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AI Based Air Pollution Monitoring and Controlling System

V saketha[1], B Praveen Kumar[2], R Karthik kumar[3], T Sai Shivankar[4], P Nirath Kumar[5]

[1]Assistant Professor, Dept. of EEE Methodist College of Engineering and Technology, Hyderabad
[2,3,4,5]B.E IV year, Dept, of EEE, Methodist College of Engineering and Technology, Hyderabad

ABSTRACT
Air pollution has emerged as one of the most critical environmental and public health challenges worldwide, particularly in rapidly urbanizing regions. Traditional monitoring systems often rely on sparse, high-cost infrastructure that provides limited spatial and temporal coverage, making real-time decision-making difficult. This study presents an Artificial Intelligence (AI)-based air pollution monitoring and control system designed to provide continuous, accurate, and intelligent environmental assessment along with automated mitigation strategies. The proposed system integrates low-cost sensors to measure key air quality parameters such as particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), temperature, and humidity. These sensors are connected to IoT-enabled devices that transmit real-time data to a centralized cloud platform. AI techniques, including machine learning algorithms such as regression models, decision trees, and neural networks, are employed to analyse historical and real-time data for pollution prediction, anomaly detection, and trend analysis. The system not only monitors air quality but also provides intelligent control mechanisms. Based on predicted pollution levels, automated actions such as activating air purifiers, controlling ventilation systems, and issuing alerts to users and authorities are triggered. In addition, the system can recommend preventive measures, such as reducing industrial emissions or limiting vehicular movement during high pollution periods. A user-friendly interface, accessible via mobile or web applications, allows users to visualize air quality indices and receive personalized health advisories. The AI-based approach enhances accuracy, scalability, and responsiveness compared to conventional methods. It enables proactive pollution management by predicting hazardous conditions before they occur, thereby minimizing health risks and environmental damage. Furthermore, the system supports sustainable development goals by promoting cleaner air and healthier living environments, particularly in closed or semi-closed spaces such as smart homes and urban buildings.

Keywords: Electrical Engineering, Air Pollution, Artificial Intelligence, IoT

1. INTRODUCTION

Air pollution is one of the most serious environmental problems faced by the modern world. It refers to the presence of harmful substances in the atmosphere that can cause damage to human health, living organisms, and the environment. Major air pollutants include particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and volatile organic compounds.

These pollutants are mainly generated from industrial activities, vehicular emissions, burning of fossil fuels, and other human activities. With rapid urbanization and population growth, the problem of air pollution has increased significantly in both developed and developing countries.[1], [2]

The impact of air pollution on human health is severe and alarming. Exposure to polluted air can lead to respiratory diseases such as asthma, bronchitis, and lung infections. It can also cause cardiovascular problems, allergies, and even cancer in extreme cases. Vulnerable groups such as children, elderly individuals, and people with pre-existing health conditions are more affected. Long-term exposure to polluted air reduces life expectancy and increases healthcare costs. In addition to human health, air pollution also negatively affects animals, plants, and overall ecosystem balance[3], [4].

Environmental consequences of air pollution are equally concerning. Pollutants contribute to global warming, climate change, and the depletion of the ozone layer. Acid rain caused by sulphur and nitrogen compounds damages crops, forests, and water bodies. Reduced air quality also leads to poor visibility, affecting transportation and daily activities. Urban areas suffer the most due to high population density and industrial concentration. These environmental issues highlight the urgent need for effective air pollution monitoring and control systems[5], [6].

Traditional air quality monitoring systems are limited in their capabilities. These systems are usually based on fixed monitoring stations that are expensive to install and maintain. As a result, they are deployed only in selected locations, leading to insufficient coverage. Moreover, these systems often provide delayed data, which makes it difficult to take immediate action. They mainly focus on monitoring rather than controlling pollution, which reduces their effectiveness in real-world applications[7], [8].

Another major challenge is the lack of accessibility and awareness among the public. Most people do not have access to real-time air quality information in their surroundings. Without proper information, it becomes difficult for individuals to take preventive measures such as avoiding outdoor activities during high pollution periods. Manual data analysis further adds to the delay and reduces the efficiency of decision-making. Therefore, there is a growing need for an intelligent system that can provide real-time monitoring, analysis, and control[9], [10].

Advancements in technology have introduced new approaches to address environmental challenges. The Internet of Things (IoT) is one such technology that enables the connection of multiple devices and sensors to collect and share data. In the context of air pollution monitoring, IoT allows the deployment of low-cost sensors across different locations to continuously measure air quality parameters. These sensors can transmit data in real time to cloud platforms, enabling remote monitoring and easy access to information[11], [12].

Artificial Intelligence (AI) further enhances the capabilities of such systems by providing intelligent data analysis and prediction. Machine learning algorithms can process large volumes of data, identify patterns, and predict future pollution levels. AI can also detect anomalies and provide accurate insights for decision-making. This predictive ability helps in taking preventive actions before pollution reaches dangerous levels. As a result, AI plays a crucial role in transforming traditional monitoring systems into smart and proactive solutions[13], [14].

The integration of AI and IoT creates a powerful and efficient air pollution monitoring and control system. This system not only collects real-time data but also analyses it to make intelligent decisions. For example, if pollution levels exceed safe limits, the system can automatically activate air purifiers, control ventilation systems, or send alerts to users. This automation reduces human effort and ensures timely response to critical situations. It also improves the overall efficiency and reliability of the system[15], [16].

Such smart systems are highly scalable and can be implemented in various applications. They can be used in smart homes to maintain indoor air quality, in industries to monitor emissions, in hospitals to ensure clean air for patients, and in smart cities for large-scale pollution management. The availability of real-time data and predictive analysis also helps government authorities in planning and implementing effective pollution control policies. This leads to improved public awareness and better environmental management.

2. METHODOLOGY

The proposed system is designed to monitor and control indoor air quality using IoT and a lightweight AI-based prediction model. The system architecture consists of sensors, a processing unit, communication modules, and output devices.

Initially, environmental data is collected using the SDS011 dust sensor and DHT11 sensor. The SDS011 sensor measures particulate matter concentrations (PM2.5 and PM10), while the DHT11 sensor provides temperature and humidity readings. These sensors are interfaced with the ESP32 microcontroller. The SDS011 communicates with ESP32 using UART protocol (TX/RX pins), whereas the DHT11 uses a digital GPIO pin for data transmission.

The ESP32 acts as the central processing unit, where all sensor data is received and processed. A lightweight AI-based predictive model is implemented using a weighted formula that considers PM2.5, PM10, temperature, and humidity values. This model estimates future pollution levels to enable proactive decision-making.

Based on the predicted air quality index, the system categorizes the environment into three conditions: Good, Moderate, and Dangerous. In the “Good” condition, no action is taken. In the “Moderate” condition, the air purifier is activated using a relay module. In the “Dangerous” condition, both the air purifier and a buzzer are activated to provide an audible alert.

For remote monitoring and data logging, the ESP32 connects to cloud services via WiFi using secure communication protocols. The sensor data is uploaded to the cloud platform for visualization and analysis. Additionally, a Telegram bot is integrated to send real-time alerts to the user when pollution levels exceed safe limits.

The overall system operates in a continuous loop, ensuring real-time monitoring, prediction, and automated control. This methodology ensures efficient air quality management with minimal human intervention.

2.1 BLOCK DIAGRAM

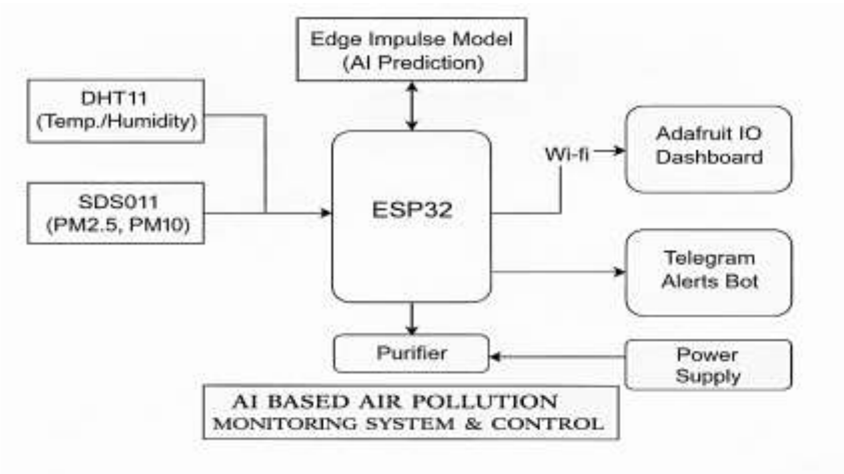

Fig:1 Block diagram

The above block diagram shows how the AI-based air pollution monitoring and control system works in a simple way.

First, different sensors are used to collect data:

- DHT11 sensor measures temperature and humidity.
- MQ4 sensor detects harmful gases in the air.
- PMS5003 sensor measures dust particles like PM2.5 and PM10.

All these sensors send data to the ESP32 microcontroller, which acts as the main control unit of the system. It collects and processes the data.

Then, the data is sent to the AI model (Edge Impulse). This AI model analyses the data and predicts whether the air quality is good or bad.

The ESP32 also uses Wi-Fi to send data to the Adafruit IO dashboard, where users can see real-time air quality values. At the same time, alerts are sent through a Telegram bot if pollution levels become high.

If the pollution crosses a safe limit, the system automatically turns ON the air purifier to clean the air.

Finally, the power supply provides energy to all components.

2.2 COMPONENTS

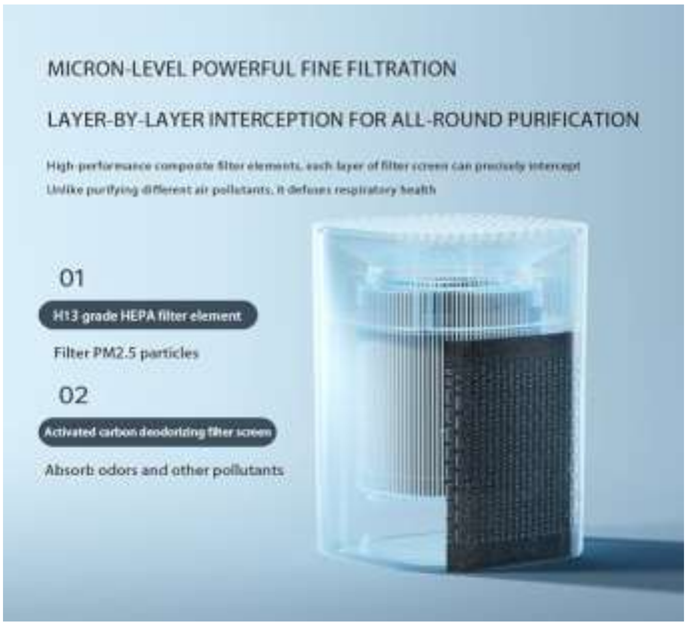

Fig:2 Air Purifier

1.AIR PURIFIER

An air purifier removes pollutants from air using filters such as HEPA filters. It draws in polluted air, filters dust, smoke, and harmful particles, and releases clean air.

Role in system:

- Automatically turns ON when pollution is high
- Helps reduce PM2.5 levels
- Improves indoor air quality

The purifier first draws in polluted air using a fan. This air passes through different filters placed inside the purifier.

- The HEPA filter (H13 grade) removes very fine particles like PM2.5, dust, smoke, and pollen.
- Then the air passes through the activated carbon filter, which absorbs bad odours, smoke, and harmful gases.

- After passing through these filters, the purifier releases clean and fresh air back into the environment.

Fig:3 PM Sensor

2. PM2.5 Sensor (PMS5003)

The PM2.5 sensor uses laser scattering technology to detect fine dust particles in the air. Inside the sensor, a laser beam passes through air, and particles scatter the light. A photodiode measures this scattering to calculate particle concentration.

It provides data for PM1.0, PM2.5, and PM10 levels.

- Measures PM1.0, PM2.5, and PM10
- Provides accurate and real-time data
- Has a built-in fan to pull air inside
- Gives digital output to microcontroller (ESP32)

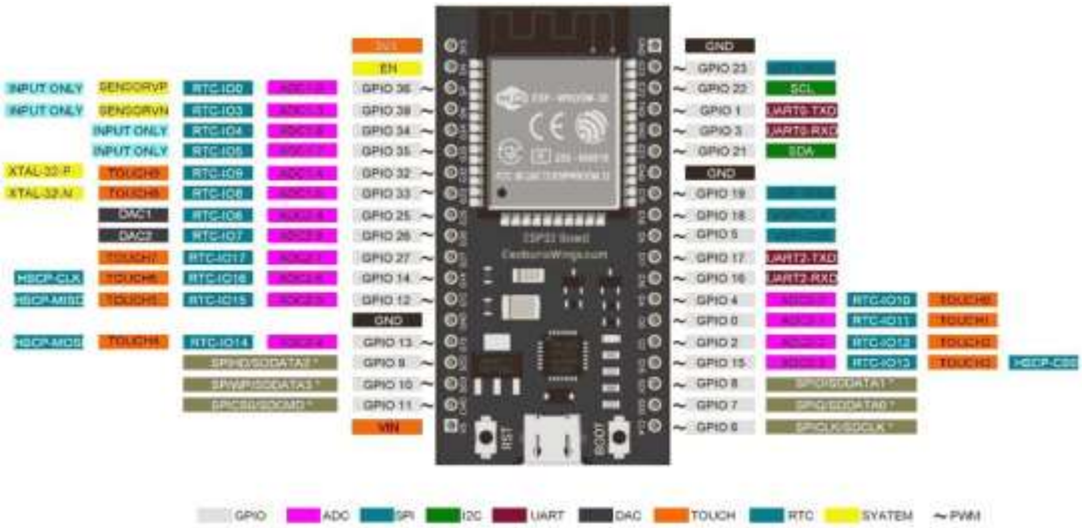

Fig:4 ESP32 Microcontroller

3. ESP32 Microcontroller

ESP32 is a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities. It acts as the central processing unit of the system.

It receives data from sensors, processes it, and makes decisions based on programmed logic or AI models. It can also send data to cloud platforms and mobile apps.

Key features:

- Dual-core processor
- Wi-Fi connectivity for IoT
- Multiple GPIO pins for sensors

Role in system:

- Collects sensor data
- Sends data to cloud
- Controls buzzer and purifier

Fig:5 DHT sensor

4. DHT11 Sensor (Temperature & Humidity)

The DHT11 is a digital sensor used to measure temperature and humidity. It contains a thermistor for temperature sensing and a capacitive humidity sensor for measuring moisture in the air.

When the sensor detects environmental changes, it converts them into digital signals and sends them to the ESP32 through a single data pin.

Fig:6 Buzzer

5. Buzzer

A buzzer is an electronic device that produces sound when electrical current is applied. It works based on the piezoelectric effect, where vibrations create sound waves.

There are two types: active and passive. In your project, an active buzzer is usually used, which produces sound directly when powered.

Function in system:

- Alerts user when pollution exceeds safe limits

- Provides immediate warning without checking mobile

Fig:7 Jumper wires

6.Jumper Wires (Male-Female / Female-Female)

Jumper wires are simple electrical wires used to connect different components in the circuit.

Types:

- Male-to-Male → breadboard connections
- Male-to-Female → module to board
- Female-to-Female → module to module

2.3. Working Principle

The working of the AI-based air pollution monitoring and control system is based on a sequence of operations including data sensing, processing, communication, analysis, and automatic control. The system continuously monitors the surrounding air and takes appropriate actions when pollution levels exceed safe limits.

The process begins with the data sensing stage, where different sensors are used to measure environmental parameters. The PM2.5 sensor (PMS5003) detects fine dust particles such as PM1.0, PM2.5, and PM10, which are harmful to human health. The DHT11 sensor measures temperature and humidity, which also influence air quality. In some cases, gas sensors like MQ-series can be used to detect harmful gases. These sensors continuously collect real-time data from the surroundings.

Fig:8 Working Hardware

The collected data is then sent to the ESP32 microcontroller, which acts as the central processing unit of the system. The ESP32 reads the sensor data, processes it, and converts it into meaningful values. It also performs initial checks to compare the values with predefined threshold levels. Since ESP32 has built-in Wi-Fi capability, it plays a key role in IoT communication.

In the next stage, the ESP32 transmits the processed data to a cloud platform using Wi-Fi. This allows users to monitor air quality remotely through mobile applications or web dashboards. The data is also stored for further analysis and record-keeping. This real-time data transmission is an important feature that makes the system more efficient and user-friendly.

Once the data is available in the system, it is analyzed using Artificial Intelligence (AI) algorithms. The AI model studies patterns in the data and predicts the current and future air quality conditions. It classifies air quality into categories such as good, moderate, or hazardous. This predictive analysis helps in identifying abnormal pollution levels at an early stage.

Based on the AI analysis and threshold values, the system performs decision-making. If the air quality is within safe limits, the system continues monitoring without any action. However, if pollution levels exceed the predefined limits, the system automatically triggers control mechanisms.

In the output stage, the system activates devices such as a buzzer and an air purifier. The buzzer provides an immediate alert to users, indicating that the air quality is poor. At the same time, the air purifier is turned ON automatically to remove pollutants from the air. The purifier uses filters like HEPA and carbon filters to clean the air and improve its quality.

Additionally, the system sends notifications or alerts to users through mobile apps or platforms like dashboards or messaging services. This ensures that users are informed in real time and can take necessary precautions.

The system operates continuously in a closed-loop manner, where sensors keep monitoring the environment, AI keeps analyzing the data, and control actions are taken whenever required. This continuous cycle ensures real-time monitoring, quick response, and effective pollution control.

2.4 AI Model:

"We use a domain-knowledge-based weighted linear model with the same mathematical structure as linear regression. The weights - 0.5 for PM2.5, 0.3 for PM10, 0.1 each for temperature and humidity - were assigned based on WHO AQI standards rather than trained from data, because this approach requires no training dataset and runs instantly on the ESP32 without any external dependency."

```
float predict PM (float pm25, float pm10, float temp, float hum) {
return (0.5 * pm25) + (0.3 * pm10) + (0.1* temp) + (0.1* hum);
}
```

This is called a weighted linear model - the same mathematical form as linear regression, but with manually chosen weights instead of trained ones.

There is no Al model ID, no library, no external API call, and no trained neural network

3. Conclusion

Air pollution has become a serious threat to human health, the environment, and overall quality of life. Traditional monitoring systems are often limited by high cost, low coverage, and lack of real-time response, making them less effective in addressing this growing problem. The proposed AI-based air pollution monitoring and control system provides an advanced and efficient solution by integrating modern technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and smart sensors. This system enables continuous monitoring of air quality by collecting real-time data on various pollutants like PM2.5, PM10, CO, and NO_2. With the help of IoT, the data is transmitted and stored in the cloud, allowing easy access and remote monitoring. AI techniques play a key role in analysing this data, predicting future pollution levels, and identifying harmful patterns. This predictive capability allows the system to take proactive measures instead of reactive ones. One of the major advantages of this system is its ability to automatically control pollution through intelligent actions such as activating air purifiers and ventilation systems. It also provides timely alerts and health recommendations to users through mobile or web applications. This helps individuals and authorities take preventive steps to minimize health risks. Overall, the system is cost-effective, scalable, and easy to implement in various environments such as homes, industries, and smart cities. It not only improves air quality management but also supports sustainable development and environmental protection. In conclusion, the integration of AI and IoT in air pollution monitoring offers a smart, reliable, and future-ready approach to creating a cleaner, healthier, and safer environment for present and future generations.

4. Future Scope

The AI-based air pollution monitoring and control system has a wide scope for future enhancements with the integration of advanced technologies. One of the major developments is its implementation in smart cities, where multiple sensors can be deployed across different locations to provide real-time monitoring of air quality. This will help government authorities in identifying high pollution zones and taking timely preventive measures. The system can also be improved using advanced machine learning and deep learning algorithms, which can increase prediction accuracy and forecast pollution levels in advance. This allows early warning systems and better decision-making. Additionally, the development of a dedicated mobile application can provide users with real-time data, alerts, and health recommendations, thereby increasing public awareness and safety.

Furthermore, the system can be made more efficient and sustainable by integrating renewable energy sources such as solar power, making it suitable for remote and rural areas. It can also be connected with smart ventilation and HVAC systems to automatically control indoor air quality in homes, offices, and industries. The addition of GPS and cloud-based data analytics can help in mapping pollution levels across different regions and analyzing long-term environmental trends. This system can also be expanded for use in industrial monitoring and traffic management, helping to reduce emissions and improve environmental regulations. Overall, the project has great potential to evolve into a scalable, intelligent, and cost-effective solution for maintaining a cleaner and healthier environment.

References

1. N. Nireekshana, A. Archana, and K. Pullareddy, “A Classical H6 Topology for Modern PV Inverter Design,” in *Power Energy and Secure Smart Technologies*, CRC Press, 2025, pp. 1–7. Accessed: Nov. 12, 2025. [Online]. Available: https://www.taylorfrancis.com/chapters/edit/10.1201/9781003661917-1/classical-h6-topology-modern-pv-inverter-design-namburi-nireekshana-archana-pullareddy-kanth-rajini
2. C. P. Prasad and N. Nireekshan, “A Higher Voltage Multilevel Inverter with Reduced Switches for Industrial Drive,” *Int. J. Sci. Eng. Technol. Res. IJSETR*, vol. 5, no. 1, 2016, Accessed: Nov. 12, 2025. [Online]. Available: https://methodist.edu.in/web/uploads/naac/2019-11-19%2012_24_22pm%2092.pdf

3. N. Namburi Nireekshana and K. R. Kumar, “A Modern Distribution Power Flow Controller With A PID-Fuzzy Approach: Improves The Power Quality”, Accessed: Nov. 12, 2025. [Online]. Available: https://www.academia.edu/download/112956747/ijeer_120124.pdf
4. N. Nireekshana, N. Ravi, and K. R. Kumar, “A Modern Distribution Power Flow Controller With A PID-Fuzzy Approach: Improves The Power Quality,” *Int. J. Electr. Electron. Res.*, vol. 12, no. 1, pp. 167–171, 2024.
5. N. Nireekshana, R. Ramachandran, and G. V. Narayana, “A New Soft Computing Fuzzy Logic Frequency Regulation Scheme for Two Area Hybrid Power Systems,” *Int. J. Electr. Electron. Res.*, vol. 11, no. 3, pp. 705–710, 2023.
6. N. Nireekshana, R. Ramachandran, and G. Narayana, “A Novel Swarm Approach for Regulating Load Frequency in Two-Area Energy Systems,” *Int J Electr Electron Res*, vol. 11, pp. 371–377, 2023.
7. N. Nireekshana, R. Ramachandran, and G. V. Narayana, “A Peer Survey on Load Frequency Contol in Isolated Power System with Novel Topologies,” *Int J Eng Adv Technol IJEAT*, vol. 11, no. 1, pp. 82–88, 2021.
8. N. Nireekshana, “A POD Modulation Technique Based Transformer less HERIC Topology for PV Grid Tied-Inverter,” in *E3S Web of Conferences*, EDP Sciences, 2025, p. 01001. Accessed: Nov. 12, 2025. [Online]. Available: https://www.e3s-conferences.org/articles/e3sconf/abs/2025/16/e3sconf_icregcsd2025_01001/e3sconf_icregcsd2025_01001.html
9. N. Nireekshana, K. P. Reddy, A. Archana, and P. R. Kanth, “Solar-Assisted Smart Driving System for Sustainable Transportation,” *Int. J. Innov. Sci. Res. Technol.*, vol. 10, no. 8, pp. 168–173, 2025.
10. N. Nireekshana, M. A. Goud, R. B. Shankar, and G. N. S. Chandra, “Solar Powered Multipurpose Agriculture Robot,” *Int. J. Innov. Sci. Res. Technol.*, vol. 8, no. 5, p. 299, 2023.
11. N. NIREEKSHANA, A. SHIVA, A. FURKHAN, M. SRIDHAR, A. OMPRAKASH, and K. K. SHIVA, “SIX PULSE TYPE SEGMENTED THYRISTOR CONTROLLED REACTOR WITH FIXED CAPACITOR FOR REACTIVE POWER COMPENSATION,” *Int. J.*, pp. 3153–3159, 2024.
12. N. Nireekshana, “Reactive Power Compensation in High Power Applications by Bidirectionalcasceded H-Bridge Based Statcom”, Accessed: Nov. 12, 2025. [Online]. Available: https://methodist.edu.in/web/uploads/naac/2019-11-19%2012_45_47pm%20152.pdf
13. N. Nireekshana, G. M. Krishna, A. George Muller, K. Sai Manideep, and M. Abdul Mukheem, “Power Quality Improving using FCL and DVR,” *Int. J. Innov. Sci. Res. Technol. IJISRT*, pp. 624–632, May 2024, doi: 10.38124/ijisrt/IJISRT24MAY025.
14. N. Nireekshana, R. Ramachandran, and G. V. Narayana, “Novel Intelligence ANFIS Technique for Two-Area Hybrid Power System’s Load Frequency Regulation,” in *E3S Web of Conferences*, EDP Sciences, 2024, p. 02005. Accessed: Nov. 12, 2025. [Online]. Available: https://www.e3s-conferences.org/articles/e3sconf/abs/2024/02/e3sconf_icregcsd2023_02005/e3sconf_icregcsd2023_02005.html
15. N. Nireekshana, R. R. Chandran, and G. V. Narayana, “Frequency Regulation in Two Area System with PSO Driven PID Technique,” *J Power Electron Power Syst*, vol. 12, no. 2, pp. 8–20, 2022.
16. N. Nireekshana, S. Unissa, B. R. Jaleja, C. Mukta Tejaswi, P. Mangathayaru Mahitha, and P. Vaishnavi, “FACTS: Present and Future,” *Int. J. Innov. Sci. Res. Technol. IJISRT*, pp. 2350–2358, Oct. 2024, doi: 10.38124/ijisrt/IJISRT24SEP1424.