ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar708

Real Time Predictive Diesel Level Monitoring in a Base Transceiver Station to Mitigate Operational Downtime

Ifeoma B. Asianuba[1]; Okeke R. Obinna[2]

[1,2]Department of Electrical/Electronic Engineering, University of Port Harcourt Rivers State Nigeria

Publication Date: 2025/04/08

Abstract: Real-time Diesel Level Monitoring System presents a solution to observe diesel levels at off grid remote base transceiver stations (BTS). Leveraging Internet of Things (IoT) technology, the system employs an Arduino Uno, sensor for data collection, interfaced with a capacitance sensor to measure fuel levels accurately. Additionally, an ESP8266 Wi-Fi module is used to facilitate remote connections, enabling seamless communication between the sensor and a central server. The operational flow is triggered by initializing the hardware, and then collection of data from the relevant sensors. The ESP8266 Wi-Fi module establishes a remote connection, transmitting the collected data to the server. At the server end, the data is received, processed and the information is stored in MySQL database, facilitating efficient retrieval and analysis. The frontend visualization provides a user-friendly interface, displaying real-time diesel level data on a dashboard. Users can interact with the system by predicting fuel levels through the "Predict" feature. This prediction was actualized using the linear regression algorithm to estimate the time left to exhaust the diesel at the BTS site. The system's architecture harmonizes hardware components, server-side processing, and frontend visualization to create an integrated and efficient fuel monitoring solution. The essence of this work can be traced to its ability to reduce down time that may arise due to fuel shortage, improve energy management and enhance operational efficiency at remote BTS sites providing valuable insights for monitoring and managing diesel resources.

Keywords: *Sensors, Real Time Prediction, Diesel Level Monitoring, Wi-Fi Module, Base Transceiver Station, Linear Regression.*

How to Cite: Ifeoma B. Asianuba; Okeke R. Obinna (2025). Real Time Predictive Diesel Level Monitoring in a Base Transceiver Station to Mitigate Operational Downtime. *International Journal of Innovative Science and Research Technology*, 10(3), 2361-2371. https://doi.org/10.38124/ijisrt/25mar708

I. INTRODUCTION

In today's world where seamless communication has become an essential and integral part of our daily lives, base transceiver stations (BTS) serve as a vital telecommunication infrastructure and crucial component for signal propagation. Yet, they operate in regions where the reliability of power supply is far from being optimal and guaranteed.

The BTS is described as a fixed mobile network transceiver that serves as an interconnection between the mobile devices and the network. It propagates radio signals to user equipment and converts the former to digital signals for the network terminals and then the Internet. The epileptic power supply from the mains grid has been a persistent issue, plaguing not only remote regions but also urban and suburban cities. The impact of unstable power supply can cause severe problems on the consistent functioning of BTS facilities. Thus, to counter this unrelenting challenge, alternative source of power ranging from diesel generators, solar, biomass, hydro, wind, etc have been deployed at some stations. The choice of the alternative source depends on the access to the power supply, cost implications, maintenance approach to mention a few.

However, the reliance on diesel to power the generators call for frequent site visits to manage and monitor diesel fuel level in the generating set. This activity can be very challenging and demands precision and foresight. However, the ability to accurately predict when the fuel might run dry or low is pivotal in preventing network disruptions and damages. With the aid of cutting-edge solutions, the efficiency and resilience of BTS facilities can be enhanced, ensuring that they facilitate network connectivity. The storage device is integrated with an interface that enables real-time monitoring and predictive analysis of diesel levels in the BTS generator. By continuously measuring the fuel level, the system will provide valuable insights into the consumption rate, the amount of diesel left and estimate how long it will last. This will help to give operators ample time to plan for refuelling operations and aid them to give near accurate financial plans for fuelling.

The real-time monitoring activity is achieved with the use of sensors installed within the diesel storage tank, to

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar708

provide data on the current volume of fuel. This information will be transmitted to the device's interface, allowing operators to access the data remotely and receive instant updates on the fuel level. The interface will display the real-time measurements in graphical representations for ease of data interpretation.

In addition to real-time monitoring of this system, the system will also leverage the use of predictive analytics to estimate when the fuel volume has reduced to a set threshold. By analysing historical data and considering factors such as generator load, weather conditions, and past consumption patterns. The device will forecast the rate of fuel consumption and project length of time the current volume will last.

The benefits of such a system are rather obvious, as it enables proactive management of fuel resources, ensuring that refuelling operations are planned well in advance to avoid unexpected power disruptions and proper financial planning. This predictive capability also optimizes operational efficiency by preventing the overfilling or underfilling of diesel tanks, reducing costs and minimizing downtime.

By combining real-time monitoring with predictive analytics, this device offers operators the ability to make informed decisions regarding refuelling operations, ultimately enhancing the reliability and performance of the BTS generator.

The BTS scenario under consideration is made to rely on diesel generators to supply electricity for optimum performance to avoid problems of sudden power outage from power grid or lack of access to power grid lines.

Traditionally, monitoring the diesel levels in BTS generators has been a manual and time-consuming process. Operators often rely on visual inspections or periodic manual measurements, which are prone to human error and delays in detecting fuel shortages and these BTS could be at remote areas with difficult access to allow for regular checks. This reactive approach can lead to unexpected fuel depletion, causing power outages and inconveniences to end-users.

The real-time monitoring of diesel levels allows operators to have instant visibility into the current volume of fuel in the storage tank. This information can be transmitted to a centralized interface accessible remotely by operators, enabling them to monitor the fuel level from anywhere and at any time. Such a system provides valuable insights by allowing operators to plan refuelling operations proactively.

II. REVIEW OF RELATED WORKS

Numerous studies have focused on diesel monitoring and management systems in various industrial applications. Kumar et al. (2018) investigated the development of a remote diesel monitoring system for power generators. The study highlighted the importance of real-time monitoring to ensure uninterrupted power supply and efficient refuelling and similarly in Muhammad Tahir et. Al (2022), the importance of real-time diesel level monitoring was achieved.

Murugesan. et al. (2018) proposed a diesel level monitoring and management system for large-scale telecom towers. The system utilized ultrasonic sensors and wireless communication to provide real-time data on diesel levels, enabling timely refuelling and reducing operational costs.

In the work by Kufel (2016), it was shown that there are three major monitoring layers in a system which include; Environment, Network and Data Collection, Presentation & Alerting layers. A visualized form of the data is presented. The work also shows an alert system is also triggered whenever a threshold is met or overcome. Zanikolas et al. (2003) showed how important it is for sensors to give near perfect readings and/or measurements thus making benchmarks to be placed on systems and the need to improve on these benchmarks. The work further discussed in-depth monitoring procedures for communication systems. Also, in the work by Mingwei Lin et al. (2016), an Experimental analysis was performed to state the need for data coherence where resource status obtained from monitoring and the actual result status has a degree of consistency.

Additionally, Xinghua Qi et al. (2023) presented an innovative idea to optimize energy modelling in power systems. While the paper primarily focused on the performance of renewable energy sources and electric vehicles with respect to the grid structure, its hybrid optimization algorithm may offer valuable insights into optimizing diesel consumption and energy management in remote telecom infrastructure. This approach aligns with the goals of efficient diesel monitoring and management systems for Base Transceiver Stations. In Antonia et al 2015, environmental conditions around a BTS were monitored alongside the energy consumption patterns with respect to traffic load and cooling strategies for the communication infrastructure. Parameters such as temperature, global radiation and noise were considered to achieve energy saving process operation. In Tefera et al 2020, a predictive analysis was carried out to mitigate sudden faults to avoid network collapse, reduced operational cost and guarantee sustained network operation. Failure arising from power system and environmental abnormalies were investigated using recurrent neural network. The work achieved a proactive solution rather a reactive approach. Ahmed et al 2024, considered, a very good network resilience and proactive approach to network maintenance using an integrated deep learning architecture. The work demonstrated a pre-emptive prediction for BTS failures while Tavengwa et al 2023 investigated BTS power system failures using XGBoost algorithm. In Chetan and Baligar 2013, the safety of the BTS was considered to achieve instantaneous notifications of activities that can disrupt the operational condition of the infrastructure. Such activity include theft, operating temperature of the device and surveillance movement. Sharma et al. (2021) implemented a real-time diesel monitoring system for remote BTS sites. The project utilized IoT technologies and predictive algorithms to ensure timely refuelling to minimize downtime. Arnaldo et al. (2018)

conducted research that addressed the issue of measurements conducted for multi-interface of fluid level in the industry. This research study focused on the importance of accurately measuring the levels and interfaces of different fluids, including oil, water, gas, and emulsions, within the complex environment of oil separators. This work underscores the importance of advanced sensor technologies in overcoming the challenges/problems associated with multi-interface level measurement, efficiency, fluid densities, corrosiveness, and viscosity. Fuel Management Systems (2023) showed the importance and need for companies to digitally monitor their fuel/fluid assets to improve security against fluid theft, create proper planned schemes and have greater control over the fluids they own.

Pic Tutorials (2014) explained that resolution, which is the ability to distinguish between nearby values was used to verify the change in capacitance level to an equivalent change in fluid levels. In Geoffrey M. Hohn (2011), it was stated that, the ability of the built system to measure fuel level can be added to the ability to calculate fuel consumption rate in present time, store data of previous fuel consumption, current and average fuel efficiency, in other to get proper analytics for the system and also store data for future study.

The reviewed literature provides valuable insights and forms the basis for the development of the proposed monitoring system. By leveraging technologies such as IoT, wireless sensor networks, and predictive algorithms, this work can contribute to the advancement of real-time predictive diesel monitoring in the context of Base Transceiver Stations.

III. METHODOLOGY

This work is made up of three main sections: hardware, software and the prediction algorithm. The hardware implementation involves the use of a modular design method, whilst the software implementation was done with C++ and Python language for programming the hardware, and implementing a user interface. Finally, a machine learning model with a given data set was used for implementing the prediction algorithm. A top-down design approach was used. Figure 1 shows the hardware, software and the prediction algorithm composition of the real time predictive diesel monitoring system in a base transceiver station.

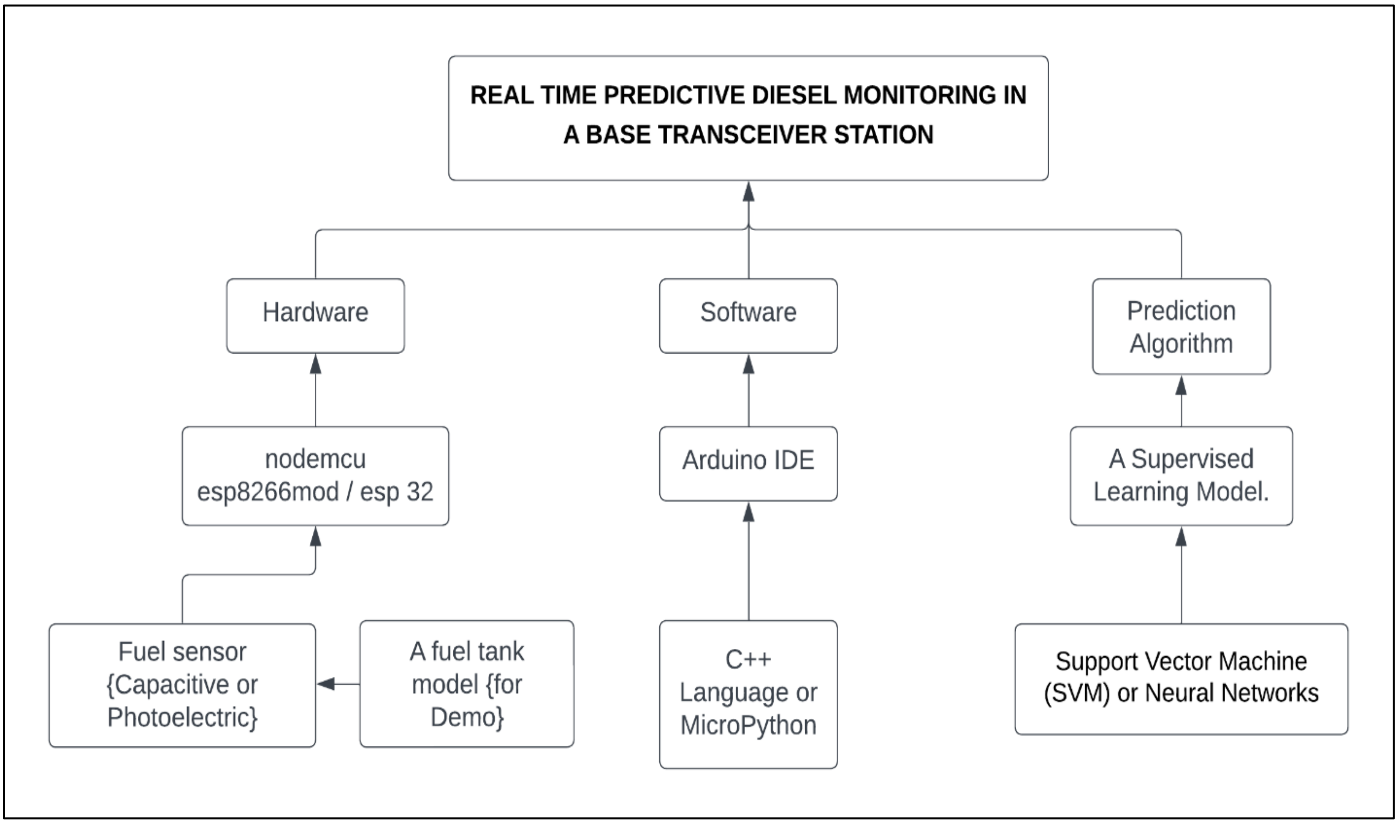

Fig 1 Composition of the Real Time Predictive Diesel Monitoring System

The hardware implementation adopts a modular design approach, incorporating the ESP8266 NodeMCU for the base microcontroller, Arduino Uno Rev3 and a fluid measurement sensor (either capacitive or photoelectric). The real-time predictive diesel monitoring system are systematically designed. For the software aspect, a top-down design approach is employed. C++ is primarily used for programming the hardware, leveraging the capabilities of Arduino IDE. This section also involves the development of a user interface for monitoring purposes which is programmed in Python. The prediction algorithm section utilizes a Machine Learning approach, employing the use of Linear regression. This involves implementing a machine learning model that makes predictions-based dataset on historical data, enhancing the system's ability to estimate fuel consumption.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar708

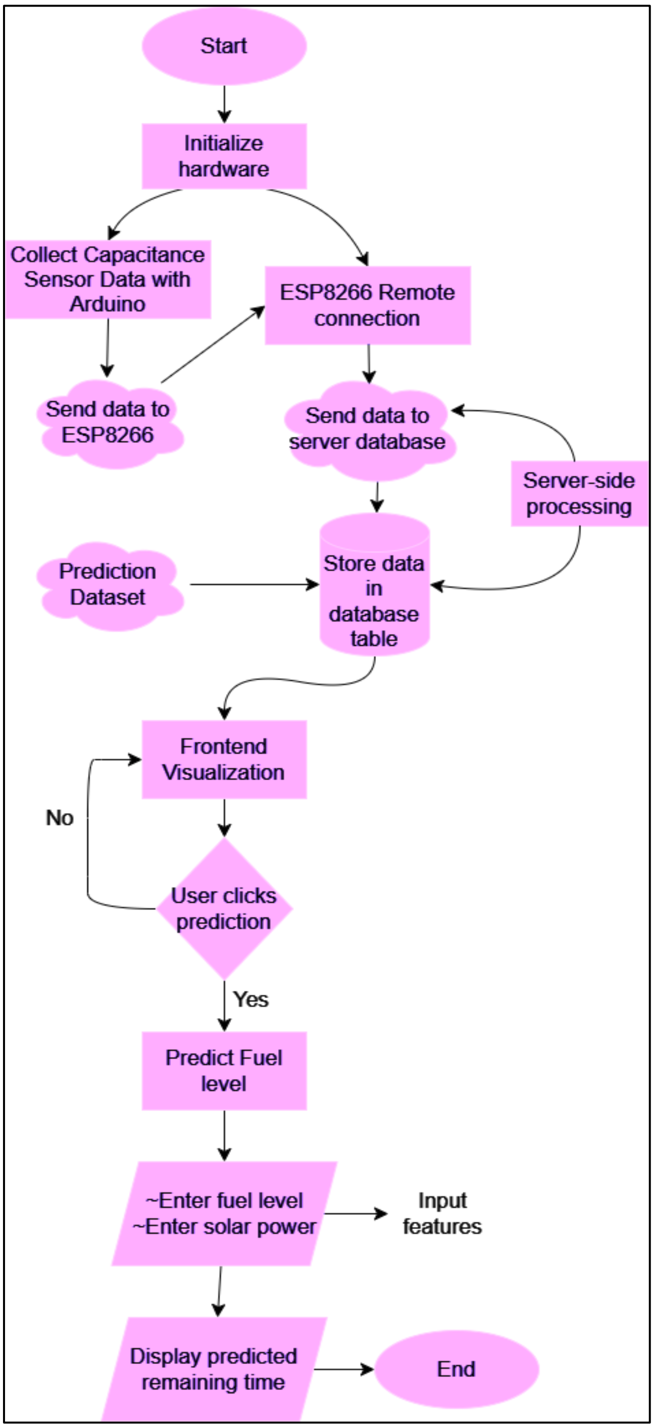

Fig 2 Flow Chart of System Operation

The ESP8266 NodeMCU Wi-Fi Module is a versatile and cost-effective microcontroller with a Wi-Fi module combination widely used in Internet of Things (IoT) projects. It is based on the ESP8266 chip, a low-cost Wi-Fi module developed by Espressif Systems. This microcontroller was unable to measure capacitance readings on its own due to its very little stray capacitance level, thus needs a more complicated circuitry to achieve it.

➢ *Research Design*

The research design for this project is a combination of exploratory research and experimental design. The exploratory research phase involves an in-depth literature review and an analysis of existing technologies, methodologies, and best practices related to diesel monitoring and predictive analysis in BTS environments. The experimental design phase includes the development and implementation of the proposed system. It incorporates the design of hardware components, selection of appropriate sensors, development of predictive algorithms, and integration with a centralized interface for real-time monitoring and control.

The experimental design phase follows an iterative process just as shown in the flow chart Fig. 2, allowing for continuous real-time testing and operations. This system allows for refinement and optimization based on continuous testing and feedback, which ensures that the real-time predictive diesel monitoring system evolves to meet the specific needs of BTS environments, accommodating variations in fuel consumption patterns and operational conditions.

By merging exploratory research and experimental design, this research methodology ensures a holistic understanding of existing knowledge, informed decision-making during system development, and adaptability to the dynamic nature of diesel monitoring in BTS facilities.

➢ *Data Collection Methods*

Data collection is a critical aspect of the work, involving the collection of real-time diesel level data, historical consumption patterns, and other relevant parameters. The following data collection methods were be employed:

- Sensor-based Data Collection: Suitable sensors are selected to measure and collect real-time diesel level data from the BTS generator tanks. This data will be continuously recorded and transmitted to a centralized database for storage and display on a frontend interface for analysis and visualization.
- Historical Data Acquisition: Historical data on diesel consumption, generator runtimes, load demands, and environmental factors are collected from existing records and data logs. This data will be used to train and validate the predictive algorithms. In this case study, controlled testing and generating test data by script was used. It is linear to simulate historical data, used for training and performing predictions.
- User Feedback and Evaluation: Feedback from users and operators of BTS sites are essential and can be gathered through surveys, interviews, and observations. This feedback will help evaluate the effectiveness and usability of the monitoring system and inform future improvements. And due to constraints mostly observation feedback would be carried out in this test case, that is research on direct observations of the fuel monitoring systems in operational BTS environments will be undertaken to assess real-world usability, identify any operational challenges, and validate the system's performance under varying conditions.

The circuit schematic design involves the integration of hardware parts to enable diesel level measurement.

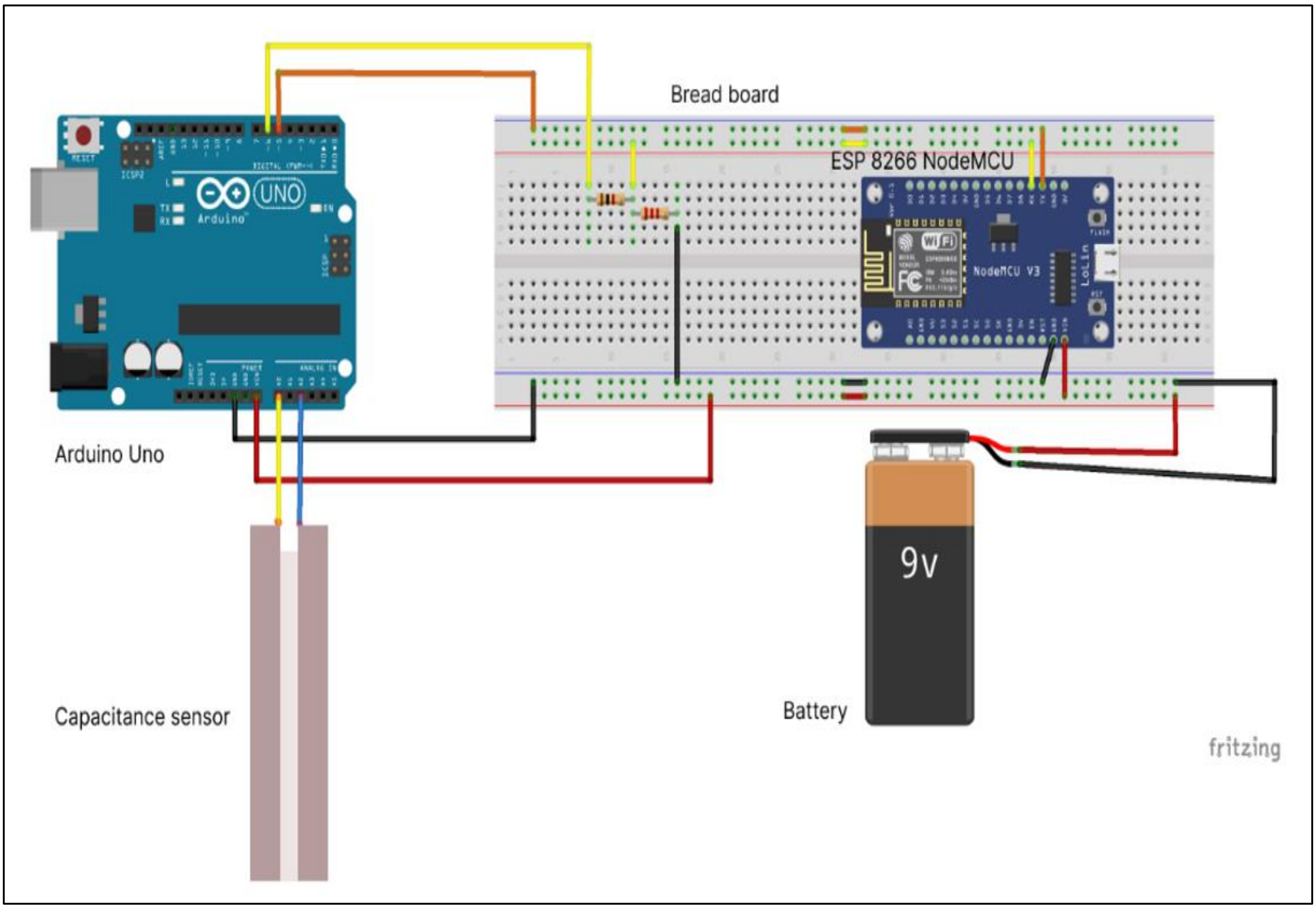

Fig 3 Schematic Circuit Design

➢ *System Architecture*

The system architecture consists of the following key components:

- Sensors: High-precision sensors are selected to measure and monitor the diesel levels in the BTS generator tanks. These sensors will provide accurate and reliable data for analysis.
- Microcontroller: A microcontroller was utilized to interface with the sensors, collect the data, and transmit it to the centralized interface. It will also control other system operations and manage power consumption.
- Communication Module: A communication module is incorporated to enable seamless transmission of data from the microcontroller to the centralized interface. This will ensure real-time monitoring and control.
- Centralized Interface: A user-friendly interface will be developed to display real-time diesel level data, predictive analysis results, and provide controls for monitoring and refuelling operations. The interface will be accessible through web or mobile applications.
- Predictive Algorithms: Advanced predictive algorithms will be designed and implemented to analyse the collected data and generate predictions regarding diesel consumption patterns and refuelling requirements. These algorithms will consider various factors such as load demands, generator runtimes, and historical data.

➢ *Display Dashboard / User Interface*

The Display Dashboard or User Interface (UI) is the gateway through which operators would interact with the real-time predictive diesel monitoring system. This section explores the design process, functionality, and key features of the UI, highlighting its role in providing operators with a comprehensive view of diesel levels, predictive analytics and system status. UI design follows established principles to ensure clarity, intuitiveness, and user-friendly interaction. And to improve interactivity data should be visualized to make easy to assimilate rather than having numbers or raw values.

The Display Dashboard incorporates several key features to empower operators and enhance their monitoring experience:

- *Real-Time Diesel Level Display:*

The main dashboard prominently displays the current diesel level in the base transceiver station (BTS) generator tank. This real-time information serves as a quick reference for operators.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar708

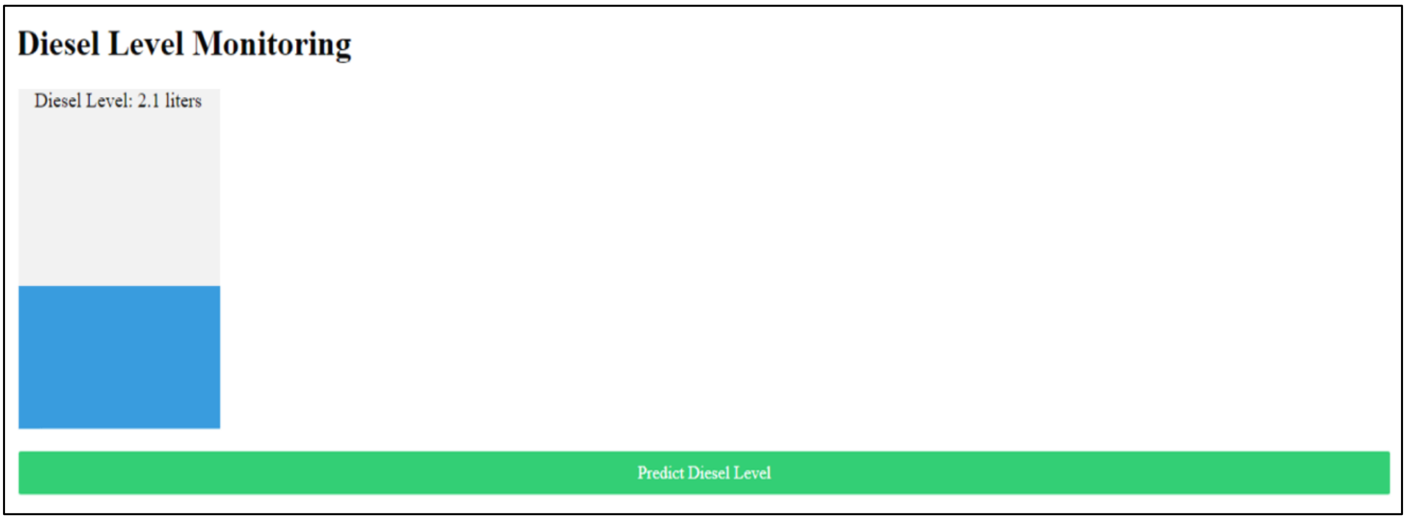

Fig 4 Real-Time Diesel Level Display

- *Historical Consumption Trends:*
  Operators can access historical diesel consumption data, enabling them to analyze past patterns and make data-driven decisions for optimizing fuel management.

- *Predictive Analytics:*
  Provides insights from predictive algorithms, offering operators forecast on when the fuel volume is likely to decrease to a certain level. Predictive analytics empower proactive refueling planning and budget planning.

Fig 5 Prediction Screen Display

➢ *Remote Monitoring:*
The UI supports remote monitoring, allowing operators to access the dashboard from any location with an internet connection. This feature enhances flexibility and facilitates prompt decision-making.

The UI seamlessly integrates with the predictive algorithms, presenting the results in a visually appealing manner. This integration allows operators to correlate real-time data with predictive insights for comprehensive decision-making.

Also, to ensure ongoing usability and relevance, the UI undergoes continuous improvement based on user feedback, technological advancements, improvements to services and emerging design trends. Regular updates aim to enhance the operator experience and address any identified areas for improvement.

IV. RESULT/DISCUSSION

➢ *Simulated and Real-World Testing:*
Simulated scenarios are used to mimic diverse operational conditions, allowing the system's response to be evaluated under various situations. The system was deployed as a prototype to simulate operational BTS environments to assess its performance in real-world conditions. This involved continuous monitoring, data collection and display of parameters over a user-friendly interface.

The results of the system testing are presented below, categorized according to the testing objectives:

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Table 1 Performance Evaluation Results

Metric	Result
Data Accuracy	The system consistently provided accurate real-time level measurements, with some little deviation rate due to high accuracy of the capacitive sensors.
Transmission Speed	Data transmission occurred in near real-time, with an average latency of 2 - 4 seconds, ensuring timely updates on diesel levels.
Responsiveness	The monitoring system demonstrated high responsiveness, updating displayed data instantly upon detecting changes in diesel levels based on the latency.

➢ *Prediction Accuracy Results:*

Testing the prediction model in fig.6 on the Jupiter notebooks, a model score of 1.0 was obtained, this due to the fact that the created case study dataset is linear not taking into considerations natural disturbances since a synthetic dataset was considered.

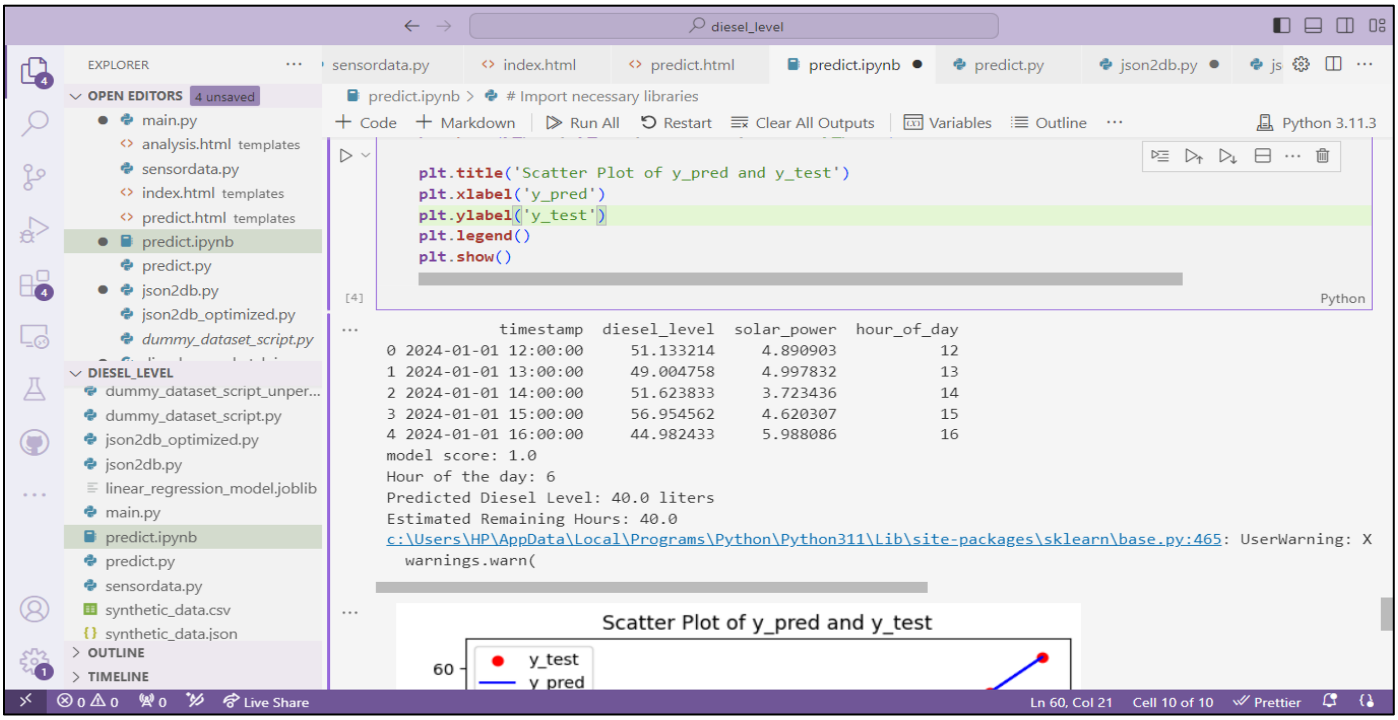


Fig 6 View of the output Test for Model Performance

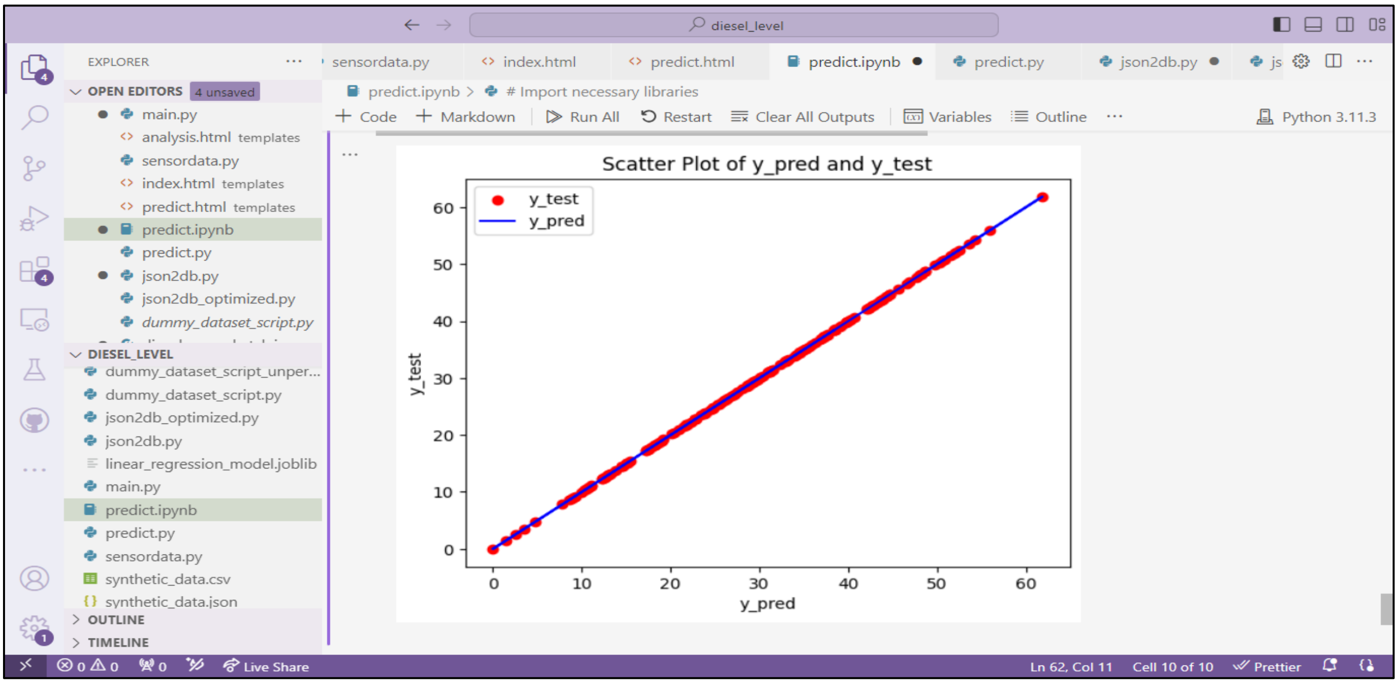
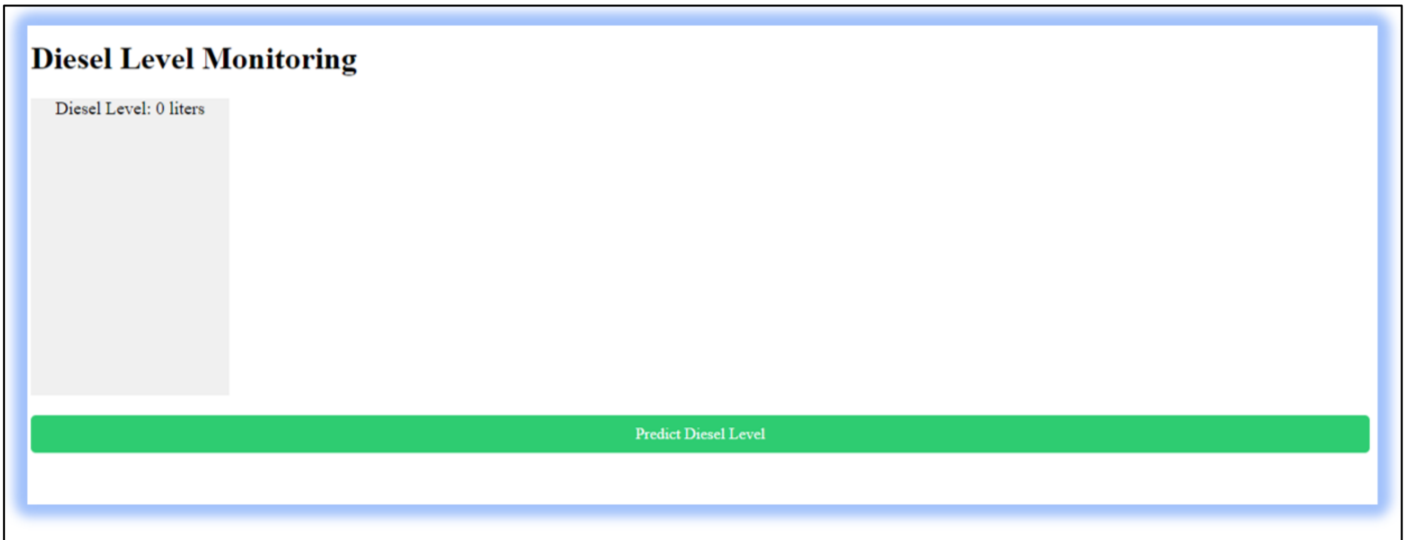


Fig 7 Graph with the Fit Plot of Predict values to actual values

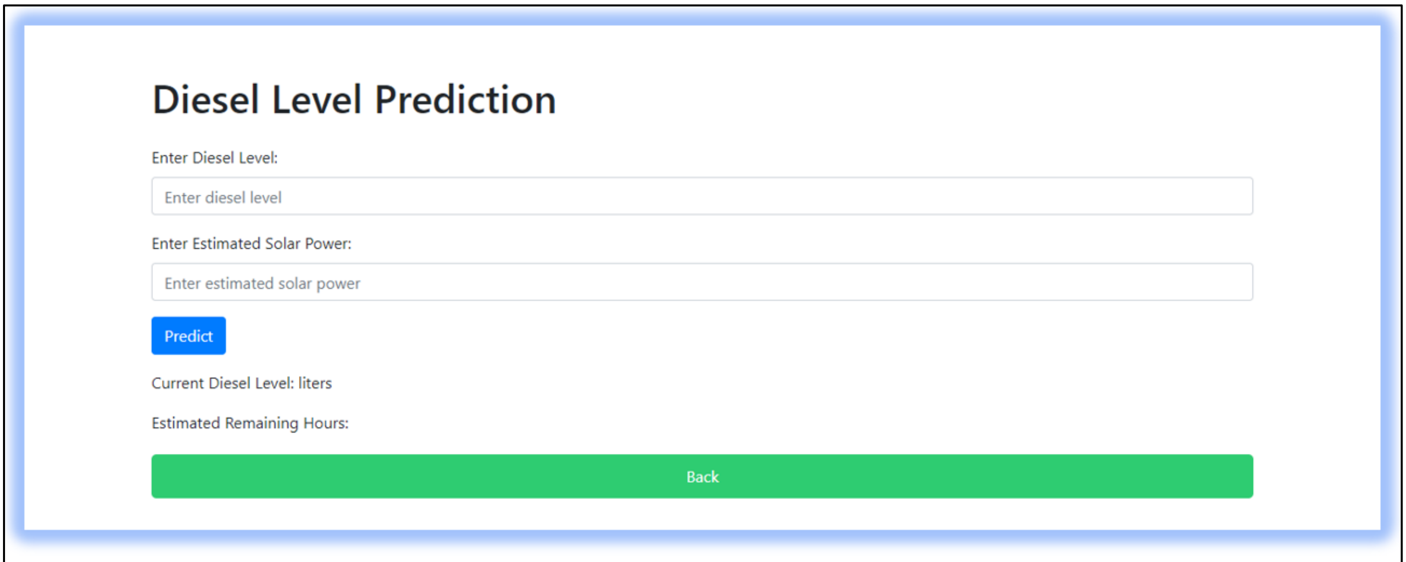
Table 2 Key Performance Indicators

Metric	Result
Diesel Consumption Estimation	The predictive algorithms exhibited a model performance of over 100%, effectively estimating diesel consumption patterns based on the dummy historical data.
Fuel Depletion Prediction	The system predicts time duration for diesel to last considering another power source like, solar is available

➢ *User Interface Assessment Results:*



(a)



(b)

Fig 8(a) View of the Visualized Tank level (b) Output Test Interface for Prediction

Table 3 Test Interface for Prediction

Metric	Result
Clarity	The user interface presented diesel level data in a clear and comprehensible manner, allowing anyone to easily interpret the information by displaying it in a pictorial format
Simplicity	The User Interface has been made as simple as possible making it easily upgradeable
Ease of Use	Due to the few functions this interface is easily understandable and easy to use.

The results obtained from the system test phase indicated a successful implementation of the real-time predictive diesel monitoring system. The high accuracy in data measurements, reliable predictive algorithm, and user-friendly interface contribute to the system's need in addressing the challenges associated with diesel monitoring in BTS environments.

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It is seen in this work (Fig 4 to Fig. 8), that Real-Time Monitoring was achieved, as the system is able updated frequently through its established remote/wireless connection with Wi-Fi module. Also, on the implementation of a predictive system which has been implemented and integrated into the web application as shown in fig. 6 to fig 8. Both the Prediction Accuracy Results and the frontend for the prediction model were actualized.

It is seen that, this system tries to successfully integrate different areas namely monitoring, analysis and remote connectivity, to create a hybrid system with each area been able to improve operations in a base transceiver system.

➢ *Feedback*

Feedback obtained from operations during the testing phase includes; observations, suggestions for improvement of system and recommendations for enhancing the overall usability and effectiveness of the monitoring system.

- *Observations:*

Table 4 Observations

Aspect	Feedback
System Usability	Positive responses, indicated by the ease of use during operations.
Interface Navigation	Minimal training required; as a very simplistic UI has been used.

- *Suggestions for Improvement:*

Table 5 Suggestions for Improvement

Aspect	User Recommendations
Additional Features	Requests for additional features, such as historical trend analysis and customizable alert thresholds.
Complete Interface workflow	To create a complete interface system with Dashboard, user login and authentication, and an integration of similar operations.
Integration Possibilities	Suggestions for integration with existing BTS management systems for seamless operation.

➢ *System Optimization Strategies*

Building on the feedback received and the identified areas for improvement, this section outlines strategies for optimizing the real-time predictive diesel monitoring system. Proposed optimizations encompass both hardware and software enhancements to elevate system performance and user satisfaction.

- *Hardware Enhancements:*

Table 6 Hardware Enhancements

Enhancement	Description
Sensor Redundancy	Implementing redundant (extra) sensors to ensure continuous data collection even if one sensor fails due to any reason.
Power Efficiency	Exploring more energy-efficient sensors and components to minimize power consumption.
Capacitance sensitivity and Anti-corrosion	Finding proper materials or methods for the capacitance sensor that can reduce the risk of corrosion and improve its minimum capacitance level. This will improve the capacitance sensitivity to measure much smaller changes in diesel levels

- *Software Enhancements:*

Table 7 Software Enhancements

Enhancement	Description
Machine Learning Refinement	Continual refinement of predictive algorithms through machine learning model updates based on ongoing data collection.
User Interface Customization	Introducing features for users to customize the interface based on specific preferences and operational needs.

- *Prediction Algorithm Enhancements:*

Table 8 Prediction Algorithm Enhancements

Enhancement	Description
Algorithm Optimization and Vectorization	Optimizing the algorithm can help improve the accuracy levels for predicting diesel consumption with real life data which is known to contain inconsistences making the data non-linear where linear regression is no longer possible, which can then enable system to accurately predict fuel consumption for a larger time period with minimal errors. Vectorization can be used to make algorithm more responsive and fast in retraining model.

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Adding More Useful Parameters to Enhance Information Gathering	Introducing features like power consumption rates, traffic rate / processing rates which might lead to higher power consumption rates, idle times / standby times for various equipment's in the BTS.

➢ *Future Prospects and Research Avenues*

As the real-time predictive diesel monitoring system proves its effectiveness, this section explores potential future prospects and avenues for further research and development. Considering emerging technologies, scalability solutions, and potential applications in related fields.

- *Integration with IoT Platforms:*

Table 9 Integration with IoT Platforms

Prospect	Description
IoT Connectivity	Exploring integration possibilities with Internet of Things (IoT) platforms for enhanced connectivity and data analytics capabilities.

- *Scalability Considerations:*

Table 10 Scalability Considerations

Prospect	Description
Larger Network Deployment	Assessing the scalability of the system for deployment in larger BTS networks and other industrial settings, also using the system to fully or partially automate processes related to fuel refilling and information gathering.

- *Cross-Industry Applications:*

Table 11 Cross-Industry Applications

Prospect	Description
Adaptation for Other Sectors	Investigating the adaptation of the monitoring system for use in sectors beyond telecommunications, such as power plants and transportation.

V. CONCLUSION

The journey through the development and implementation of the real-time predictive diesel monitoring system for base transceiver stations (BTS) has been marked by significant achievements and advancements. This system presents a transformative solution for BTS facilities, revolutionizing fuel management practices and ensuring a reliable and uninterrupted power supply. The successful implementation of this system is anticipated to have a lasting impact on the efficiency and sustainability of BTS operations. Through the collaborative efforts in hardware design, software development, and the integration of predictive algorithms, this work has successfully achieved the set objectives. The real-time monitoring system provides an accurate, up-to-the-minute diesel level data, while the predictive analytics provide proactive refuelling planning, minimizing downtime and ensuring uninterrupted power supply.

REFERENCES

[1]. Ahmed Sofia , Tsegamlak Terefe, Dereje Hailemariam, Machine learning for base transceiver stations power failure prediction: A multivariate approach,e-Prime - Advances in Electrical Engineering, Electronics and Energy, Volume 10, 2024, 100814, ISSN 2772-6711, https://doi.org/10.1016/j.prime.2024.100814.

[2]. Antonio Spagnuolo, Antonio Petraglia, Carmela Vetromile, Roberto Formosi, Carmine Lubritto, (2015). Monitoring and optimization of energy consumption of base transceiver stations, Energy, Volume 81, 2015, Pages 286-293, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2014.12.040.

[3]. Arnaldo G. Leal-Junior, Carlos Marques, Anselmo Frizera, Maria José Pontes, (2018). Multi-interface level in oil tanks and applications of optical fiber sensors.

[4]. Capacitance measurement with the Arduino Uno, (2014). PIC Tutorials. https://wordpress.codewrite.co.uk/pic/2014/01/21/cap-meter-with-arduino-uno/index.html

[5]. Chetan Patil and Channabasappa Baligar. Base Transceiver Station (BTS) Safety and Fault Management. International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075 (Online), Volume-3 Issue-7, December 2013. Pp 48-52.

[6]. Fuel Management Systems, (2023). Banlaw group. https://www.banlaw.com/fuel-management-systems/

[7]. Geoffrey M. Hohn, (2011). Computerized Fuel Management System for a Foss Tugboat. A thesis submitted in University of Washington graduate school.

[8]. Łukasz Kufel, (December 2016). Tools for Distributed Systems Monitoring. Retrieved from https://www.researchgate.net/publication/311863266_Tools_for_Distributed_Systems_Monitoring

[9]. Mingwei Lin, Zhiqiang Yao, Fei Gao, Yang Li (2016). A Virtual Machine Instance Anomaly Detection System for IaaS Cloud Computing. Retrieved from https://www.researchgate.net/publication/302922016

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25mar708

_A_Virtual_Machine_Instance_Anomaly_Detection_System_for_IaaS_Cloud_Computing

[10]. Muhammad Tahir, Syed Muhammad Nabeel Mustafa, Rabia Enam, Najma Ismat, (August 2022). Real Time Monitoring and Control of Electrical Diesel Generator through Internet of Things. Retrieved from https://www.researchgate.net/publication/362964974_Real_Time_Monitoring_and_Control_of_Electrical_Diesel_Generator_through_Internet_of_Things

[11]. Murugesan C. and Marimuthu C. N. (2018). Cost optimization of PV-Diesel Systems in Nanogrid Using L J Cuckoo Search and its Application in Mobile Towers.

[12]. Pankaj Kumar, Nitai Pal, Himanshu Sharma, (2022). Optimization and techno-economic analysis of a solar photo-voltaic/biomass/diesel/battery hybrid off-grid power generation system for rural remote electrification in eastern India.

[13]. Serafeim Zanikolas, Rizos Sakellariou, (2005). A taxonomy of grid monitoring systems. Retrieved from https://www.researchgate.net/publication/222511463_A_taxonomy_of_grid_monitoring_systems

[14]. Tavengwa Masamha, Clayton Gwava, Blessing Mapinge and Jacqueline Kiwa C. Predictive maintenance of base transceiver station power system using XGBoost algorithm: A case study of Econet Wireless, Zimbabwe The 9th African Conference on Information Systems and Technology 2023 pp1-7.

[15]. Terfera Y. Y., T. Kibatu, B. S. Shawel and D. H. Woldegebreal, "Recurrent Neural Network-based Base Transceiver Station Power Supply System Failure Prediction," *2020 International Joint Conference on Neural Networks (IJCNN)*, Glasgow, UK, 2020, pp. 1-7, doi: 10.1109/IJCNN48605.2020.9206978.

[16]. Xinghua Qi, Bahadar Nawab Khattak, Sara Saeedi, (2023). Optimal energy modeling and planning in the power system via a hybrid firefly and cuckoo algorithm in the presence of renewable energy sources and electric vehicles.