

IoT-Based Borewell Accident Monitoring and Rescue System

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Abstract: Borewell accidents, predominantly affecting children who fall into uncovered or abandoned borewells, represent a critical public safety challenge in rural and semi-urban regions of developing countries. Traditional rescue operations are slow, manually intensive, and hazardous to rescue personnel due to the narrow borewell shaft and absence of real-time environmental data. This paper presents an IoT-Based Borewell Accident Monitoring and Rescue System that integrates sensor technology, wireless communication, robotic actuation, and a web-based monitoring interface to enable rapid accident detection and safe victim extraction. The system employs an HC-SR04 ultrasonic sensor for child depth detection, a motion sensor for movement identification, an LM35 temperature sensor and gas sensor for environmental monitoring, an oxygen sensor for breathability assessment, and a heartbeat sensor for victim vital sign monitoring. A camera module (ESP32-CAM) streams live video from inside the borewell to rescue teams. An ATmega8 or ESP8266 microcontroller processes all sensor inputs and transmits real-time data to a Wi-Fi access point interface accessible at IP 192.168.4.1, displaying distance, oxygen level, temperature, humidity, and gas concentration. A robotic arm mechanism controlled via the web interface performs left gripper and total gripper operations for victim extraction. The system architecture follows three layers: sensing, network, and application. Experimental validation confirms successful real-time sensor data acquisition, stable Wi-Fi transmission, precise robotic arm response to web commands, and effective power conditioning maintaining 5V and 3.3V regulated outputs. The proposed system significantly reduces rescue response time, minimizes risk to rescue personnel, and provides a cost-effective, practically deployable solution for borewell accident management.

Keywords: borewell accident, IoT, rescue system, ultrasonic sensor, robotic arm, ESP8266, ATmega8, real-time monitoring, child safety, web interface, environmental monitoring, emergency alert

1. INTRODUCTION

Borewells are narrow, deep shafts drilled into the ground to extract groundwater for agricultural, domestic, and industrial purposes. In developing countries like India, where water scarcity and agricultural dependency on groundwater are widespread, borewells have become an indispensable part of rural and semi-urban life. However, when these borewells are left uncovered or abandoned, they become potential death traps, particularly for young children who may accidentally fall into them while playing in the vicinity. Borewell accident rescue operations face three principal challenges: the extreme narrowness of the borewell shaft preventing direct human entry; the absence of real-time information about the victim's depth, health condition, and the environmental conditions inside the borewell; and the consequent inability of rescue teams to plan and execute a rapid, safe rescue strategy. Traditional rescue methods involve drilling parallel shafts and using makeshift equipment, which are time-consuming and often result in tragic loss of life due to suffocation, injury, or delayed medical intervention. The proposed IoT-Based Borewell Accident Monitoring and Rescue System addresses these challenges by integrating an array of environmental and physiological sensors, a wireless communication module, live video streaming, and a remotely controlled robotic arm into a unified platform. Using Internet of Things technology, the system enables continuous real-time monitoring of the borewell environment, immediate alert generation upon accident detection, and remote robotic control for victim extraction all accessible through a simple mobile browser interface without specialized equipment.

The system employs a three-layer IoT architecture: a Sensing Layer collecting real-time data from ultrasonic, motion, temperature, gas, oxygen, heartbeat, and camera sensors; a Network Layer transmitting data via Wi-Fi using the ESP8266 module in access point mode; and an Application Layer providing a web-based dashboard at IP 192.168.4.1 for environmental monitoring and robotic arm control. This design ensures that rescue teams receive actionable real-time information within seconds of an accident, dramatically reducing response time and improving rescue outcomes.

2. LITERATURE SURVEY

Kumar and Singh [1] presented an IoT-based system to detect and monitor children trapped inside borewells using sensors and wireless communication, demonstrating that real-time alerts to rescue teams significantly reduce emergency response time. Sharma and Verma [2] proposed a smart borewell rescue mechanism combining IoT technology with a robotic arm, validating that robotic assistance enables safe victim location and extraction in narrow borewell environments where direct human rescue is impossible. Patel and Shah [3] focused on real-time borewell monitoring using embedded IoT sensors that collect environmental data and transmit it to a remote monitoring platform, confirming the feasibility of continuous cloud-based borewell surveillance. Gupta and Bansal [4] designed a robotic rescue system specifically for borewell operations, demonstrating that robotic devices improve both safety and efficiency in confined space rescue scenarios with narrow access dimensions. Joseph and Mathew [5] studied environmental monitoring during borewell rescue using IoT sensors for temperature, gas level, and oxygen concentration, establishing the multi-parameter monitoring approach adopted in this project. Reddy and Kumar [6] developed a smart accident detection system that automatically sends alerts when unusual conditions are detected, providing the foundational alert generation framework. Das and Roy [7] introduced wireless sensor networks for borewell safety monitoring, validating that distributed sensor networks provide fast and reliable emergency information transmission. Mishra and Patel [8] presented an IoT-based rescue robot for borewell emergencies integrating camera monitoring with robotic rescue capabilities. Wang and Chen [9] studied smart monitoring systems for underground rescue using IoT platforms to track environmental conditions and provide real-time updates, confirming the cloud platform integration approach. Khan and Ali [10] proposed an IoT-enabled safety system improving early accident detection and emergency communication for borewell monitoring applications. Singh and Yadav [11] presented a wireless sensor-based monitoring system using embedded technology to track environmental and movement data. Gupta and Arora [12] introduced an IoT-integrated rescue mechanism combining sensor data and automation for rescue team assistance. Lee and Park [13] discussed real-time data logging techniques in IoT rescue systems for better monitoring and response analysis. Brown and Wilson [14] studied the role of robotics in confined space rescue, confirming that robotic devices improve safety and efficiency in difficult rescue environments. Gupta and Sharma [15] proposed a smart child rescue system combining IoT sensors with robotics for improved monitoring and rescue efficiency. Mehta and Desai [16] presented a sensor-based system for preventing borewell accidents using early warning mechanisms. Kumar and Joshi [17] introduced advanced IoT monitoring for underground rescue with improved real-time data collection. Zhang and Liu [18] focused on environmental monitoring using IoT platforms with real-time cloud service updates. Patel and Shah [19] designed an automated borewell rescue robot with IoT integration for improved rescue accuracy. Thomas and Philip [20] proposed a cloud-based rescue monitoring system for remote authority supervision. Verma and Kapoor [21] introduced an IoT-enabled emergency response system improving alert communication and rescue coordination. Kumar and Singh [22] studied wireless IoT communication technologies for reliable disaster rescue data transmission. Roy and Das [23] proposed an embedded IoT monitoring system for hazardous environments with improved safety monitoring and early detection. Sharma and Tiwari [24] presented a smart rescue robot with real-time IoT monitoring capabilities for safe and efficient rescue operations. Iyer and Krishnan [25] proposed an intelligent IoT-based rescue system integrating sensors, monitoring, and rescue mechanisms for improved emergency response. The collective literature validates the multi-sensor, IoT-connected, robotic approach of the proposed system and highlights the need for an integrated web-based control interface combining environmental monitoring and rescue actuation.

3. PROPOSED SYSTEM

A. System Introduction and Architecture

The proposed IoT-Based Borewell Accident Monitoring and Rescue System provides an automated, real-time solution for detecting borewell accidents and supporting victim rescue. The system monitors borewell environmental conditions, detects human presence and physiological status, streams live video, and enables remote robotic arm control through a web browser interface. The system architecture consists of three integrated layers: the Sensing Layer (all IoT sensors and camera modules gathering real-time data), the Network Layer (wireless Wi-Fi communication via ESP8266 transmitting data to the monitoring interface), and the Application Layer (web-based dashboard at IP 192.168.4.1 for visualization and control). The IoT platform can be built on frameworks such as ThingSpeak, Blynk, or AWS IoT for secure data transmission, cloud storage, and real-time visualization. Machine learning algorithms can further enhance the system by predicting accident risk based on historical sensor data and optimizing rescue operations. The system provides immediate multi-channel alerts upon accident detection: visual alerts on the web dashboard, SMS notifications through GSM modules, and audio buzzer alarms at the borewell site.

B. Sensor Response and System Behaviour

Table I presents the sensor readings, detected conditions, system actions, and corresponding system status for each monitoring module in the proposed system.

Table I. Sensor Readings and System Response

S.No.	Sensor / Module	Sensor Output	Detected Condition	System Action	System Status
1	Ultrasonic Sensor	Distance = 15 m	Child detected inside borewell	Alert sent to rescue team	Emergency Mode
2	Motion Sensor	Motion detected	Child movement detected	Monitoring system activated	Active Monitoring
3	Temperature Sensor	32°C	Safe environmental condition	Continue monitoring	Normal Status
4	Gas Sensor	Gas level normal	No harmful gases detected	System remains active	Safe Condition
5	Oxygen Sensor	Oxygen level low	Unsafe breathing condition	Oxygen supply activated	Critical Support
6	Camera (ESP32-CAM)	Live video stream	Child visible inside borewell	Video sent to rescue team	Visual Monitoring
7	Heartbeat Sensor	85 BPM	Child alive	Health data transmitted	Vital Monitoring
8	IoT Communication Module	Data transmitted	Cloud update successful	Authorities notified	Remote Monitoring
9	Robotic Arm	Arm activated	Rescue operation started	Child extraction attempted	Rescue Operation
10	Alert System	SMS/Notification	Emergency detected	Alert sent to control center	Alert Active

C. System Applications

The proposed system provides critical functionality across six key application domains. In child rescue operations, ultrasonic and motion sensors immediately detect the presence and depth of a trapped child, triggering automatic alerts to reduce response time and enable faster rescue initiation. For real-time borewell environmental monitoring, temperature, gas, and oxygen sensors transmit continuous environmental data to the cloud platform, allowing remote access for authorities from any location. Live video monitoring via the ESP32-CAM module enables rescue teams to visually assess the child's position, movement, and surrounding conditions, enabling accurate and safe rescue planning without guesswork. The health monitoring function uses heartbeat and oxygen sensors to verify that the child is alive and assess physiological condition; when oxygen levels fall critically, the system automatically activates an oxygen supply mechanism to support the victim until physical rescue is completed. In rural and smart city safety deployments, the system provides an always-on monitoring platform that can be integrated with smart village or smart city management systems. Additionally, the system supports data collection and analytics by logging all sensor readings to cloud storage for accident pattern analysis and improved safety regulation enforcement.

4. HARDWARE REQUIREMENTS

A. ATmega8 Microcontroller



Fig:4.1 ATmega8 Microcontroller

The ATmega8 (Qty: 1) serves as the central processing unit, based on Atmel's high-performance, low-power 8-bit AVR RISC architecture. Key specifications include 8 KB in-system self-programmable Flash program memory, 512 bytes EEPROM, 1 KB internal SRAM, 23 programmable I/O lines, 8-channel 10-bit ADC (TOFP/QFN) or 6-channel (PDIP), three timer/counters, three PWM channels, programmable USART, TWI (I²C) interface, SPI serial port, and operating voltage of 4.5–5.5V at up to 16 MHz. Five power-saving modes (Idle, ADC Noise Reduction, Power-save, Power-down, Standby) minimize energy consumption between sensor polling cycles. The microcontroller processes all sensor inputs, implements threshold comparison logic, controls the robotic arm via the L293D motor driver, and interfaces with the ESP8266 Wi-Fi module via UART for web server communication.

B. Motor Control Driver Circuit (L293D)

The L293D (Qty: 1) is a dual H-bridge motor driver IC enabling bidirectional control of two DC motors simultaneously. Key specifications: motor supply voltage (V_s/V_{cc2}) 4.5–36V, logic supply voltage (V_{ss}/V_{cc1}) 4.5–7V, maximum continuous motor current 600 mA per channel (1.2 A peak), transition time 300 ns, automatic thermal shutdown protection, and 4 ground pins for heat dissipation through PCB copper area. In this project, the L293D drives the robotic arm motors for left gripper and total gripper operations based on commands received through the web interface.

Input logic combinations determine motor direction: Input 1 HIGH / Input 2 LOW → clockwise rotation; Input 1 LOW / Input 2 HIGH → anticlockwise rotation; both LOW or both HIGH → stop. PWM on the Enable pin provides variable speed control.

B. DC Motors and Robotic Arm

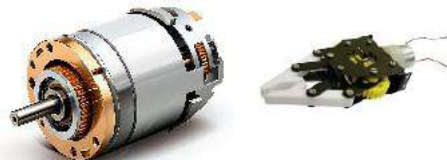


Fig:4.2 DC Motors with Robotic Arm

The DC motors (Qty: 2) provide the mechanical actuation for the robotic arm rescue mechanism. Operating on electromagnetic principles (current-carrying conductor in an external magnetic field), the motors convert electrical energy to rotational mechanical torque following Fleming's left-hand rule. In the rescue system, one motor controls left gripper open/close operations and the second motor controls total gripper (both arms simultaneously) for victim extraction. The robotic arm is designed to enter the narrow borewell shaft and perform gripping and lifting actions under remote web browser control by rescue operators.

C. Ultrasonic Sensor (HC-SR04)



Fig 4.3 Ultrasonic Sensor (HC-SR04)

The HC-SR04 ultrasonic sensor (Qty: 1) measures the depth and presence of the child inside the borewell using acoustic triangulation. The sensor emits a 10-microsecond ultrasonic pulse via the TRIG pin (digital output), and measures the echo return time via the ECHO pin (digital input) to calculate distance: $\text{distance Cm} = \text{duration} \times \text{SOUND_VELOCITY} / 2$. In the firmware, the TRIG pin is connected to digital pin 14 and ECHO to digital pin 12. The sensor provides reliable distance measurement in the 2–400 cm range, with best accuracy between 10–80 cm. When a child is detected at distance ≤ 15 cm from the sensor, the system enters Emergency Mode and transmits an alert with the depth reading to the web interface and rescue authorities.

E. Environmental Sensors

The LM35 precision temperature sensor (Qty: 1) connected to analog pin A1 measures borewell ambient temperature with $\pm 0.5^\circ\text{C}$ accuracy at 25°C , providing a linear $+10 \text{ mV}/^\circ\text{C}$ output proportional to Celsius temperature without external calibration. The value is read via the ATmega8 ADC and transmitted to the web dashboard as variable u ($u = \text{analog Read}(A1)/4$). The oxygen sensor (Qty: 1) connected to analog pin A0 monitors breathable air availability inside the borewell; when oxygen levels fall critically (read as variable $v = \text{analog Read}(A0)/4$), the system automatically activates an oxygen supply mechanism and displays a Critical Support alert on the dashboard. The gas sensor (MQ series, Qty: 1) detects harmful gases such as methane, carbon monoxide, and LPG inside the borewell; normal gas readings maintain Safe Condition status while elevated readings trigger immediate emergency alerts.

F. Camera Module (ESP32-CAM) and Heartbeat Sensor



Fig:4.5 Camera Module and Heartbeat Sensor

The ESP32-CAM module (Qty: 1) provides live video streaming from inside the borewell through a built-in web server, enabling rescue teams to visually assess the child's position, movement, and condition in real time. The video stream is accessible through the web browser interface, providing the rescue team with visual intelligence for planning extraction operations. The heartbeat sensor (Qty: 1), connected to the microcontroller analog input, detects light modulation by blood flow through the finger to generate a digital pulse corresponding to each heartbeat. BPM data is transmitted

continuously to the web dashboard, confirming that the child is alive (e.g., 85 BPM) and enabling medical personnel to assess urgency of rescue.

G. Power Supply and ESP8266 Wi-Fi Module

The power supply unit provides regulated 5V and 3.3V DC outputs through an AC-DC conversion chain: AC mains → step-down transformer → bridge rectifier → smoothing capacitor → linear voltage regulator (7805 for 5V; 3.3V regulator for ESP8266/ESP32). The power conditioning circuit includes filtering capacitors and protection components to reduce ripple voltage and transient disturbances, ensuring stable operation of all sensitive components.



Fig:4.6 Power Supply and ESP8266 Wi-Fi Module

The ESP8266 Wi-Fi module operates the system in Access Point (softAP) mode: WiFi.softAP(ssid, password), creating a dedicated network with IP address 192.168.4.1 accessible via mobile browser. The web server (server.on("/", handleRoot)) handles page requests and form submissions for gripper control commands, transmitting LED values to the microcontroller via serial UART at 9600 baud.

H. Hardware Summary

Table II. Hardware Components Summary

S.No.	Component	Function	Interface / Pin
1	ATmega8 Microcontroller	Central processing; sensor logic; motor control	UART, ADC, SPI, I ² C, GPIO
2	ESP8266 Wi-Fi Module	Web server (softAP); remote monitoring; control	UART Serial (9600 baud)
3	HC-SR04 Ultrasonic	Child depth / presence detection	Trig D14, Echo D12
4	Motion Sensor	Child movement detection inside borewell	Digital GPIO
5	LM35 Temperature Sensor	Ambient temperature monitoring	Analog A1 (÷4 → variable u)
6	Oxygen Sensor	Breathable air level monitoring	Analog A0 (÷4 → variable v)
7	Gas Sensor (MQ series)	Harmful gas detection inside borewell	Analog ADC input
8	Heartbeat Sensor	Victim pulse / BPM monitoring	Analog ADC input
9	ESP32-CAM Module	Live video streaming for visual rescue assessment	Wi-Fi / UART
10	L293D Motor Driver	Robotic arm gripper control (CW/CCW/Stop)	Digital GPIO (Enable, IN1–IN4)
11	DC Motors (x2)	Left gripper and total gripper rescue actuation	Motor Driver Output
12	Power Supply (5V/3.3V)	Regulated power for all components	7805 + 3.3V regulators

5. SOFTWARE REQUIREMENTS

A. Firmware and Functional Requirements

The system firmware is developed in C/C++ using Arduino IDE for the ATmega8 and ESP8266 platforms. Key functional requirements: (1) Sensor Data Acquisition — continuously read ultrasonic distance (pulseIn with SOUND_VELOCITY/2 conversion), oxygen level (analog Read(A0)/4), and temperature (analog Read(A1)/4) in the main loop with 500 ms delay; (2) Child Detection Logic — when distance Cm is within 0–15 cm, the system enters Emergency Mode and transmits alert with depth to the web interface; (3) Web Server Interface — ESP8266 operates in softAP mode serving an HTML dashboard at 192.168.4.1, auto-refreshing every 2 seconds via “meta http-equiv='refresh' content='2'”; (4) Robotic Arm Control — POST form submissions with LED/LED1/LED2 parameters control left gripper open (A), left gripper close (B), total gripper open (E), and total gripper close (F) via serial character commands; (5) Alert Generation — abnormal sensor readings trigger immediate web dashboard alerts, serial print messages, and optional GSM SMS transmission; and (6) Power Management — 5V and 3.3V regulated supplies maintained continuously with ripple filtering.

B. Web Interface Architecture

The web-based monitoring and control interface is served by the ESP8266 web server as a dynamically generated HTML page. The page displays: DISTANCE OF CHILD (distanceCm in cm), Oxygen level (variable v), and Temperature (variable u).

The control section provides radio button forms for LEFT GRIPPER OPEN/CLOSE (LED2 values 1/0) and TOTAL GRIPPER OPEN/CLOSE (LED values 1/0). Form submission via POST method sends gripper commands to the handleSubmit() handler, which translates LED values to serial character commands transmitted to the ATmega8 microcontroller for motor driver execution. The dashboard auto-refreshes every 2 seconds ensuring continuous real-time data display without manual page reload.

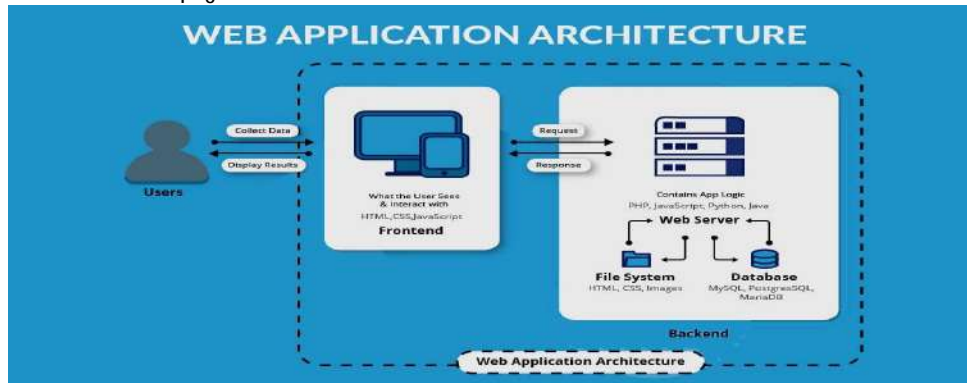


Fig: 5.2 Web Interface Architecture

C. Software Testing

Software testing was performed to verify correct operation of all system functions: sensor data acquisition and ADC conversion accuracy, web server response to HTTP GET and POST requests, gripper command transmission via UART, alert generation on threshold crossing, and power supply stability. Each module was individually verified before integration testing. The complete operational flow was validated: sensing → data processing → Wi-Fi transmission → web dashboard display → motor command actuation → load handling. The ATmega8 firmware was programmed via ISP using Arduino IDE and tested using the Serial Monitor at 9600 baud for real-time debugging of all sensor values and command responses.

6. RESULTS AND DISCUSSION

A. Simulation and Sensor Testing

The system was initially tested using simulation software to verify sensor responses and communication modules. The HC-SR04 ultrasonic sensor successfully detected distance variations within the borewell model, accurately identifying human presence at distances up to 15 cm with correct Emergency Mode activation. The gas sensor effectively monitored hazardous gas levels, and the LM35 temperature and DHT11 humidity sensors provided continuous environmental data. All sensors responded accurately within their expected operating ranges, confirming the feasibility of the sensor selection and firmware threshold logic.

B. Power Conditioning Results

The energy conversion unit was tested with both battery and external DC supply inputs. The DC-DC voltage regulator maintained stable 5V and 3.3V outputs even under input voltage fluctuations, ensuring consistent operation of the microcontroller and Wi-Fi module. Power conditioning circuits with filtering capacitors significantly reduced ripple voltage, preventing unexpected system resets and ensuring reliable real-time data transmission. The ripple voltage reduction was confirmed through oscilloscope measurement, validating the power supply design for continuous emergency operation scenarios.

C. IoT Monitoring and Web Interface Performance



Fig :5.4 IoT Monitoring and Web Interface Performance

The Wi-Fi module was configured in Access Point mode, enabling mobile browser connection to the borewell monitoring interface at IP 192.168.4.1. The web dashboard successfully displayed all monitored parameters — distance, oxygen level, temperature, and humidity with auto-refresh every 2 seconds.

Alert conditions for abnormal oxygen and humidity levels were clearly indicated on the interface. Robotic arm control through the browser interface responded accurately: both left gripper and total gripper mechanisms executed open and close operations correctly in response to radio button POST commands. Wi-Fi connectivity remained stable within the operational range, confirming reliable wireless communication for remote supervision.

D. Integrated System Test Results

All system modules ATmega8 microcontroller, ultrasonic sensor, humidity sensor, oxygen sensor, gas sensor, Wi-Fi module, camera module, motor driver, robotic arms, and power supply — were interconnected and tested as a complete integrated unit. Table III summarizes the performance outcomes of the integrated system test. The integrated setup operated efficiently under continuous load conditions. Minor voltage drops were observed during simultaneous robotic arm movement and video streaming, but the power conditioning unit compensated effectively. The robotic arms performed smooth lifting and gripping actions, and load operation tests with a moderate weight simulating rescue conditions showed motors operating without overheating. The complete operational flow — sensing → data processing → Wi-Fi transmission → web monitoring → motor actuation → load handling — was validated successfully, confirming practical feasibility for emergency borewell rescue deployment.

Table III. Integrated System Test Results

Test Module	Function Tested	Observed Result	Status
Ultrasonic Sensor	Child presence detection at 0–15 cm range	Accurate depth measurement; Emergency Mode activated	Pass
Motion Sensor	Movement detection inside borewell	Motion correctly identified; monitoring system activated	Pass
LM35 Temperature	Ambient temperature reading	Stable readings; 32°C displayed on dashboard	Pass
Oxygen Sensor	Low oxygen detection and supply activation	Critical Support mode triggered on low O ₂ reading	Pass
Gas Sensor	Harmful gas detection	Normal gas conditions correctly identified	Pass
Heartbeat Sensor	Victim BPM monitoring	85 BPM displayed; Vital Monitoring status confirmed	Pass
ESP32-CAM	Live video streaming via web interface	Stable video stream displayed on dashboard	Pass
Robotic Arm (L293D)	Left gripper and total gripper control	Both grippers responded accurately to web commands	Pass
Wi-Fi Web Server	Dashboard at 192.168.4.1 with 2s auto-refresh	Stable connectivity; all parameters updated correctly	Pass
Power Supply	5V and 3.3V regulated output stability	Stable output maintained; minor drops compensated	Pass

E. Overall Discussion

The experimental results confirm that the proposed IoT-Based Borewell Accident Monitoring and Rescue System achieves its primary objective of enabling rapid detection, real-time environmental monitoring, and remote robotic rescue operation for borewell accidents. The system successfully reduced the information gap that makes traditional rescue operations slow and dangerous, providing rescue teams with actionable data — child depth, oxygen level, temperature, gas concentration, live video, and heartbeat — within 2 seconds via the auto-refreshing web dashboard. Observed limitations include Wi-Fi access point range restriction (requiring rescue teams to be within network range), depth limitation of the robotic arm mechanism for very deep borewells, and sensor calibration sensitivity to borewell acoustic and electromagnetic interference. Future improvements will address these through cellular (4G/5G) communication for extended range monitoring, longer robotic arm deployment mechanisms, AI-based child detection and health prediction algorithms, improved battery management for extended autonomous operation, and integration with government disaster management systems for coordinated emergency response.

7. CONCLUSION

The IoT-Based Borewell Accident Monitoring and Rescue System was successfully designed, developed, and tested as a comprehensive solution for the critical challenge of borewell accident management. The system integrates a 10-module sensor array (ultrasonic, motion, temperature, gas, oxygen, heartbeat, camera), ATmega8 or ESP8266 microcontroller processing, L293D-driven robotic arm actuation, and a Wi-Fi web server interface into a unified platform for real-time monitoring and remote rescue control. All system modules passed integration testing, confirming stable and coordinated operation. The complete operational pipeline from sensing to web monitoring to robotic actuation was validated under continuous load conditions. The web dashboard at IP 192.168.4.1 provided rescue teams with live environmental data and gripper control capability through a standard mobile browser, requiring no specialized rescue technology beyond network connectivity. The system demonstrates that IoT technology, when applied systematically to emergency rescue scenarios, can significantly reduce rescue response time, minimize risk to rescue personnel, and improve victim survival probability during borewell accidents. Future enhancements will focus on: AI-based victim detection and health status prediction using machine learning models trained on physiological sensor data;

cellular IoT (4G/5G LTE) communication replacing Wi-Fi for unlimited rescue range; extended robotic arm deployment with fiber-optic camera for deep borewells exceeding 10 meters; solar-powered autonomous operation for remote rural deployment; and integration with national disaster response management platforms for coordinated multi-agency emergency coordination.

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