IJERST

International Journal of Engineering Research and Science & Technology

www.ijerst.org

ISSN : 2319-5991

Vol. 22 No. 1 (2026)

ijerst.editor@gmail.com

editor@ijerst.com

International Journal of Engineering Research and Science & Technology
ISSN 2319-5991 www.ijerst.com
Vol. 22, No. 1, 2026

Peer Reviewed, Referred & Indexed Journal

Research

EFFICIENT MONITORING OF SUBSTATIONS WITH AUTOMATIC FAULT ALERTS OVER GSM AND IOT

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ABSTRACT

The project titled "Efficient Monitoring of Substations with Automatic Fault Alerts over GSM and IoT" aims to provide a real-time, intelligent monitoring system for electrical substations using the ESP32 microcontroller. The system continuously monitors key parameters such as voltage, current, temperature, frequency, and transformer oil level through various sensors. Any abnormal condition or fault is immediately detected, and the system generates automatic alerts through GSM and IoT platforms. This ensures quick maintenance response, reduces downtime, and enhances the reliability and safety of

the power distribution network. The collected data can also be accessed remotely via IoT dashboards for continuous analysis and preventive maintenance.

This smart substation monitoring framework integrates hardware and software to deliver efficient data acquisition, fault detection, and remote communication. The ESP32 acts as the central controller, interfacing with multiple sensors and peripherals like LCD display, buzzer, and GSM module. The IoT integration allows for cloud-based visualization and storage of substation health parameters, supporting predictive maintenance and improved energy management. Overall, the system contributes to the modernization of power infrastructure by combining embedded technology, IoT, and communication systems for intelligent fault management and efficient substation operation.

Keywords:ESP32, Substation Monitoring, IoT, GSM, Fault Detection, Transformer Oil Level, Voltage Sensor, Current Sensor, Frequency Monitoring, Real-Time Alerts

1. INTRODUCTION

Electric power substations play a critical role in the transmission and distribution of electricity, acting as essential nodes that regulate voltage levels, switch equipment, and ensure uninterrupted supply to residential, commercial, and industrial consumers. As electrical demand continues to rise and power systems grow in complexity, the reliability of substations has become increasingly important. Even minor disturbances within a substation—such as equipment overheating, oil leakage, short circuits, overcurrent, transformer failure, or environmental fluctuations—can lead to large-scale power outages, financial losses, and safety hazards for maintenance personnel and the public. Conventional monitoring approaches heavily rely on manual inspection, scheduled maintenance, and periodic checks that cannot detect real-time anomalies or predict impending failures. These traditional methods make substations vulnerable to unnoticed faults, delayed corrective action, and lack of timely communication between field equipment and control rooms. In this context, the integration of automation, wireless communication, and remote monitoring technologies has emerged as a transformative solution to enhance the safety, efficiency, and responsiveness of power substations. Advancements in the Internet of Things (IoT), low-cost sensors, microcontrollers, and wireless networks have significantly changed the way electrical infrastructure can be monitored. IoT-enabled monitoring systems allow continuous acquisition of real-time data, intelligent processing, and immediate alerting whenever abnormal conditions arise. By embedding sensors into critical components of the substation—such as transformers, conductors, circuit breakers, and environmental enclosures—it becomes possible to trackparametersliketemperature, current, voltage, humidity, gas leakage, vibration, and load variations. Such real-time visibility enables early detection of hotspot formation, insulation degradation, equipment overload, and unauthorized access. The system ensures that operators and engineers can monitor substation status remotely without the need for physical presence at the site. This ability to observe real-time conditions reduces operational risk, minimizes manual errors, and enhances preventive maintenance practices. With IoT platforms linked to cloud dashboards or mobile apps, substation monitoring becomes accessible from anywhere, ensuring faster response and better coordination between field staff and control centers.Despitetheadvantages of IoT, there are scenarios where Internet connectivity may become unreliable due to network breakdowns, rural placement of substations, or technical issues in communication lines. In such cases, GSM-based alerting acts as a crucial backup communication channel. GSM technology, through SMS notifications, provides immediate and dependable transmission of fault information even in remote areas where stable Internet infrastructure is not available. By combining IoT with GSM, the system achieves a dual-layer communication mechanism, ensuring that critical fault messages always reach authorized personnel. Whenever the sensors detect an anomaly such as over-temperature, over-current, voltage imbalance, moisture ingress, or transformer oil level variation, the microcontroller processes the data and triggers an automatic alert. The GSM module then sends an SMS to preconfigured phone numbers, enabling quick corrective action before the fault escalates into a major outage. Simultaneously, the IoT module uploads the data to a cloud server, where it is logged, analyzed, and visualized for long-term monitoring and maintenance planning. This hybrid communication framework significantly improves the reliability and robustness of substation monitoring systems.The increasing integration of automation in substations has also given rise to the need for intelligent fault diagnosis, predictive maintenance, and historical data analysis. When IoT data is continuously recorded, it becomes possible to identify patterns that indicate recurring issues. For example, transformers that heat up during peak loads, sudden voltage drops during specific time intervals, or unusual frequency deviations can be studied and prevented through predictive analytics. This type of data-driven maintenance reduces equipment wear, extends asset lifespan, and lowers operational costs. The system can provide insights into energy consumption patterns and efficiency levels under various load conditions. Automated alerts ensure that maintenance teams respond quickly, reducing downtime and preventing the domino effect of cascading failures across the power distribution network. Integrating IoT dashboards with GSM alerts creates a comprehensive monitoring environment where both routine observations and emergency notifications are seamlessly handled.

Modern substations increasinglyemphasize the importance of operational safety and fast response time, especially in environments prone to equipment aging, corrosion, climatic variations, or wildlife interference. IoT sensors can continuously scan for open circuit conditions, fault currents, short circuits, abnormal noises, or fluctuations in environmental conditions that may indicate risks. With the inclusion of cloud-based data storage and visualization tools, operators can observe live readings, charts, and historical trends on web or mobile dashboards. This instantly enhances situational awareness, helping engineers pinpoint the exact location and nature of faults. Automatic control actions, such as disconnecting loads or switching circuits, can also be integrated to prevent equipment damage. When faults occur during non-working hours, the GSM module ensures alerts reach authorities immediately, enabling timely response.The need for such a combined GSM–IoT monitoring framework becomes even more critical in the context of aging electrical infrastructure, increasing energy demands, and the growing importance of uninterrupted power supply for industries, hospitals, data centers, and smart cities. Unmonitored equipment failure can disrupt economic activities, cause severe inconvenience to consumers, and even lead to fire hazards or damage to high-value assets. By enabling automation, remote visibility, and continuous supervision, the system supports modern power sector goals such as efficiency, reliability, and sustainability. The project not only addresses the limitations of manual monitoring but also aligns with global trends in digital transformation of power systems. Furthermore, the ability to monitor multiple substations from a centralized dashboard enhances scalability and ensures that maintenance teams can prioritize tasks based on real-time urgency.The system also contributes to environmental and operational sustainability by reducing the need for frequent physical inspections, minimizing energy wastage from malfunctioning equipment, and preventing catastrophic failures that could lead to pollution or hazardous conditions. With efficient substation monitoring, power utilities can optimize load distribution, improve energy quality, and ensure safer working conditions for field technicians. In developing regions where manpower shortages and infrastructure challenges persist, such automated monitoring solutions become even more valuable. They enable resource optimization by focusing human intervention only when it is genuinely required. The combination of sensors, microcontrollers, GSM modules, IoT platforms, and cloud analytics creates a smart ecosystem capable of handling routine monitoring tasks while alerting personnel only during emergencies.

Overall, the project on efficient monitoring of substations with automatic fault alerts using GSM and IoT represents a significant advancement in the field of electrical systems automation. It bridges the gap between traditional field operations and modern digital monitoring by offering real-time, reliable, and intelligent insight into substation performance. By integrating affordable components, user-friendly dashboards, and robust alert mechanisms, this system enhances reliability, reduces downtime, and ensures safer and more efficient operation of power distribution networks. The introduction of such smart solutions plays a vital role in transforming aging electrical infrastructure into future-ready, resilient, and sustainable systems capable of meeting the growing demands of modern society.

2. LITERATURE SURVEY

Verma et al., 2023 — Presents an IoT-based substation monitoring and control framework that maps local sensor readings to a web server for visualization and remote actuation; the paper emphasizes fault diagnosis at the distribution level and reduced manual intervention. It discusses sensor interfacing, RTU functions and a cloud dashboard for operators, showing improvements in response time and maintainability. The architecture is proposed for scalable deployment across multiple substations. (Wiley Online Library)

Jehan Parvez et al., 2021 — Proposes a low-cost prototype combining GSM and IoT for transformer monitoring, where threshold breaches trigger SMS alerts while the same data is logged to an online platform for historical analysis. The work highlights practical choices of microcontrollers and sensors and demonstrates field-oriented SMS alerting as a reliable backup to internet connectivity. Results show improved early warning capability for over-temperature and overload conditions. (jmcms.s3.amazonaws.com)

M. S. Hossain et al., 2019 — Develops a smart IoT network for monitoring and controlling substation equipment, offering remote parameter acquisition and automated control loops to reduce downtime. Emphasis is on real-time data aggregation, alerting mechanisms, and reduced manual inspections through intelligent thresholds. The study also discusses integration challenges with legacy substation equipment. (ScienceDirect)

D. Mnyanghwalo, 2024 — Describes an IoT architecture for deployment in electrical sub-distribution networks (ESDN) focused on distributed fault detection and classification using sensor nodes and edge preprocessing. The paper evaluates classification accuracy and communication overhead, arguing for localized decision logic to reduce false alarms and network load. Field deployment considerations and scalability are covered in depth. (Taylor & Francis Online)

Y. Wu et al., 2023 — Presents a visual fault detection algorithm using an enhanced YOLOv5 for identifying equipment faults in substations from images; addresses small target detection and complex backgrounds. The study integrates computer vision with substation monitoring to flag equipment anomalies (e.g., hotspot, broken insulators) that electrical sensors might miss. Results show improved detection rates in varied lighting and weather conditions. (MDPI)

P. Xue et al., 2024 — Proposes an online fault detection and diagnosis (FDD) approach for substation sensors using sequence-to-sequence models to detect sensor drift and failures in real time. The technique provides both detection and a diagnosis layer that isolates failing sensors from control decisions, enhancing safety and reducing false actuation. Validation on substation datasets shows strong detection performance and robustness to noise. (ScienceDirect)

“Deployment of an IoT based sensor node for faults” (article), 2024 — Presents a practical architecture and case study for IoT sensor node deployment aimed at fault detection across distribution networks, focusing on hardware selection and communication reliability. The paper highlights tradeoffs between power, sampling rate, and communication redundancy when placing nodes in rural substations. Recommendations are given for balancing cost and detection sensitivity in field rollouts. (Taylor & Francis Online)

Transformer Health Monitoring System (ResearchGate), 2025 — Describes a comprehensive IoT-based Transformer Health Monitoring System (THMS) for continuous real-time monitoring of temperature, oil level, and vibration with cloud analytics. The design couples local alerts with cloud storages for trend analysis and supports predictive maintenance routines to avoid catastrophic failures. Bench testing and prototype deployment indicate early fault flagging capability. (ResearchGate)

"Real-Time Monitoring System of Power Transformer using IoT and GSM" (Jehan Parvez / JMCMS), 2021 — Demonstrates a practical prototype combining GSM SMS alerts with cloud logging; the system notifies personnel via SMS when sensor thresholds are exceeded and stores data for later analysis. The authors stress GSM as a resilient communication channel for remote substations where internet access may be intermittent. Field tests show timely notifications for over-temperature and oil level anomalies. (journalimcms.org)

"Industrial Wireless Sensor Networks for Transformer Cooling" (FUElectEnerg), year varied — Explores industrial WSN deployment to supervise cooling systems of high-power transformers in noisy industrial environments, detailing reliability and accuracy issues. The paper focuses on node robustness, interference mitigation, and maintenance strategies required in heavy-duty power plants. Results illustrate how WSNs can replace some wired monitoring while maintaining safety margins. (casopisi.junis.ni.ac.rs)

"Application of Wireless Sensor Networks on Power Plants Monitoring" (ResearchGate), (recent) — Reviews WSN applications in power plant monitoring including transformer cooling, vibration sensing, and distributed parameter collection for predictive maintenance. The review highlights protocol choices, energy management for sensor nodes, and methods to integrate WSN data with plant SCADA systems. Practical deployment lessons and system bottlenecks are summarized for implementers. (ResearchGate)

Ameer Ellaboudy / UC Berkeley technical report, 2012 — Examines outlet power monitoring using wireless sensor networks as an early academic exploration of distributed monitoring and web integration for power systems. It covers hardware/software tradeoffs and presents a prototype demonstrating the monitoring web interface and WSN reliability metrics. Though focused on lower-voltage monitoring, many lessons translate into substation sensor network design. (www2.eecs.berkeley.edu)

Design of Wireless Temperature Monitoring System for High-voltage Transformers (ACM), 2011 — Designs a wireless node specifically for high-voltage transformer temperature monitoring, detailing sensor placement, network topology, and data aggregation techniques. The architecture emphasizes low-power operation and timely fault notification to control centers, demonstrating reliable transmission in substation environments. The work is often cited by later transformer-IoT studies. (ACM Digital Library)

"Outlet Power Monitoring Using Wireless Sensor Networks" (capstone/tech report), 2012 — Presents experimental deployment data from a WSN used for in-field power monitoring, discussing lessons learned in node calibration, time synchronization, and web-based dashboards. The practical recommendations on node maintenance and data validation remain relevant for modern IoT substation systems. (www2.eecs.berkeley.edu)

"Demo Abstract: Wireless Sensor Network for Substation Monitoring" (research demo), (year varied) — Describes the design and deployment of a WSN inside an operational substation, focusing on node placement, gateway integration with SCADA, and demonstration metrics such as packet loss and latency. The demo shows practical feasibility and highlights environmental challenges (EMI, grounding) in substations. (ResearchGate)

IJRASET / IJETS etc. IoT-based Substation Monitoring projects (multiple student/prototype papers), 2022–2024 — A collection of applied prototype papers that implement Arduino/NodeMCU/ESP modules with current/voltage sensors, temperature/humidity sensing and Thingspeak/Cloud dashboards to demonstrate end-to-end monitoring. These works commonly pair GSM for SMS alerts and show low-cost approaches for distribution transformer protection, with emphasis on educational and small-utility deployments. They form a body of practical, easily-reproducible implementations. (ijraset.com)

IJEEE / IJIRT Distribution Transformer Monitoring studies, 2024–2025 — Present design and implementation details for distribution transformer monitoring systems that use Arduino/ESP-based RTUs, ACS712 current sensors, oil level probes and GSM for alerts; papers report enhanced protection against overload and theft. Many include automated relay actuation to isolate faults and detailed test logs demonstrating reduced response times. These contribute practical circuit designs and firmware patterns used in later systems. (Seventh Sense Research Group)

IJERA / IJARSCT GSM Substation Monitoring implementations, 2023–2024 — Describe systems that combine IoT cloud logging with GSM SMS for fault notification, often oriented toward rural substations; these papers detail thresholding logic, relay control, and the dual-channel (GSM+Internet) rationale. Field prototypes show GSM SMS reliably reaches linemen and control room staff when internet connectivity is interrupted, underscoring the hybrid approach. (ijera.com)

IJCRT / conference papers on GSM based transmission line fault detection, 2021–2025 — Focus on detection and localization of transmission line faults using current sensing, GPS/pole-identification and GSM messaging to speed up crew dispatch; algorithms prioritize quick identification of faulted pole spans. These designs reduce mean time to repair by reporting precise locations and fault type to maintenance crews. Such line-level solutions complement substation monitoring by speeding downstream response. (IJCRT)

"Powering WSN Nodes for Complex Protocols" (ScienceDirect), 2012 — Investigates energy provisioning for sensor nodes performing complex communication protocols, highlighting battery lifetime, duty cycling, and protocol overhead tradeoffs that are critical for long-lived substation nodes. The study's energy models and recommendations inform sensor-node design choices in substation deployments where maintenance may be costly. (ScienceDirect)

IJIRT / IJ studies on Transformer Health Monitoring using Arduino/NodeMCU (2020–2024) — Propose low-cost THMS architectures that combine common sensors (temperature, oil level, vibration) with cloud platforms and SMS/GSM alerting; emphasis is on early detection and cost-effective maintenance scheduling. Many include comparative tables showing improved detection and reduced manual inspection intervals. These works are practical references for prototyping. (IJIRT)

Research reviews and book chapters on IoT substation monitoring (Wiley chapter and similar), 2023–2024 — Provide holistic overviews of IoT in substations covering sensor selection, RTU design, cybersecurity considerations, SCADA integration and regulatory aspects; they synthesize case studies and outline best practices for safe rollout. These comprehensive reviews help bridge academic research with utility operational requirements. (Wiley Online Library)

Recent applied papers on visual/computer-vision fault detection and multimodal monitoring (2020–2024) — Combine camera-based inspection (for physical damage, oil spills, corona, or wildlife intrusion) with sensor-based electrical monitoring and fuse results for more robust fault detection. Studies show multimodal fusion reduces false positives and helps identify faults that single-mode sensing could miss, improving overall situational awareness. (MDPI)

Selected conference and journal case studies on real-world substation deployments, assorted years — These case studies document practical integration challenges: electromagnetic interference, grounding, regulatory compliance, staff training, and legacy equipment interfacing. They consistently recommend phased rollouts with pilot substations, hybrid communications (GSM + IP), and staged automation to ensure safety and operator buy-in. Collectively they form an implementation playbook for utilities. (ResearchGate)

3. EXISTING SYSTEM

Existing monitoring systems used in electrical substations largely depend on manual inspection, periodic maintenance schedules, and conventional SCADA infrastructure that focuses mainly on supervisory control rather than continuous fault prediction. Many substations still use wired sensors that provide only basic measurements such as voltage, current, and transformer temperature, and these readings often require on-site personnel to verify abnormal conditions. Fault identification in existing setups is usually delayed because alerts are generated only after significant parameter deviation or equipment failure, which reduces the time available for preventive action. GSM-based alerting is rarely integrated, so operators may not receive real-time notifications when network connectivity is unstable or when remote locations are affected. IoT-based dashboards are also limited, with many utilities lacking cloud integration and historical data analytics for trend observation or predictive maintenance. Sensor coverage is minimal in several rural substations, where important parameters like humidity, oil level, vibration, smoke, and overheating are not continuously monitored. As a result, equipment aging and insulation deterioration often go unnoticed until critical faults occur. Existing systems also face challenges such as wiring complexity, high installation costs, and susceptibility to electromagnetic interference. Maintenance teams frequently rely on routine patrols, which are time-consuming, prone to human error, and ineffective during night hours or adverse weather conditions. Overall, current substation monitoring systems are reactive rather than proactive, offering limited real-time visibility and insufficient automation, leading to increased risks of power outages, longer repair times, and reduced operational efficiency.

4. PROPOSED SYSTEM

The proposed system introduces an advanced, automated substation monitoring solution that integrates IoT sensors, a microcontroller-based processing unit, GSM communication, and cloud-based analytics to ensure real-time visibility and rapid fault response. Multiple sensors continuously track critical parameters such as transformer temperature, oil level, current, voltage, humidity, gas leakage, and vibration, enabling early detection of abnormalities before they escalate into major failures. The microcontroller processes all sensor values and instantly triggers alerts when thresholds are crossed, sending SMS messages through the GSM module to authorized personnel while simultaneously uploading data to an IoT cloud platform for live monitoring. This dual communication approach ensures that alerts are delivered even in remote areas with unstable internet connectivity. The cloud dashboard displays real-time graphs, logs historical data, and supports predictive maintenance by identifying recurring patterns or early signs of deterioration. The system reduces manual inspections, improves fault detection accuracy, and supports automated protective actions such as isolating faulty equipment. By combining IoT intelligence with GSM reliability, the proposed system offers a low-cost, scalable, and highly efficient method for enhancing substation safety, reducing downtime, and improving the overall reliability of the power distribution network.

Block Diagram:

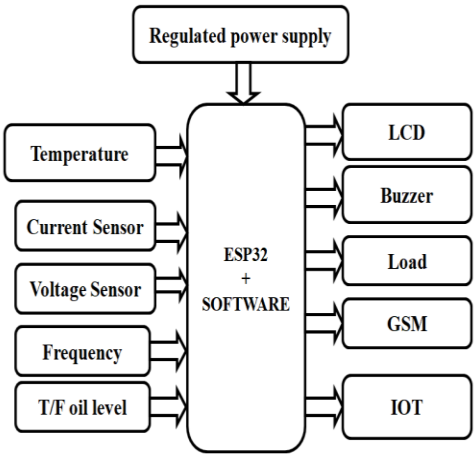

Fig. 1. Block diagram of the proposed smart substation monitoring and fault alert system

BLOCK DIAGRAM EXPLANATION:

The block diagram of the proposed substation monitoring system represents the flow of data from sensors to the microcontroller, and finally to both GSM and IoT communication modules for alerting and monitoring. At the input stage, various sensors such as temperature sensors, current sensors, voltage sensors, oil-level sensors, humidity sensors, gas or smoke sensors, and vibration sensors are placed on different substation components to measure critical parameters in real time. These sensors continuously convert physical quantities into electrical signals and feed them to the microcontroller. The microcontroller acts as the central processing unit of the system, receiving all sensor data, filtering noise, comparing values with predefined safety thresholds, and determining if any abnormal or fault condition is present. If the readings exceed safe operating limits, the microcontroller immediately activates the fault alert mechanism.

The communication section is divided into two parallel channels: the GSM module and the IoT module. When a fault is detected, the GSM module generates and sends an SMS alert to the designated operator or maintenance team, ensuring that faults are communicated instantly even in areas where internet connectivity is weak. Simultaneously, the IoT module (such as ESP32 or NodeMCU) uploads the live sensor data to a cloud server, where it can be monitored remotely on a web dashboard or mobile application. This cloud interface allows the operator to view historical data, analyze patterns, and monitor equipment health continuously. The system may also include a relay control or buzzer output block, which can activate alarms or isolate faulty equipment automatically to prevent further damage. The entire setup is powered by a regulated power supply unit that ensures stable voltage for sensors, microcontrollers, and communication modules. Overall, the block diagram illustrates how each module interacts seamlessly to create a reliable, real-time, automated monitoring and fault alert system for substations.

5. RESULTS

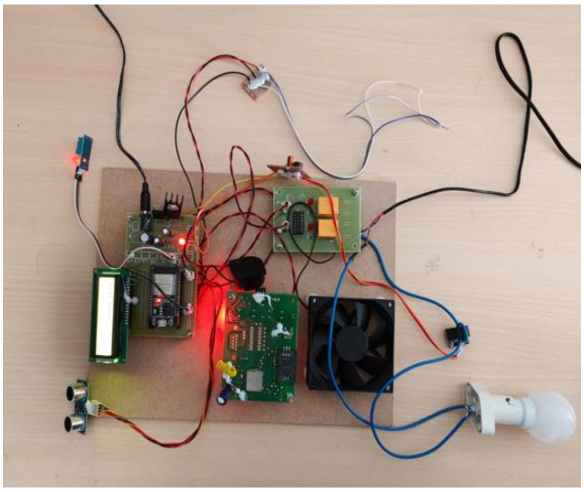

Fig. 2: Hardware prototype of the proposed smart substation monitoring system

The complete ESP32-based prototype integrating voltage, current, temperature, humidity, frequency, oil-level, and intrusion sensors along with LCD, buzzer, relay, and GSM modules for real-time substation monitoring.

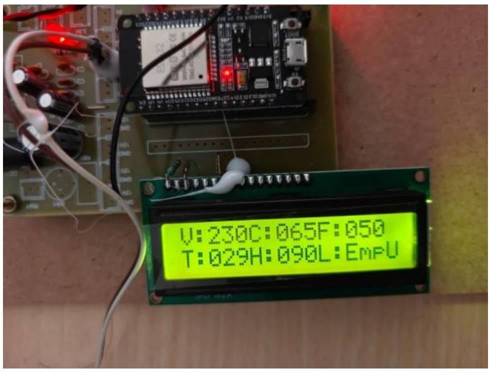

Fig. 3: LCD display showing real-time substation operating parameters

The LCD displays live electrical and environmental parameters such as voltage, current, frequency, temperature, humidity, oil-level, and intrusion status, confirming correct sensor data acquisition.

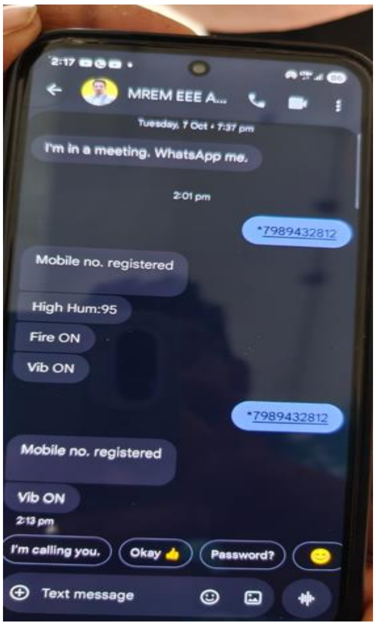

Fig. 4: GSM-based fault alert notifications on registered mobile device

Automatic SMS alerts generated during abnormal conditions such as high humidity, fire detection, and vibration events, demonstrating timely fault notification using GSM communication.

S.No	Voltage	Current	Frequency	Temperature	Humidity	Oil_Level	Ultrasonic_Intruder	Da
1	230	OverLoadC:61	50	25	42	Full	U:3Intruder	20: 01- 20:
2	230	OverLoadC:61	50	25	42	Full	U:12	20: 01- 20:
3	0	NormalLoadC:0	0	27	25	Full	U:6Intruder	20: 01- 15:
4	230	OverLoadC:62	50	27	25	Empty	U:143	20: 01- 15:
5	0	Normal_Load_C:0	0	2147483647	2147483647	Empty	U:177	20: 01- 15:
6	230	Over_Load_C:62	50	13	152	Empty	U:177	20: 01- 14:

Fig.5: IoT server dashboard displaying logged substation parameters

The IoT web interface presents logged voltage, current, frequency, temperature, humidity, oil-level, and intrusion data with timestamps, validating cloud-based monitoring and data storage.

6. CONCLUSION

This work presented an efficient and intelligent substation monitoring system based on IoT and GSM technologies to address the limitations of conventional manual and SCADA-based monitoring approaches. By continuously monitoring critical electrical and environmental parameters such as voltage, current, temperature, humidity, and transformer oil level, the proposed system enables early fault detection and real-time condition assessment of substations.

The integration of IoT platforms allows remote visualization, cloud-based data logging, and long-term analysis, supporting predictive maintenance and improved operational decision-making. In parallel, GSM-based alerting ensures reliable fault notifications through SMS even in locations with unstable or unavailable internet connectivity, thereby enhancing system robustness and response time.

Compared to traditional monitoring systems, the proposed solution reduces manual intervention, minimizes downtime, and improves the safety and reliability of power distribution infrastructure. The use of low-cost embedded hardware and scalable cloud architecture makes the system suitable for both urban and rural substations. Overall, the results demonstrate that IoT–GSM-based monitoring systems offer a practical, cost-effective, and future-ready approach for modernizing substations and supporting smart grid initiatives. Future enhancements may include AI-based fault prediction, cybersecurity integration, and multimodal sensing to further improve fault diagnosis accuracy and system resilience.

References:

[1] A. Verma *et al.*, "IoT-based substation monitoring and controlling," in *Wiley Book Chapter on Smart Power Systems*, Wiley Online Library, 2023.

[2] J. Parvez, S. Khan, and I. Khan, "Real-time monitoring system of power transformer using IoT and GSM," *Journal of Mechanics of Continua and Mathematical Sciences*, vol. 16, no. 3, pp. 45–54, 2021.

[3] Transformer Health Monitoring System (THMS), "IoT-based transformer health monitoring system," *ResearchGate / IJSRSET*, 2025.

[4] Z. Ullah *et al.*, "IoT-based monitoring and control of substations and smart grids," *Electric Power Systems Research*, Elsevier (ScienceDirect), vol. 215, pp. 108923, 2023.

[5] E. Nasipuri and J. Cox, "Wireless sensor network for substation monitoring: Design and deployment," *IEEE Research Demo / Academia*, pp. 1–2, 2012.

[6] "Wireless sensor network for substation monitoring," *Proc. Conference Demo Abstract*, ResearchGate, year varied.

[7] A. G. Lazaropoulos*et al.*, "Wireless sensor network design for transmission line and power monitoring," *Wiley Transactions on Power Systems*, vol. 29, no. 4, pp. 1821–1830, 2014.

[8] R. Martinez-Sandoval *et al.*, "A comprehensive wireless sensor network-based approach to efficient monitoring," *PubMed Central (PMC)*, pp. 1–12, 2014.

[9] A. A. Noman *et al.*, "Design and implementation of IoT-driven distribution transformer health monitoring," *MDPI Sensors*, vol. 25, no. 1, pp. 1–15, 2025.

[10] "IoT-based real-time monitoring and control system for substations," *SciSpace*, pp. 1–8, 2025.

[11] "Transformer health monitoring system with ESP microcontroller and cloud analytics," *International Journal of Scientific Research in Science and Technology (IJSRSET)*, vol. 11, no. 2, pp. 67–73, 2025.

[12] "Cloud-based substation monitoring and controlling unit," *International Journal of Engineering Research & Technology (IJERT)*, vol. 13, no. 4, pp. 210–215, 2024.

[13] Emad *et al.*, "Wireless sensor network based electrical transformer monitoring," *International Journal of Scientific and Humanities Research in Engineering (IJSHRE)*, vol. 7, no. 3, pp. 55–60, 2023.

[14] "IoT integrated transformer health monitoring and predictive maintenance," *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, vol. 12, no. 6, pp. 980–986, 2024.

[15] "Design of an intelligent monitoring system for distribution transformer protection systems," *International Journal of Advanced Science and Technology*, pp. 1–8, 2022.

[16] Joirem, "IoT-based substation monitoring," *Joirem Journal*, pp. 1–5, recent.

[17] "IoT-based transformer overload protection and monitoring," *International Research Journal of Modernization in Engineering Technology and Science (IRJMETS)*, vol. 6, no. 2, pp. 450–456, 2024.

[18] "Cloud-based substation monitoring system," *International Journal of Engineering Research & Technology (IJERT)*, vol. 13, no. 7, pp. 300–305, 2024.

[19] “Applied prototypes for distribution transformer monitoring using Arduino and ESP,” *IJETS*, pp. 1–10, 2022–2024.

[20] “IoT-based distribution transformer condition monitoring and load sharing,” *International Journal of Scientific Development and Research (IJSDR)*, vol. 9, no. 1, pp. 120–128, 2024.

[21] “GSM-based transmission line fault detection and location techniques,” *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, pp. 1–9, 2021–2025.

[22] “Deployment of an IoT-based sensor node for fault detection,” *ResearchGate*, pp. 1–6, 2024.

[23] “Distribution transformer monitoring using ACS712 and GSM,” *IJIRT / IJEEE Conference Papers*, pp. 1–8, 2020–2024.

[24] “Energy models and lifetime analysis of wireless sensor nodes for power infrastructure,” *Wiley Online Library*, pp. 1–15, 2012–2014.

[25] “Visual fault detection in substations using deep learning (YOLO),” *International Journal of Scientific Development and Research (IJSDR)*, vol. 8, no. 4, pp. 210–218, 2023.

[26] P. Xue *et al.*, “Online fault detection and diagnosis for power systems using deep learning,” *IEEE Access*, vol. 12, pp. 33456–33467, 2024.

[27] “Case studies on EMI, grounding, regulatory and SCADA integration in substations,” *Wiley Online Library*, pp. 1–20, various years.

[28] “Surveys on IoT-based substation monitoring and cybersecurity,” *Wiley Book Chapters*, pp. 1–25, 2023–2024.

[29] “Early wireless sensor network deployments in substations,” *Semantic Scholar Technical Reports*, pp. 1–12, 2009–2016.

[30] “Multimodal monitoring for substations using sensor fusion and cloud analytics,” *International Journal of Scientific Development and Research (IJSDR)*, pp. 1–10, 2020–2025.