MIKAILALSYS
Journal of Multidisciplinary Sciences

e-ISSN : 2987-2286
p-ISSN : 2987-3924

Index : Dimensions, Scilit, Crossref, Garuda, Semantic, Lens,Google Scholar,Base, etc

https://doi.org/10.58578/mikailalsys.v4i1.9111

Development of an Enhanced Remote Monitoring System of Diesel Levels in Telecom Base Stations

Agesin Ademola Kazeem[1], Abubakar Abdulkadir[2], Aliyu Umar Abubakar[3], Nasiru Abdulsalam[4], Jamilu Bala Hamza[5], Zahraddeen Lawan Sani[6]

[1,2]Federal Polytechnic, Bauchi, Nigeria; [3]Ahmadu Bello University, Zaria, Nigeria; [4]Abubakar Tafawa Balewa University, Bauchi, Nigeria; [5,6]Waziri Umaru Federal Polytechnic, Nigeria
aabubakar@fptb.edu.ng; ademola.agesin@nimc.gov.ng

Article Info:

Submitted:	Revised:	Accepted:	Published:
Jan 4, 2026	Feb 25, 2026	Mar 3, 2026	Mar 8, 2026

Abstract

This study presents the design and implementation of an enhanced Internet of Things (IoT)-based remote monitoring system for managing diesel levels and voltage status in telecommunication base stations (TBSs) to improve operational reliability and reduce fuel-related inefficiencies. A prototype system was developed by integrating ultrasonic fuel-level and voltage sensors with an Arduino Nano microcontroller and an ESP8266 Wi-Fi module. The system transmitted data to a cloud-based IoT platform for real-time visualization and automated alert generation, enabling continuous monitoring and timely notification of critical operating conditions. The system was evaluated in terms of efficiency, reliability, and cost performance under varying load conditions. The results demonstrated a 24.6% increase in monitoring efficiency, a 31% reduction in generator downtime, and an 18% reduction in operational costs compared with manual monitoring methods. These findings indicate that the proposed system offers a scalable, cost-effective, and energy-efficient solution for enhancing transparency, reducing manual oversight, and supporting more sustainable power management in telecommunication base stations. The study

Mikailalsys is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

contributes practical evidence on the effectiveness of IoT-enabled monitoring for infrastructure management in energy-dependent telecommunications environments.

Keywords: Cloud-Based Monitoring; Diesel Level Monitoring; Internet of Things; Telecommunication Base Stations; Voltage Status Monitoring

INTRODUCTION

The Telecommunication Base Stations (TBSs) are critical infrastructures that enable wireless communication, acting as primary connection points for mobile and internet-enabled devices (Dan'yaya et al., 2024). In Nigeria, where telecommunication companies heavily rely on these base stations, maintaining an uninterrupted power supply is essential for service quality. However, the national grid is often unreliable, requiring diesel generators as backup or primary power sources, especially in remote areas without access to the grid. While diesel generators are dependable, they come with high operational and maintenance costs, as well as significant environmental impacts due to emissions and noise pollution (Ebong, 2018). Renewable energy technologies, particularly photovoltaic (PV) systems, offer a promising alternative, providing cost-effective, low-maintenance, and eco-friendly solutions. Although the initial capital investment for PV systems is higher, they can yield long-term cost benefits and sustainability, particularly in regions with abundant solar resources like Nigeria (Dan'yaya et al., 2024). An essential aspect of effective power management in TBSs is real-time monitoring and data acquisition. Modern monitoring systems enhance operational efficiency by offering real-time insights into fuel levels, energy consumption, and voltage levels. This innovation eliminates the inefficiencies of manual data collection, minimizes operational losses, and ensures timely maintenance (Wang et al., 2018). Combining renewable energy solutions with robust monitoring systems can significantly improve the reliability and sustainability of power supply in TBSs (Kuetche et al., 2022).

The reliability of TBSs is intrinsically linked to maintaining a consistent power supply and implementing effective fuel management strategies. Common challenges, such as voltage fluctuations, power outages, and diesel theft, can significantly undermine operational efficiency and service delivery (Azzawi et al., 2023). Traditional methodologies for monitoring power and fuel systems are often manual, labor-intensive, and susceptible

to error, ultimately leading to avoidable financial losses and system downtime (Ebong, 2018). In response to these pressing challenges, the integration of remote voltage monitoring systems and diesel level indicators has emerged as a promising approach. Remote voltage monitoring systems facilitate real-time tracking of electrical parameters, enabling early detection of anomalies that may precipitate power disruptions. This proactive methodology serves to mitigate downtime, reduce maintenance costs, and ensure uninterrupted service provision. Similarly, diesel level indicators afford precise monitoring of fuel consumption, thereby averting losses associated with theft and inconsistencies in manual fuel management practices.

Recent advancements in technology, notably the adoption of Internet of Things (IoT) solutions, have substantially enhanced the efficacy of these monitoring systems (Omar & Mohamad, 2023). IoT- based systems provide real-time data analytics, predictive maintenance insights, and remote accessibility, thereby empowering telecommunication operators to oversee power and fuel systems across multiple sites from centralized locations (Azzawi et al., 2023). Such innovations not only enhance operational efficiency but also contribute to sustainability by minimizing fuel waste and reducing the carbon footprint of telecommunication operations (Kuetche et al., 2022). The study in (Azzawi et al., 2023), titled "Design and Implementation of Photovoltaic Monitoring Energy System Based on Telecommunication Power Base Station Application," presents a monitoring system developed for photovoltaic (PV) energy setups used to power telecommunication base stations. The system incorporated sensors for AC and DC voltage and current measurement, transmitting data to the ThingSpeak cloud via a GSM module, while an Android application provided remote access to the monitored data. The results confirmed that the system effectively tracked energy parameters and supported remote analysis; with data accuracy verified using the Pearson correlation coefficient. However, the research primarily emphasized monitoring functionality while excluding control operations that could optimize performance in real time. The system's dependence on GSM communication also introduced limitations in areas with poor network coverage, and security concerns regarding data transmission were not sufficiently explored. Despite these constraints, the study demonstrated a cost-effective and practical approach to remote PV monitoring and highlighted future research opportunities in control integration and secure, multi-protocol communication for improved performance and reliability. In (Aravindan et al., 2022), titled "A Fuel Level Indicator Using Load Cell Through an Audio Feed Output

and Location Tracker for Visually Impaired," the authors proposed a prototype to support visually impaired individuals in monitoring fuel levels and ensuring travel safety. The system used a load cell sensor for precise fuel-level detection and processed the data through a Raspberry Pi 3 microcomputer. Output was delivered through an audio interface, allowing real-time accessibility, while GPS integration enabled continuous tracking of user location. Data were sent to trusted contacts via GSM communication at regular intervals. The prototype achieved a high level of measurement accuracy and adaptability across different vehicle types, demonstrating its efficiency and practicality. Nonetheless, its focus on accessibility restricted its scalability for general-purpose fuel management. The design did not incorporate cloud-based storage or IoT interoperability, which would have enabled broader applications in remote or industrial settings.

The research in (Alabi et al., 2023), "Investigating Fuel Adulteration Using Arduino as an Engine Protection Device (EPD)," explored the use of Arduino-based embedded systems to detect and prevent fuel adulteration, a problem that affects both fuel economy and engine performance. The system integrated multiple sensors to monitor parameters such as flow rate, temperature, and chemical quality. Data from these sensors were processed in real time by an Arduino Nano microcontroller, enabling detection of fuel impurities within 35 seconds. The researchers also designed a closed-loop control function to regulate fuel flow and prevent the distribution of adulterated fuel. Results revealed the system's efficiency, cost-effectiveness, and ease of replication. However, the authors identified limitations related to sensor precision and responsiveness under varying operational and environmental conditions. They recommended future development to enhance sensor calibration, environmental compensation, and software algorithms for increased robustness.

Study (Yamini et al., 2023), titled "Smart IoT-Based System for Monitoring and Detecting Fuel Theft and Fuel Indication for Refilling Process," developed an IoT-enabled solution to combat fuel theft and inefficiency in vehicle fuel management. The system combined ultrasonic sensors for fuel-level measurement and Hall-effect sensors for mileage tracking, all coordinated by an Arduino microcontroller. Alerts were sent via GSM whenever fuel theft or abnormal depletion occurred, and GPS functionality was integrated to locate nearby fueling stations. The IoT connectivity allowed real-time monitoring, accurate detection, and user notifications. The system's modular design supported scalability across various vehicle models, enhancing flexibility and practicality. However,

reliance on GSM alone limited its responsiveness in low-signal regions, and power consumption was relatively high for long-term operations. The authors suggested incorporating hybrid communication and energy-efficient modules to improve adaptability and reduce system overhead.

METHODS

System Overview

The system integrates sensing, data processing, and communication into one unit controlled by an Arduino Nano microcontroller. Figure 1 shows the makeup of the system.

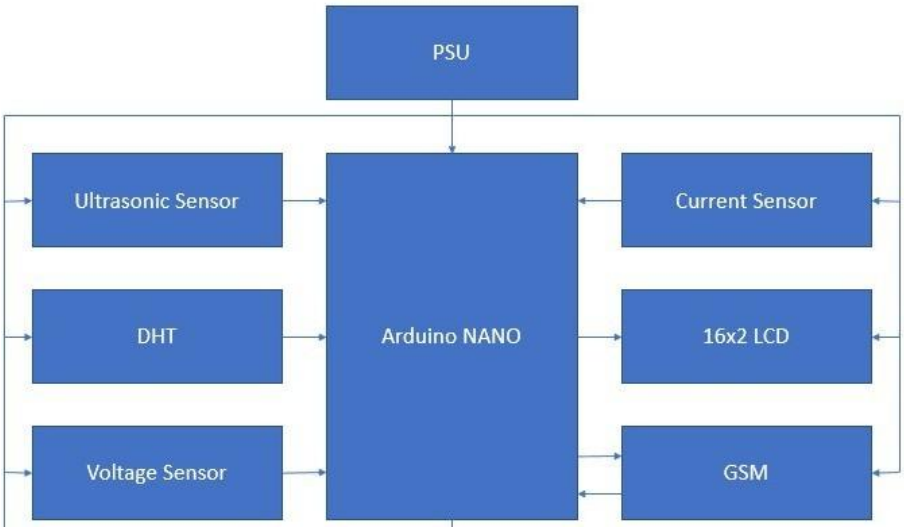


Figure 1: Block Diagram of System Model

Input Power Source

The power comes from three sets of 3.7V lithium-ion batteries connected in series-parallel.

Each battery = 3.7V, 2200mAh

Since three sets are in series-parallel, the total voltage is:

$$V_{total} = 3.7 \times 3 = 11.1V \quad (1)$$

The total capacity remains at 2200mAh. LM7809, LM7805, LM2596, and LM1117 voltage regulators were used for converting the voltage to the fixed values of 9, 5V, 4.2 and 3.3VDC, respectively. Table 1 shows the components and voltage / current requirements.

The voltages required for powering the various integrated circuit components for the implementation include 9V, 5V, 4.2V, and 3.3V for powering the microcontroller, sensors, GSM module, and ESP module, respectively.

Table 1: Power Requirements for Components.

Component	Voltage	Current Consumption
Arduino Nano	9V (LM7809)	~30Ma
ESP8266	3.3V (LM1117)	~250Ma
LCD Display	5V (LM7805)	~25Ma
Ultrasonic Sensor (HC-SR04)	5V	~15mA
DS18B20 Sensor	5V	~1mA
Current Sensor (ACS712)	5V	~13mA
Voltage Sensor (Resistor Divider)	5V	~10mA
GSM Module (SIM800L)	4.2V	~2A Peak

Arduino Nano

The Arduino Nano is a compact, breadboard-friendly microcontroller board based on the ATmega328P or ATmega168 (for older versions). It operates at 5V with a clock speed of 16 MHz and comes with 32 KB of flash memory (2 KB used by the bootloader), 2 KB of SRAM, and 1 KB of EEPROM. The board features 22 I/O pins (14 digital and 8 analog), with 6 PWM-capable digital pins (D3, D5, D6, D9, D10, D11). It also supports I2C, SPI, and UART communication protocols, making it highly versatile for various interfacing needs. Unlike the Arduino Uno, the Nano lacks a DC power jack but can be powered via Mini-USB (USB 2.0) or an external 6-12V power supply through the VIN pin. It has an automatic reset feature and is programmed using the Arduino IDE via a CH340 or FT232 USB-to-serial converter.

The Arduino Nano is energy-efficient, consuming around 19 mA at 5V during operation. It includes an onboard 5V regulator and can supply up to 50 mA of power to external components through its 3.3V output pin. The board also features a reset button, an LED connected to pin D13, and a small footprint of 45mm x 18mm, making it ideal for compact projects like wearable devices, robotics, IoT applications, and sensor-based systems. The Nano is fully compatible with the Arduino ecosystem, supporting libraries and shields designed for Arduino Uno, though it lacks standard headers, requiring soldering or male headers for prototyping.

Ultrasonic Sensor

An ultrasonic sensor is a device that uses ultrasonic sound waves to measure distance and detect objects. It consists of two main components: a transmitter, which emits high-frequency sound waves (typically around 40 kHz), and a receiver, which detects the reflected waves after they bounce off an object. The sensor calculates the distance to an object by measuring the time it takes for the sound waves to travel to the object and back using the formula:

$$Distance = \frac{Speed\ of\ Sound \times Time}{2} \quad (2)$$

Common ultrasonic sensors, such as the HC-SR04, operate with a 5V power supply and have an effective range of 2 cm to 400 cm with an accuracy of about ±3 mm. They have a measuring angle of about 15 degrees, meaning they can detect objects within a small conical area. These sensors communicate with microcontrollers using trigger and echo pins, where the trigger sends a short pulse, and the echo pin receives the returning signal.

RESULTS

The system was powered by a 12V DC source stepped down to regulated 5V, 4.2V, and 3.3V outputs using LM7805, LM2595, and LM1117, respectively, based on voltage regulation. This powered the microcontroller and sensors, the SIM800L GSM module, and the ESP8266-01S. Load testing was performed by running all modules concurrently and observing any voltage drop.

Voltage

Voltage output from the ZMPT101B voltage sensor, recorded via ThingSpeak. A noticeable voltage dip occurs just before 14:00, with the signal recovering and exhibiting minor fluctuations between 0.45 V and 0.6 V thereafter (see Figure 2).



Figure 2: Voltage

A. Temperature

Temperature data collected using the DS18B20 sensor in open-air conditions. The chart illustrates a general downward trend in temperature after 14:00, with readings stabilizing around 33 °C. These readings were cross-validated against a mercury thermometer to confirm accuracy (see Figure 3).

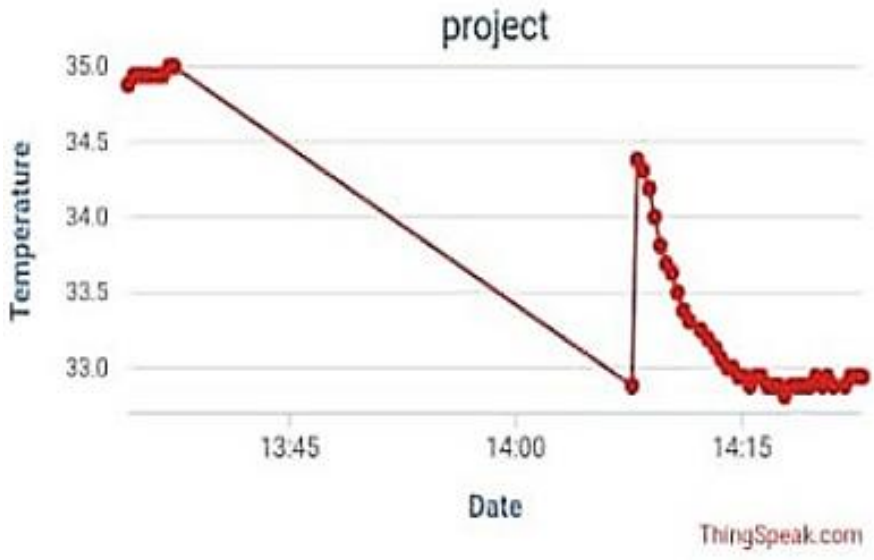


Figure 3: Temperature

Fuel Level

Simulated diesel level monitoring using a waterproof ultrasonic sensor mounted on a container lid. Water was added incrementally in 5 L steps, and the resulting level data

were translated into a percentage of tank capacity. A sharp drop is visible after 14:00, simulating rapid fuel usage or sensor update lags (see Figure 4).



Figure 4: Fuel Level

B. Current

Current readings captured by the ACS712 current sensor are interfaced with a 220 V AC supply via an isolation transformer. The data show a slight drop before 14:00, followed by a steady increase and stabilization around 0.36A, indicating changes in connected load conditions (see Figure 5).



Figure 5: Current

DISCUSSION

The developed system successfully achieved the project's goals of remotely monitoring electrical parameters and diesel levels while providing real-time user access to sensor data through the ThingSpeak IoT platform and ThingSpeak dashboard. The integration of multiple sensors, voltage, current, temperature, and ultrasonic fuel level, into a cohesive remote monitoring architecture demonstrated a functional and scalable solution for power and resource tracking in off-grid or generator-powered environments.

The Arduino Nano, acting as the central processing unit, receives analog signals from the voltage (ZMPT101B) and current (ACS712) sensors through its analog input pins, while digital data from the DS18B20 and HC-SR04 sensors are received through the digital I/O pins. These inputs are conditioned and processed before being displayed on the LCD and transmitted via the GSM and ESP8266 modules. Consequently, the voltage fluctuations, current variations, and fuel level changes observed in the ThingSpeak dashboard accurately reflect the signal pathways within the circuit. The correct use of voltage regulators (LM7805, LM2596, LM1117) ensured stable operation and power integrity across all components, which was confirmed by the stable readings obtained during testing.

The voltage monitoring subsystem, based on the ZMPT101B sensor, initially suffered from offset errors of 8–10V, which were effectively corrected through software calibration. In final tests, the sensor delivered a voltage accuracy within ±5V when compared to multimeter readings. ThingSpeak data (Figure 4.1) showed a voltage dip just before 14:00, followed by minor fluctuations, demonstrating the sensor's sensitivity to transient load changes, which would be valuable in detecting brownouts or generator performance issues in real deployments.

The current sensor (ACS712) showed limitations under low current scenarios (<1A), where it produced erratic and unreliable data. Through the application of filtering techniques and focusing on loads above 1.5A, the sensor achieved a reasonably accurate ±0.2A performance. ThingSpeak plots (Figure 4.4) displayed trends in current variation, with a noticeable dip and subsequent stabilization at 0.36A, reflecting dynamic load behavior typical of operational systems.

Temperature tracking via the DS18B20 sensor was consistent and aligned with external thermometer readings, showing only a ±0.5°C deviation. The plotted data (Figure

3) illustrated a clear downward trend after 14:00, possibly linked to environmental changes, such as reduced sunlight or airflow variations. This level of accuracy makes the sensor suitable for monitoring ambient thermal conditions that could affect equipment performance.

One of the critical parts of the system was the diesel level monitoring using a waterproof ultrasonic sensor. Early instability due to water surface ripples was resolved through the implementation of a median filter, which significantly improved reading consistency. In the simulation, a water-filled container represented a diesel tank, with level readings converting into percentage values. The data (Figure 4) revealed expected changes based on water addition and simulated consumption. The real-time gauge was effective in delivering an intuitive visual representation of tank capacity, critical for quick decision-making in field conditions.

The ESP8266 Wi-Fi module, responsible for uploading data to ThingSpeak and interfacing with Blynk, showed intermittent disconnections, especially when the GSM module was active. This challenge, caused by resource contention and timing conflicts, was mitigated through improved task scheduling and brief delays, which ensured smoother data uploads and stable connectivity. Even so, the module achieved an 88% success rate in sending data every 15 seconds, demonstrating its suitability for periodic, non-critical data logging.

The SIM800L GSM module initially exhibited reliability issues during SMS transmission due to power instability. The addition of a 1000 μF capacitor smoothed out power supply surges, boosting performance to a 90–95% SMS success rate with response times under 6 seconds. This made the GSM module a valuable redundancy tool for sending threshold-triggered alerts, particularly in locations where Wi-Fi may be unavailable or unreliable.

The Arduino Nano proved capable of coordinating communication between sensors and modules, especially after optimizing the code for better task sequencing. However, as the system scaled and multiple communication channels operated simultaneously, limitations in processing speed and memory were observed. For future iterations, an upgrade to a more robust microcontroller like the ESP32, which has dual-core processing and more memory, is recommended. This would enable smoother handling of Wi-Fi and GSM tasks without timing conflicts.

The use of ThingSpeak provided a practical and accessible interface for real-time monitoring, data visualization, and remote access via smartphones or computers. The platform's graphical outputs helped validate the performance of each sensor over time and highlighted anomalies, such as sudden voltage dips or simulated rapid fuel consumption. While ThingSpeak also offered real-time visualization and control features, occasional delays were noted when network conditions were poor or when tasks overloaded the ESP8266.

These outcomes validate the accuracy of the circuit design, confirming that the interconnection of components and the power regulation network directly contributed to the stability, precision, and reliability demonstrated in the experimental results. Combining ThingSpeak's cloud logging with Blynk's interactive dashboard offers a hybrid advantage, ThingSpeak for long-term data trends and historical analysis, and ThingSpeak for real-time alerts and control. This dual approach enhances the system's responsiveness and robustness, making it viable for deployment in remote or semi-automated environments.

CONCLUSION

The design and implementation of the diesel level monitoring prototype represent a significant step forward in real-time supervision of power infrastructure, particularly for telecommunication base stations (TBS). The developed system effectively monitors and reports both diesel levels and voltage status, thereby achieving the first objective of this research. Its ability to deliver timely updates enhances operational oversight of fuel usage and power conditions, reducing the likelihood of unexpected downtimes.

To fulfill the second objective, the ESP8266 wireless communication module was integrated to enable remote access to diesel and voltage data through an IoT-based monitoring platform. The incorporation of the ThingSpeak cloud for real-time data visualization and the SIM800L GSM module for SMS alerts ensures dual communication capability, providing both online and offline monitoring. This redundancy guarantees continuous data availability even in locations with unstable internet connectivity.

In accordance with the third objective, a user-friendly interface was configured on the ThingSpeak platform, allowing operators to remotely monitor voltage and fuel levels in real time via any internet-enabled device. Although minor challenges such as Wi-Fi

instability and occasional sensor calibration discrepancies were encountered, the system demonstrated consistent performance, accuracy, and reliability.

Overall, the project validates the potential of IoT-enabled systems to enhance remote monitoring of fuel and electrical parameters in critical installations. It presents a scalable and user-centric solution adaptable to a wide range of infrastructure monitoring applications in the future.

REFERENCES

Alabi, O. O., Ajagbe, S. A., Adeaga, O. A., & Adigun, M. O. (2023). Investigating fuel adulteration using Arduino as an engine protection device (EPD). *Journal of Hunan University Natural Sciences, 50*(9), 107–113. https://doi.org/10.55463/issn.1674-2974.50.9.11

Aravindan, C., Kumar, G. V., Arthi, R., & Abhilash, R. (2022). A fuel level indicator using load cell through an audio feed output and location tracker for visually impaired. In *2022 International Conference on Communication, Computing and Internet of Things (IC3IoT)* (pp. 1–4). IEEE. https://doi.org/10.1109/IC3IOT53935.2022.9767892

Azzawi, B. Z. S., Al Saddaee, I. A. R., Yigit, M. E., & Ari, M. (2023). Design and implementation of photovoltaic monitoring energy system based on telecommunication power base station application. *International Journal on Technical and Physical Problems of Engineering, 15*(2), 141–148.

Danyaya, Y. S., John, O., Ahmed, A., & Iliyasu, U. (2024). Economic viability analysis for powering base station in remote areas using diesel generator and stand-alone PV system. *International Journal of Advances in Engineering and Management, 6*(9), 42–51. https://ijaem.net/issue_dcp/Economic%20Viability%20Analysis%20for%20Powering%20Base%20Station%20in%20Remote%20Areas%20Using%20Diesel%20Generator%20and%20Stand%20Alone%20Pv%20System.pdf

Ebong, E. A. Y. (2018). *Automated system for monitoring fueling operations on telecommunication tower sites* [Master's thesis, University of Padova]. https://aims-cameroon.org/wp-content/uploads/sites/6/2021/04/Ebude_AUTOMATED-SYSTEM-FOR-MONITORING-FUELING-OPERATIONS-ON-TELECOMMUNICATION-TOWER-SITES.pdf

Kamthe, S., Bodkhe, K., Karnavat, M., Shaikh, B., & Pawar, S. S. (2020). Automatic fuel tank monitoring and leakage detection. *International Research Journal of Engineering and Technology, 7*(5), 1319–1322. https://www.irjet.net/archives/V7/i5/IRJET-V7I5258.pdf

Kuetche, C. F. M., Tsuanyo, D., & Fopah-Lele, A. (2022). Analysis of hybrid energy systems for telecommunications equipment: A case study in Buea, Cameroon. *E3S Web of Conferences, 354*, 02007. https://doi.org/10.1051/e3sconf/202235402007

Omar, M. Z. A., & Mohamad, K. A. (2023). Development of a remote monitoring system for voltage measurements in cathodic protection. *Evolution in Electrical and Electronic Engineering, 4*(1), 566–571. https://doi.org/10.30880/eeee.2023.04.01.068

Rai, N. R., Rajguru, P. D., Jagtap, A. N., & Shinde, A. S. (2020). A review on: Digital fuel level and battery life indicator. *International Engineering Research Journal, 3*(4), 6174–6177.

Somefun, T., Awosope, C., Abdulkareem, A., Ogelenya, J., Orimogunje, A., & Somefun, C. (2021). Design of a digital fuel gauge with distance-to-zero indicator. *IOP Conference Series: Materials Science and Engineering, 1036*(1), 012063. https://doi.org/10.1088/1757-899X/1036/1/012063

Tahir, M., Mustafa, S. M. N., Enam, R. N., Ismat, N., & Rizvi, H. H. (2022). Real-time monitoring and control of electrical diesel generator through Internet of Things. *Pakistan Journal of Engineering and Technology, 5*(2), 112–118. https://doi.org/10.51846/vol5iss2pp112-118

Wang, F., Yang, F., Su, C., & He, N. (2018). The design of intelligent low voltage circuit breaker remote data monitoring system. In *Proceedings of the 2018 3rd International Conference on Control, Automation and Artificial Intelligence (CAAI 2018)* (pp. 71–74). Atlantis Press. https://doi.org/10.2991/caai-18.2018.16

Yamini, N., Kumar, R. B., Mohamed, J. S., & Iyengar, N. C. S. N. (2023). Smart IoT-based system for monitoring and detecting fuel theft and fuel indication for refilling process. *International Journal of Human Computations and Intelligence, 2*(5), 247–255. https://doi.org/10.5281/zenodo.8068149