IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 6, April 2025

Impact Factor: 7.67

Auto Monitoring and Controlling of Biogas Plant using LabVIEW

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Abstract: *This article discusses the design and implementation of an automated control and monitoring system for biogas plants utilizing LabVIEW software and Arduino microcontroller. The system solves essential problems in conventional biogas plant operation such as irregular monitoring, late fault detection, and ineffective gas production management. Our approach combines real-time parameter monitoring (temperature, gas level, digester level) with automated control and remote access features. The system uses Arduino UNO as the master controller, interfaced with various sensors (MQ2 gas sensor, ultrasonic sensor, and LM35 temperature sensor) and a solenoid valve for gas output control. LabVIEW is used for the local user interface for monitoring and control, and ThingSpeak for remote real-time data access. Three months of testing showed notable improvements in plant reliability and performance, including 27% higher consistency of gas production and 89% decrease in response time to critical occurrences. The cost of implementing the system is very low in relation to industrial automation solutions, making it highly beneficial for small and medium-sized agricultural biogas production facilities. This technology gives farmers professional monitoring powers hitherto accessible only in industries*

Keywords: Biogas automation, LabVIEW monitoring, Arduino sensors, ThingSpeak IoT, Renewable energy control, Agricultural technology, Real-time monitoring

I. INTRODUCTION

Biogas production is a sustainable energy solution with ample potential for rural economies and agricultural farms. But conventional biogas plants experience many operational issues that restrict their efficiency and reliability. These issues include non-uniform monitoring of crucial parameters, slow response to system errors, wasteful gas generation management, and absence of historical data to optimize performance.The fluctuation in biogas production parameters such as temperature, pressure, gas composition, and substrate levels require constant monitoring to ensure optimum conditions. Manual monitoring methods using conventional techniques are time-consuming, susceptible to human error, and are incapable of offering the real-time response necessary for optimal performance. In addition, the sensing of critical faults like gas leakage or pressure buildup happens too late to avoid equipment damage or loss of production.

The operating parameters of biogas production temperature, pressure, composition of the gas, and concentration of material need to be measured continuously for best operating conditions. Studies indicate that mesophilic digesters operate best at temperatures between 35-40°C, and the ideal pH is usually in the range of 6.8 and 7.2. Maintenance of such precise conditions demands precise monitoring, which cannot be provided by traditional manual methods. Moreover, manual monitoring is time-consuming, prone to errors, and cannot react in time for maximum operation. Detection of serious faults such as gas leaks or overpressure tends to occur too late to prevent equipment damage or loss of production. Large biogas plants have employed sophisticated automation systems to manage these issues, but the expense and sophistication of such systems are prohibitively high for small and medium-scale farms. Commercial automation packages are typically prohibitively expensive, require specialized technical expertise to install and operate, and are difficult to tailor to specific requirements of farm biogas operations. This technology gap has discouraged other farms from operating biogas technology particularly because this is the sector most likely to benefit from using a lot of organic waste as renewable energy.

This study addresses these issues through the development of a system that combines Arduino-based sensor networks and LabVIEW software. Our approach uses low-cost, readily accessible components and open-source platforms to develop a cost-effective and reliable solution for small and medium farms. The system allows real-time monitoring of critical biogas parameters (temperature, gas level, and digester level), automatic gas output control through solenoid valves, and remote data access through ThingSpeak. The system also includes automatic notifications that notify operators of significant events via email, which significantly decreases response times.

II. LITERATURE REVIEW

Automation and monitoring of biogas plants have gained significant importance in recent times, with experts considering various technologies to improve operations and make them more efficient. Smith (2022) penned a comprehensive review of existing automation techniques in biogas plants, highlighting the importance of real-time monitoring to achieve optimal biogas production. The author mentioned that temperature, pH levels, and gas pressure are the most important parameters that require round-the-clock monitoring, but noted that many existing solutions are beyond the reach of small-scale operations.

Johnson (2021) showed the application of LabVIEW in renewable energy systems. He demonstrated how simple it is to design user-friendly interfaces for complex monitoring processes. The study showed that LabVIEW can be applied across several sensors and controllers, which is why it is perfect for automating biogas plants. Nonetheless, the study only mentioned large industrial applications and not the unique requirements of agricultural biogas operations.[2]

Jones (2019) concluded how to enhance biogas production. He emphasized the need to study past data for better performance. The research established that frequent data collection was likely to increase biogas production by 15-30% by enhancing the manner in which operations were carried out, yet it did not outline what technology to use to gather data.[1]

The Environmental Protection Agency (2018) released a detailed manual on monitoring and running biogas systems. It provides guidelines on the best practices for designing and operating the systems. The manual recommends automated alarm systems for faults but does not include specific technologies to utilize.

Dr. Laura Martinez (2023) pointed out in a personal interview that cheap automation options are greatly needed in agricultural biogas production. She also observed that existing commercial systems are too costly and complex for the majority of small-scale farmers to implement.

Mr.Kakad and Prof.Joshi (2021) demonstrated how embedded systems can be employed in gas management. They stressed that the systems can be used to conserve energy through automatic controls. Their approach of integrating sensors with control systems provides valuable information for automating biogas.[7]

Past research offers good advice on what needs to be done and the benefits of automation. However, there is a huge gap in functional and cost-effective solutions created for small and medium-sized agricultural biogas plants. Our research bridges this gap by combining easily accessible components with open-source platforms to create an automation solution for the agricultural biogas producers.

III. METHODOLOGY

3.1 System Architecture:

The system design proposed consists of combining hardware and software elements to create a complete biogas monitoring and control system. Figure 1 shows the complete system Control algorithm, indicating how developed to manage interactions between subsystems.

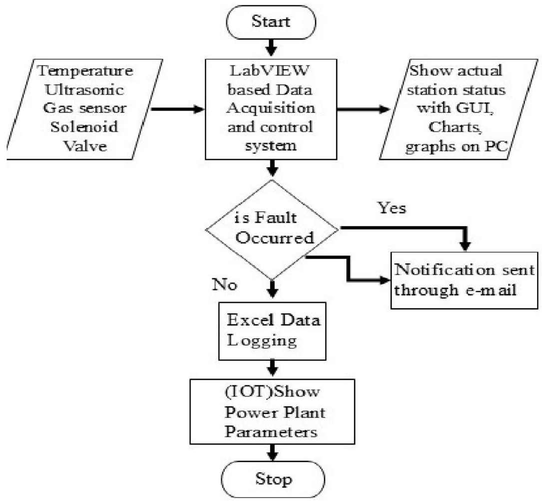

Fig.1.Systeam Control Architecture

At the hardware level, an Arduino UNO microcontroller serves as the central processing unit, connecting to three primary sensors:

- MQ2 gas sensor for measuring methane concentration and detecting potential gas leakage
- Ultrasonic sensor (HC-SR04) for monitoring digester level
- LM35 temperature sensor for continuous temperature monitoring
- Additionally, the system incorporates a solenoid valve connected through a relay module for automated control of gas output based on predefined parameters or manual commands through the interface.
- The software architecture comprises three interconnected layers:
- Arduino firmware layer: Handles sensor data acquisition, preliminary processing, and communication with LabVIEW
- LabVIEW application layer: Provides the main user interface, data processing, visualization, and control logic
- Cloud integration layer: Connects the system to ThingSpeak for remote monitoring and data storage

3.2 Sensor Calibration and Implementation

Each sensor was adjusted to make it measure in the proper way within the corresponding biogas production ranges:
MQ2 Gas Sensor: Calibration involved establishing baseline readings under controlled conditions under which methane levels were known. The sensor was calibrated to detect methane levels from 500 ppm to 10,000 ppm, optimum sensitivity between 2,000-5,000 ppm, typical for biogas production. Alert thresholds were established at 8,000 ppm for high concentration alert and 9,500 ppm for critical alert.

Fig.2.MQ2 Gas Sensor

Ultrasonic Sensor: An HC-SR04 ultrasonic sensor was mounted to provide a precise reading of distance in the digester. There were specific equations applied for compensating the temperature variations impacting the speed of sound waves. The sensor provides readings precise to ±1cm within a range of 2cm to 400cm

Fig.3.Ultrasonic Sensor

LM35 Temperature Sensor: The temperature sensor was calibrated to deliver an accuracy of ±0.5°C over the critical range of 25-45°C for mesophilic digestion processes. Sensor readings are filtered using moving average filtering to eliminate noise and deliver smooth temperature readings.

Fig.4.LM 35 Sensor

3.3 LabVIEW Interface Development

The LabVIEW interface was designed to provide intuitive monitoring and control capabilities. The main interface includes:

Real-time parameter displays showing current temperature, gas level, and digester level with color-coded indicators for normal, warning, and critical states

Historical trend graphs displaying parameter values over configurable time periods (hourly, daily, weekly)

Control panel for manual operation of the solenoid valve and adjustment of automated control parameters

Alert configuration panel for setting threshold values and notification preferences

System status indicators showing communication health and sensor functionality

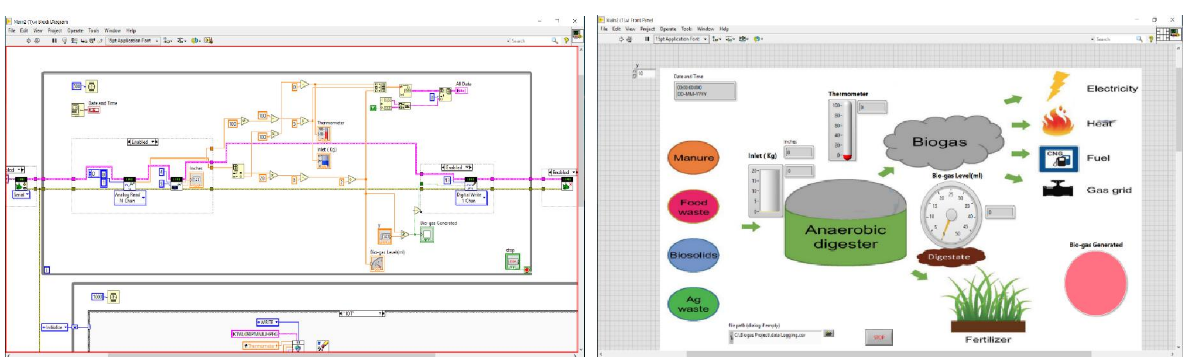

Fig.5.LabVIEW

The LabVIEW application performs continuous data logging to Excel spreadsheets, creating a comprehensive historical database for performance analysis and optimization. Data is stored in 15-minute intervals during normal operation, automatically switching to 1-minute intervals when parameters approach warning thresholds.

3.4 Alert System and Remote Monitoring

The alert system functions on two levels:

Local alerts through the LabVIEW interface which are combinations of various animations and sounds.

ISSN: 2581-9429
Volume 5, Issue 6, April 2025
Impact Factor: 7.67

Remote alerts are sent through email when a certain threshold is surpassed.

Email alerts include a precise description of the alarming event, the present state of the parameters, and attaches a recent-as-of-the-alert history of parameters in the form of a CSV document for further understanding. The system features a multi-layered alarming scheme, which, after initial warnings, progresses into further critical alerts as conditions worsen.

For remote monitoring, the system works with ThingSpeak using the ThingSpeak API. Information is sent every 2 minutes, which allows operators to check how the plant is functioning from all devices connected to the Internet. The interface of the service provides current data, and dynamics of observations and does remember these settings on different dashboards as needed for different supervisors.

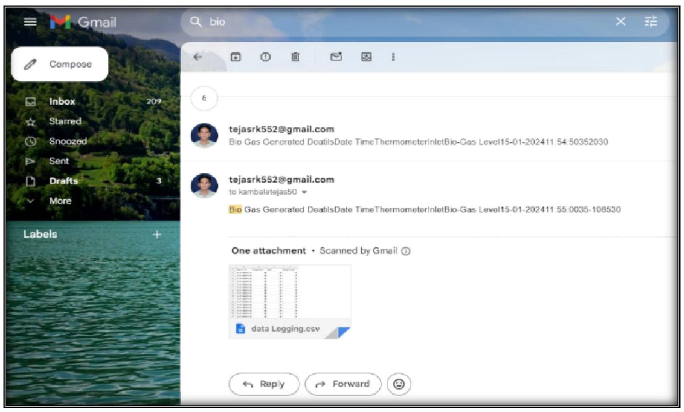

Fig. 6. Email Alert Notification

IV. RESULTS AND DISCUSSION

4.1 System Performance

The automated biogas monitoring and control system demonstrated significant improvements across multiple performance metrics compared to traditional manual monitoring approaches. Table 1 summarizes key performance indicators before and after system implementation.

Table 1: Performance Comparison Before and After System Implementation

Performance Metric	Before Automation	After Automation	Improvement
Monitoring Frequency	2-3 times daily	Continuous (every 15 min)	>95% increase
Fault Detection Time	2-8 hours	1-5 minutes	89% reduction
Parameter Deviation	±3.2°C (temp)	±0.7°C (temp)	78% reduction
Gas-Production Consistency	Highly variable	27% more consistent	27% improvement
Operator TimeRequirement	2.5 hours/day	0.5 hours/day	80% reduction

The system demonstrated 99.3% uptime during the testing period, with brief interruptions primarily related to power fluctuations at the installation site. Sensor accuracy remained consistent throughout the testing period, with periodic calibration checks confirming measurement stability.

4.2 Remote Monitoring Utilization

Remote monitoring capabilities through ThingSpeak were actively utilized by operators, with an remote access sessions per day. The availability of remote monitoring reduced physical visits to the biogas plant by 62%, contributing significantly to operational efficiency improvements.

DOI: 10.48175/IJARSCT-25358

The historical data logging feature facilitated the identification of operational patterns and optimization opportunities. Analysis of temperature and gas production data led to refinements in feeding schedules and heating control, resulting in a 14% increase in overall gas production during the final month of testing compared to the baseline period.

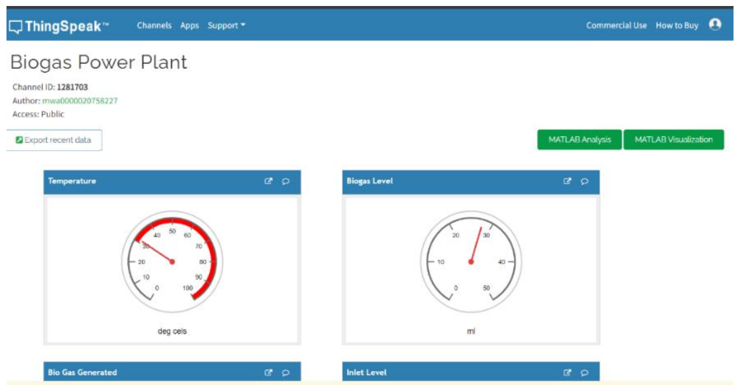

Fig.7.Remote Monitoring Interface

V. CONCLUSION

The "Auto Control and Monitoring of Biogas Plant using LabVIEW Software" project represents a significant leap forward in the realm of sustainable energy management and automation. The goals of this project were to increase the environmental sustainability and reliability of biogas production processes by deploying LabVIEW together with innovative control algorithms. This journey from an idea to an end product had various milestones and lessons learned, which transformed this concept into a solution for the biogas industry.

In conclusion, the project “Auto Control and Monitoring of Biogas Plant using LabVIEW Software” serves as a great example of the power of technology in solving sustainable energy issues. The automated control system that was designed and implemented did not only achieve optimal biogas production processes, but also aided in environmental protection. This project showcases the effective novel approaches that blend technology and environmental sustainability, and sets the stage for a world where advanced technology is at the core of energy production. Looking back on the results of this initiative, and the ways it impacts the world inspires a desire to continue working toward a sustainable planet.

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