Juan Camilo López, Cindy Paola Guzman, Nataly Bañol Arias, Marcos J. Rider, Luiz C.P. da Silva, "An IoT-based energy management system for AC microgrids with grid and security constraints", Applied Energy, vol. 337, no. 120904, pp. 1-8, 2023, https://doi.org/10.1016/j.apenergy.2023.120904.

[21] Kalvagadda Lohit Reddy, Dodda Deepthi Reddy, Bhukya Srikanth,Bhukya Lavanya and Dr. K. Shiva Rama Krishna, "IoT based Monitoring for Wind Energy System with Fuzzy & Pid Controller", International Journal of Creative Research Thoughts (IJCRT) vol. 10, no. 6, pp. 1-7, June 2022.

[22] Muhammad Shahzad Nazir, Fahad Alturise, Sami Alshmrany, Hafiz. M. J Nazir, Muhammad Bilal, Ahmad N. Abdalla, P. Sanjeevikumar and Ziad M. Ali, "Wind Generation Forecasting Methods and Proliferation of Artificial Neural Network: A Review of Five Years Research Trend", sustainability-MDPI Journal, vol.12, no.3778, pp. 1-27, May 2020, https://doi.org/10.3390/su12093778.

[23] Tayeb Brahimi, "Using Artificial Intelligence to Predict Wind Speed for Energy Application in Saudi Arabia", energies-MDPI Journal, vol.12, no.4669, pp. 1-16, Dec 2019, https://doi.org/10.3390/en12244669.

[24] Fei Chen, Zhongguang Fu and Zhiling Yang, "Wind power generation fault diagnosis based on deep learning model in internet of things (IoT) with clusters", Cluster Computing, vol.21, no.S1, pp.4013-4025, March 2018, https://doi.org/10.1007/s10586-018-2171-6.