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Smart Aqua Control: IoT-Based Water Management and Motor Safety System

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Abstract

Efficient monitoring and control of heavy-duty water motors are essential for optimizing performance, preventing failures, and reducing maintenance costs. This paper presents an IoT-enabled motor health monitoring and remote operation system that integrates real-time sensor data acquisition, predictive maintenance, and automated control. The system employs an Arduino UNO board, ACS720 current sensor, DS18B20 temperature sensor, vibration sensor, and JSN-SR04T ultrasonic sensor to identify motor faults such as phase imbalance, overloads, and dry runs. A YF-S201 flow sensor and water level sensors facilitate effective water supply management. The system includes an LCD display and a web-based dashboard for real-time monitoring. Furthermore, machine learning models, including Linear Regression for efficiency prediction, Random Forest Regression for lifespan estimation, and Logistic Regression for failure detection, enhance predictive maintenance capabilities. The proposed system offers a cost-effective and automated solution for safe and efficient motor operation, thereby improving reliability in pumping stations and household water systems.

Keywords: Predictive Maintenance, Remote Motor Operation, Machine Learning for Fault Detection, Real Time Data Acquisition.

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1. Introduction

In industrial and agricultural applications, heavy-duty water motors are essential for maintaining a continuous and efficient water supply. However, these motors are susceptible to electrical faults, mechanical wear, phase imbalances, overheating, and dry runs, which can result in increased downtime, elevated maintenance costs, and suboptimal operation. Conventional monitoring and control systems typically depend on manual inspections or SCADA-based solutions, which are often costly, complex, and lack real-time predictive capabilities.

To address these challenges, this paper introduces an Internet of Things (IoT) based motor health monitoring and remote operation system that offers real-time monitoring, predictive maintenance, and automated control. The system employs various sensors to continuously track motor parameters:

1. ACS720 current sensor for detecting overloads and dry runs.
2. DS18B20 temperature sensor for overheating detection.
3. Vibration sensor for mechanical fault identification.
4. JSN-SR04T ultrasonic sensor for dry run detection based on water presence.
5. YF-S201 water flow sensor to monitor water flow in the pipeline.
6. Float and water level sensors for overhead tank (OHT) water level monitoring.
7. Voltage sensor for real-time voltage analysis.

The system is centered around an Arduino UNO board, which processes sensor data and presents it on an LCD screen and a web-based interface. A relay module is incorporated to facilitate automatic motor control, ensuring that the motor shuts off when a dry run or fault is detected. Additionally, machine learning models are utilized to enhance predictive maintenance, including Linear Regression for efficiency prediction, Random Forest Regression for lifespan estimation, and Logistic Regression for failure prediction. This project aims to deliver a cost-effective, real-time monitoring solution for pumping stations and household water systems, thereby reducing maintenance costs, preventing motor failures, and optimizing motor operation. The subsequent sections of this paper will discuss related work, system architecture, implementation details, experimental results, and future enhancements.

2. Related Work

Behzad Ousat and others studied CAPTCHA systems in contemporary web settings, revealing their brittleness and inefficiency against developing threats. Lauren Silva Rolan Sampaio presented a general picture of AI-facilitated attacks, describing their conceptual foundation and the capabilities of emerging prototypes. Junmei Wang and Xinning Liu analyzed security weaknesses using DVWA to measure the strength of software systems, whereas Muhammad Idris et al. created a vulnerable web application based on OWASP API threats to test real-world threats. Bonika Gaur investigated the techniques and real-world experience of penetration testing on web applications and made core contributions to ethical hacking practices. Richard Amankwah and colleagues compared open-source and commercial vulnerability scanners, providing empirical answers to their effectiveness in practical use. Alla D. Pinchuk et al. presented PentestHUB as an environment for developing ethical hacking skills using practical experiences. M. Buvana discussed CSRF vulnerability mitigation techniques and developed new defense mechanisms. Philipp Zech, Michael Felderer, and Ruth Breu focused on knowledge-based testing methods applying logic programming to enhance security in web applications. Then, Oyetunji Oyelakin et al. touched on the contributions of digital forensics and cybersecurity practices in cybercriminal tracking, demonstrating investigative methods in contemporary threat environments.

3. Proposed Work

The proposed IoT-enabled motor health monitoring and remote operation system is designed to ensure the efficient and safe operation of heavy-duty water motors in industries, pumping stations, and households. The system leverages sensor-based monitoring, IoT connectivity, and machine learning-driven predictive maintenance to detect electrical faults, phase imbalances, overheating, and dry runs in real time. The integration of multiple sensors enhances accuracy, while a relay module provides automatic motor shut-off in case of critical failures. The web-based dashboard enables remote monitoring and control, reducing maintenance costs and preventing unexpected breakdowns. The block diagram represents the architecture of IoT based water management and motor safety system in “Figure 1”.

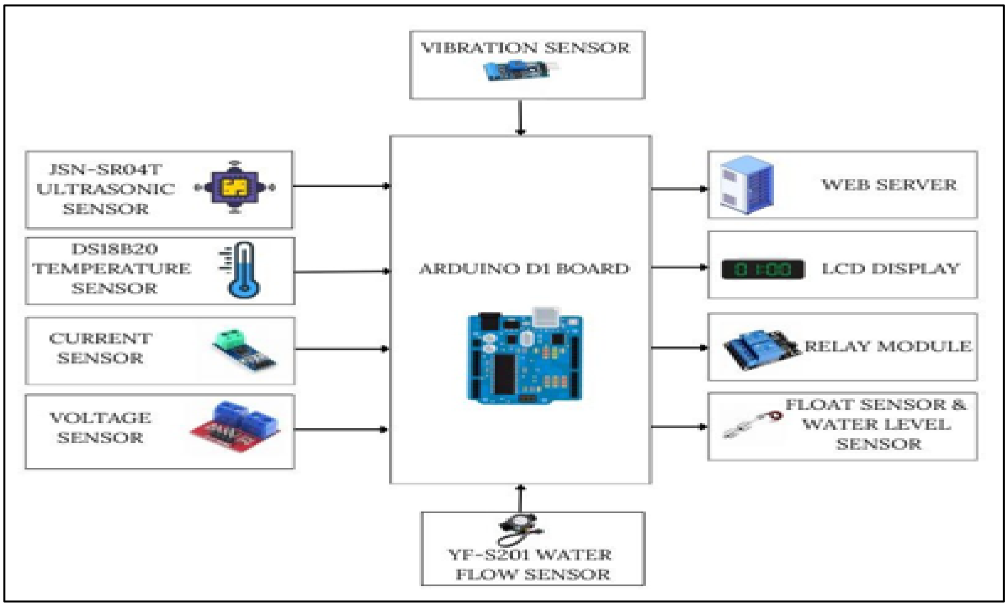

Figure 1. Block Diagram of the Proposed Work

3.1 Work Flow

Smart Aqua Control integrates an Arduino D1 board with several sensors to control and monitor water usage effectively while providing motor protection through IoT-based automation. The system starts gathering real-time data from different input sensors mounted on the Arduino D1 board. The JSN-SR04T ultrasonic sensor measures the water tank level by detecting the distance from the water surface. Concurrently, the DS18B20 temperature sensor measures the water temperature, which is critical in agro and industrial applications. The YF-S201 water flow sensor measures the rate of water flow, enabling the system to track consumption habits and identify irregularities such as leakage or overuse. In addition, the current and voltage sensors constantly monitor the electrical parameters of the motor to sense overloads, dry running, or undervoltage, allowing for advanced motor safety control. The vibration sensor detects abnormal vibrations, which could indicate mechanical failures in the motor or the pump system. Supplementing these are the float and water level sensors, which function as a backup system to monitor water levels, adding redundancy and precision in water control.

All sensor readings are captured by the Arduino D1, which is the control unit. The board is Wi-Fi compliant, enabling data transfer to a web server where it can be logged, remotely monitored, and analyzed using an IoT dashboard. The system also provides real-time values locally on an LCD display for users to see immediately. Whenever critical situations are sensed, such as low water levels, unusual flow, or dangerous electrical states, the Arduino activates the relay module to switch the motor ON or OFF automatically, thereby protecting the hardware. Essentially, this process guarantees intelligent, automated, and secure water management through the application of several sensor inputs to real-time feedback and control through local as well as remote interfaces. It solves issues faced by regular water systems, such as wastage, manual reliance, and motor breakdown, thus providing a more effective and dependable solution using IoT and embedded systems.

4. Hardware Setup

- **Arduino UNO**

The brains of the system are the Arduino UNO and Arduino D1 (NodeMCU) microcontroller boards, which interface with all sensors, process their data, and carry out control logic. The D1's Wi-Fi capabilities allow real-time data transmission to cloud platforms or web dashboards for IoT-based remote monitoring and motor control, whereas the UNO is usually utilized in offline embedded applications.

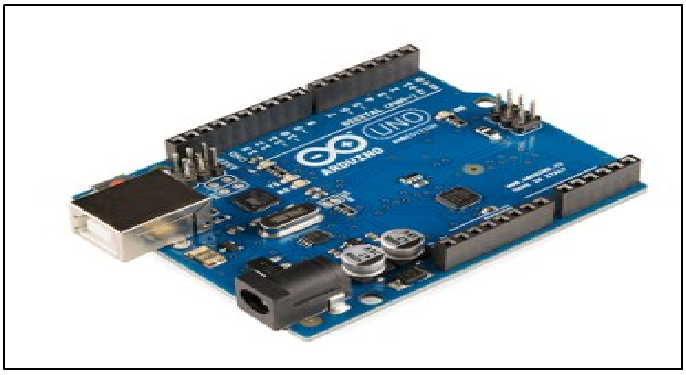

Figure 2. Arduino UNO

- **ACS720 Current Sensor**

The electric current passing through the motor is measured by the ACS720, a Hall-effect-based current sensor. By continuously monitoring current levels and transmitting real-time data to the microcontroller for analysis and preventative action, it plays a crucial part in identifying overcurrent scenarios, such asoverload or dry run conditions.

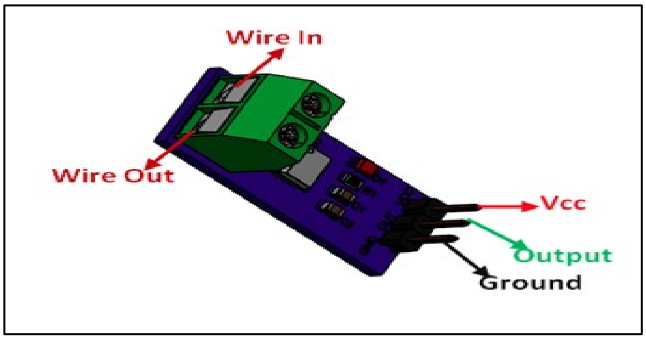

Figure 3. ACS720 Current Sensor

- **DS18B20 Temperature Sensor**

The digital temperature sensor DS18B20 is designed to provide precise temperature readings with minimal wiring. It is utilized in the system to monitor the water or motor housing temperature in order to detect overheating problems that could cause motor damage or efficiency loss. This allows for prompt shutdowns or alerts.

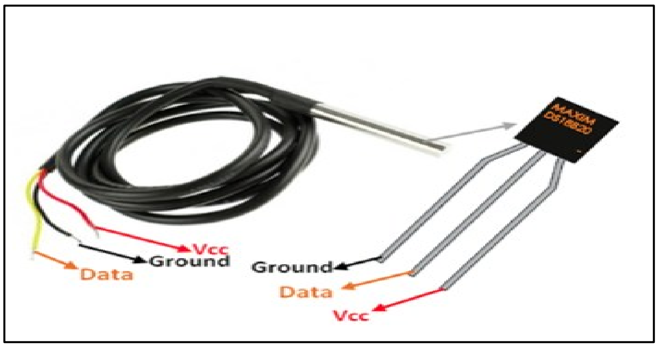

Figure 4. DS18B20 Temperature Sensor

- **Sensor for Vibration**

The motor or pump assembly's mechanical vibrations or movements are detected by a vibration sensor, such as the SW-420. By detecting irregular vibrations and alerting the controller to take corrective action, it is used to identify abnormal conditions like imbalance, misalignment, or internal mechanical failures.

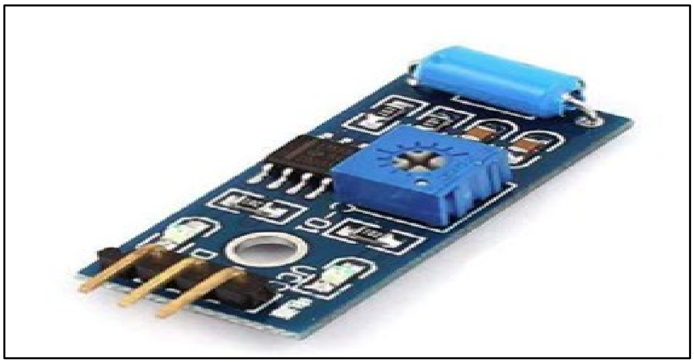

Figure 5. SW-420 Vibration Sensor

- **Ultrasonic Sensor JSN-SR04T**

A waterproof ultrasonic sensor called the JSN-SR04T is used to measure the water level in tanks or reservoirs without coming into contact with them. It assists in detecting low water levels or empty tanks by measuring the distance between the sensor and the water surface. This is essential for avoiding motor dry runs and preserving a steady water supply system.

Figure 6. JSN-SR04T Ultrasonic Sensor

- **Water Flow Sensor YF-S201**

The YF-S201 is a flow sensor that uses a revolving impeller and an integrated Hall-effect sensor to measure the rate at which water flows through a pipe. It is crucial for identifying irregularities like obstructions, leaks, or zero flow situations, and when required, it initiates automatic motor shutdown to prevent damage or water waste.

Figure 7. YF-S201 Waterflow Sensor

- **Water Level and Float Sensors**

The water level in subterranean or overhead tanks is detected and indicated by the use of water level and float sensors. To prevent overflow or dry running of the motor, they enable automated motor control to fill or stop filling tanks by providing binary or analog signals based on water height.

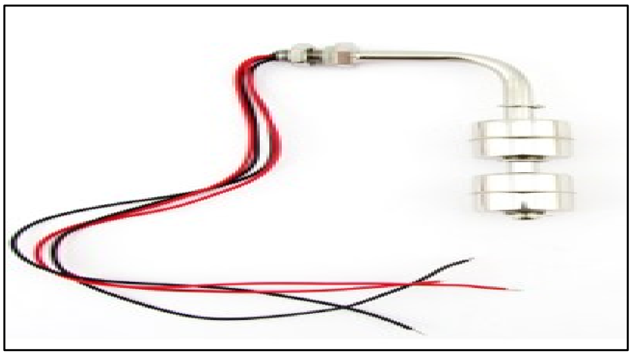

Figure 8. Water Level and Float Sensors

- **Module for Relays**

The Arduino controls the relay module, which functions as an electronic switch. It is employed to switch the motor on or off in response to anomalies found in sensor data. In the event of serious malfunctions, such as dry running, overheating, or unusual vibration, this enables the system to automatically cut power.

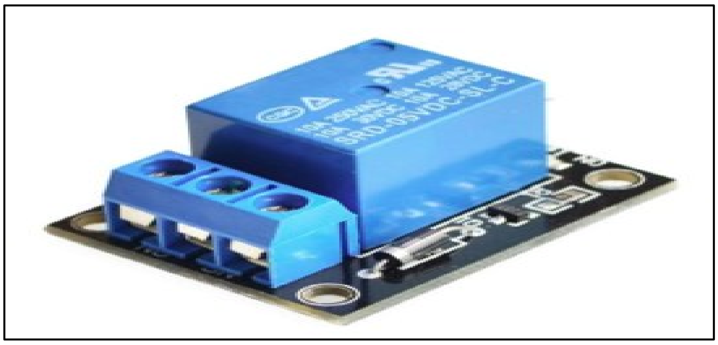

Figure 9. Module for Relays

- **16x2 LCD Display**

Local users can see real-time sensor data and system status, It facilitates speedy decision-making and troubleshooting by providing instantaneous on-site visibility of water levels, temperature, current, and flow rate without requiring access to the online dashboard.

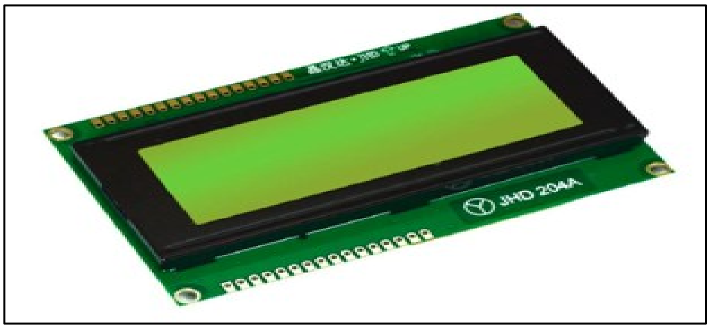

Figure 10. YF-S201 Waterflow Sensor

4.1 Sensor Integration and Fault Detection

The system incorporates various sensors with an Arduino UNO board to control and monitor motor operation and protect against inefficiencies and common failures. The ACS720 current sensor detects irregular current levels, recognizing overloads and dry runs. The DS18B20 temperature sensor senses overheating to prevent thermal damage, while the vibration sensor tracks mechanical problems such as misalignment or bearing wear. The JSN-SR04T ultrasonic sensor detects the presence of water in pipes by examining refraction time differences, avoiding dry runs, and the YF-S201 water flow sensor guarantees uniform water flow, turning off the motor in case of none.

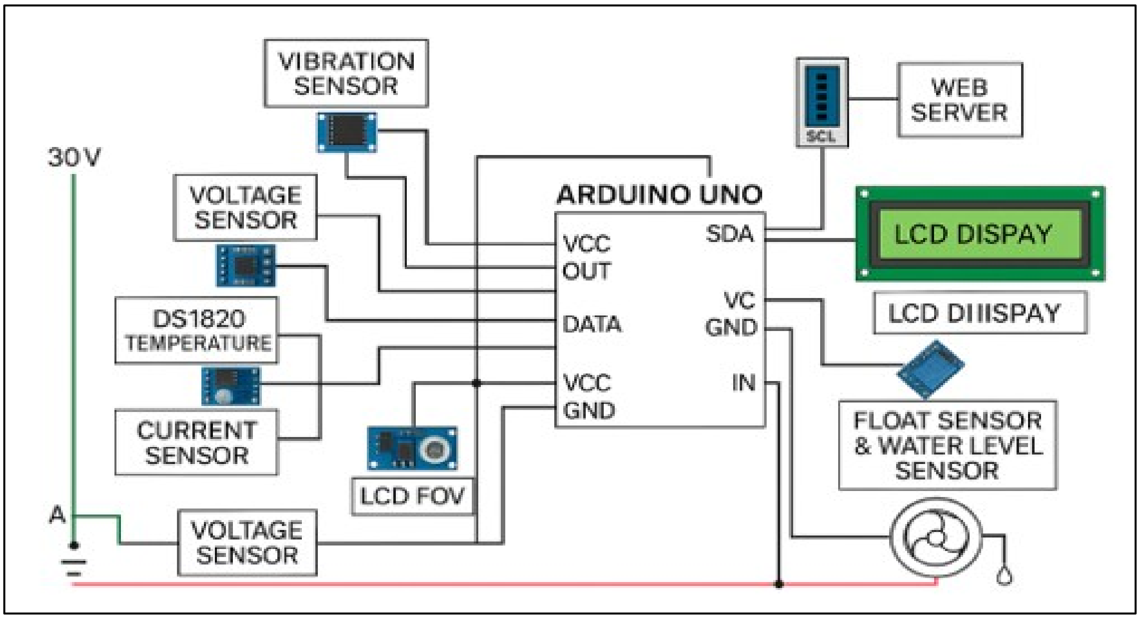

Figure 11. Proposed Circuit diagram

Float and water level sensors also automate motor operation based on tank levels to prevent overflows or dry running, and a voltage sensor detects phase imbalance or power oscillations to ensure electrical stability. All of the sensor data is processed in real-time by the Arduino UNO and interfaced with a web-based monitoring interface. If any major anomalies are found, a relay module is triggered to turn off the motor, thereby securing the system while ensuring operational efficiency. Figure 11 illustrates the circuit diagram of the proposed system.

4.2 Web-Based Remote Monitoring and Control

The system is integrated with a web-based dashboard, developed using HTML, JavaScript, and CSS, which allows users to: View real-time sensor data, monitor motor efficiency and health status, receive fault alerts and notifications, and remotely turn ON/OFF the motor.

4.3 Machine Learning for Predictive Maintenance

Integrating machine learning models enables fault prediction and motor performance optimization before failures occur.

4.4 Predictive Model Implementation

The Smart Aqua Control system utilizes a blend of IoT architecture and machine learning models to provide predictive maintenance and automatic motor safety. Linear Regression helps predict trends in motor efficiency to ensure appropriate scheduling of maintenance, while Random Forest Regression uses past sensor data to predict motor lifespan. Logistic Regression determines the health of motors and signals whether they are healthy or may fail, which allows for early intervention. which are trained using real-time sensor data, are run on edge devices or cloud servers for responsive, in-situ operation. The system features an Automated Fault Handling and Safety Mechanism that actively addresses anomalies: overload or overheating will trigger auto-motor shutdown, dry run is sensed with relay-controlled motor de-energization, lack of water flow creates alerts and stops the operation, and phase imbalance brings user notification and system lockout to avoid damage. The IoT-centric design utilizes microcontrollers like ESP8266, ESP32, or Arduino with WiFi modules to read motor and environmental parameters, sending data to cloud-hosted web servers like ThingSpeak, Firebase, AWS IoT Core, Blynk, or Adafruit IO using common communication protocols (e.g., MQTT, HTTP). This arrangement provides effective water resource management, improved motor protection, and lower maintenance expenditure through predictive analytics and real-time control.

The proposed system stands out from existing systems by combining real-time water level management, motor protection, remote monitoring, and automated alerts into a single IoT framework

5. Results and Discussion

5.1 Model Training and Evaluation

Three machine learning models are utilized for predictive maintenance:

Linear Regression for Efficiency Prediction: This model analyzes historical sensor data to predict the motor's efficiency based on power consumption and load variations.

Table 1 illustrates the predictive capabilities of the Linear Regression model regarding motor efficiency, utilizing parameters such as voltage, current, power, and temperature.

Table 1. Linear Regression

Voltage (V)	Current (A)	Power (W)	Temperature (C)	Predicted Efficiency (%)
220	5.2	1144	45	87.2
215	4.8	1032	43	85.9
230	5.5	1265	48	89.1
210	4.5	945	41	83.7
225	5.0	1125	46	86.5

This enables a comprehensive evaluation of performance across diverse operational conditions. Random Forest Regression for Motor Lifespan Estimation: This model assesses a range of operational parameters to estimate the remaining useful life (RUL) of the motor, thereby facilitating proactive maintenance planning.

Table 2. Random Forest Regression

Total Runtime (hrs)	Vibration (Hz)	Load (%)	Temperature (C)	Predicted Lifespan (hrs)
1500	60	75	45	3200
2000	55	70	42	2900
2500	65	80	47	2700
1800	58	74	44	3100
2200	62	78	46	2800

The Random Forest Regression model, illustrated in table 2, utilizes operational metrics such as total runtime, vibration, load, and temperature to estimate the motor's remaining useful life (RUL). By providing accurate lifespan projections, this approach supports predictive maintenance.

Logistic Regression for Fault Detection: A binary classification model that assesses whether the motor is functioning normally or is at risk of failure based on sensor inputs.

Table 3. Logistic Regression

Voltage (V)	Current (A)	Vibration (Hz)	Temperature (c)	Water Flow (L/min)	Fault Detected (Yes/No)
220	5.2	60	45	10	No
215	6.5	70	52	8	Yes
230	5.0	55	43	12	No
210	7.0	75	55	5	Yes
225	5.8	65	48	9	No

Based on variables such as voltage, current, vibration, temperature, and water flow, the Logistic Regression model is used to determine whether the motor is functioning normally or is at risk of failing, as seen in table 3. Faults are successfully detected by the model, especially when values surpass typical operating thresholds.

Table 4. Comparative Table: Proposed Work vs Existing System

Feature	Existing Systems	Proposed Work (Smart Aqua Control)
Water Level Monitoring	Manual or basic float sensors	Ultrasonic/pressure sensors with real-time cloud logging
Motor Control	Manual switch or timer-based	Automated control via IoT based on tank level & schedule
Motor Dry-Run Protection	Often absent	Yes – automatic shut-off when water source is empty

Communication Protocol	Basic GSM or local relay-based	HTTP/MQTT with cloud & app integration
Remote Monitoring	Rare or limited to SMS	Web dashboard/mobile app with real-time data
Energy Efficiency	No optimization	Prevents motor overuse through intelligent control
Leakage/Overflow Detection	Not integrated	Optional add-on via sensors (e.g., water presence sensor)
User Alerts	SMS only	Real-time alerts via app, email, or dashboard notifications
Data Logging and Analytics	Absent or minimal	Cloud-based storage with trend analysis
Platform Scalability	Hard-wired, fixed systems	Modular, can scale to multiple tanks/pumps easily

The distinctions between the suggested intelligent motor monitoring framework and the current conventional systems are highlighted in Table 4.

The integration of IoT and machine learning within the proposed motor health monitoring framework provides an advanced solution to the challenges associated with remote motor operation and predictive maintenance. By utilizing IoT sensors to collect real-time data on voltage, current, temperature, vibration, and water flow, and leveraging machine learning algorithms to analyse this data, the system accurately predicts motor efficiency, identifies potential failures, and optimizes operational performance.

This technological synergy enhances motor reliability by ensuring proactive fault detection and reducing unplanned downtimes. The user-friendly model illustrates the system’s capability to provide real-time insights into motor health, ultimately leading to improved energy efficiency and cost-effective maintenance strategies. By implementing intelligent monitoring, the system enables users to make data driven decisions to maximize motor lifespan and ensure uninterrupted operation.

The system processes real-time sensor data, applying machine learning models to predict motor efficiency, detect faults, and estimate lifespan. The predicted results are displayed on the LCD screen and a web dashboard, enabling users to monitor performance remotely. The relay module automatically controls the motor, shutting it down in case of anomalies such as a dry run, overload, or phase imbalance.

The system processes the sensor readings and categorizes motor conditions based on predefined thresholds. The Linear Regression model estimates motor efficiency, while the Random Forest Regression model predicts motor lifespan based on historical performance trends. Additionally, the Logistic Regression model provides fault detection alerts, ensuring that potential failures are identified before they escalate.

This seamless integration of IoT, real-time monitoring, and predictive analytics represents a robust and intelligent motor health management system. The results demonstrate the effectiveness of the proposed framework in enhancing motor longevity, reducing energy consumption, and improving operational efficiency across various applications, from pumping stations to industrial automation.

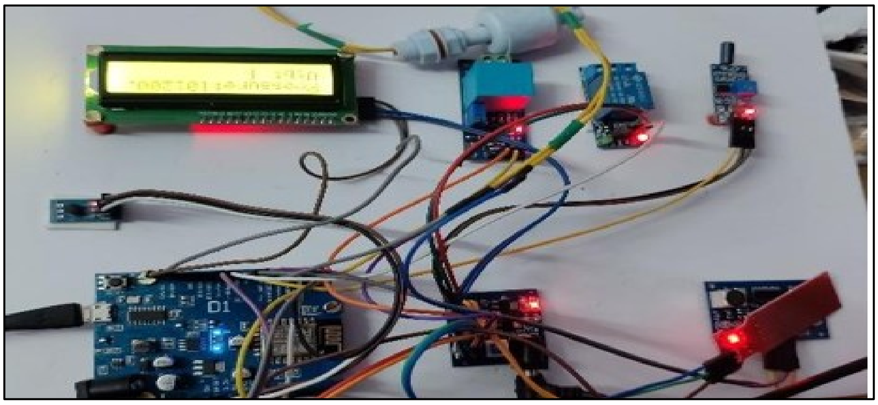

Figure 12. Hardware Output

As illustrated in Figure 12, the system provided real-time feedback following the successful integration of the sensors and microcontroller. The web interface, which facilitates remote diagnostics and monitoring, compiles this data and presents it in a user-friendly format, as demonstrated in Figure 13.

Figure 13. Web Dashboard

6. Conclusion

The proposed IoT-enabled motor health monitoring and remote-control system offers a cost-effective, intelligent, and scalable solution for ensuring the efficient operation of heavy-duty water motors. By integrating real-time sensor monitoring, predictive maintenance using machine learning, and remote control via a web-based dashboard, the system enhances fault detection, reduces downtime, and optimizes energy usage. With automated fault handling, real-time alerts, and predictive analytics, the system prevents issues such as overheating, dry runs, and phase imbalances, ensuring safe and reliable motor operation. The use of machine learning models further enables early fault detection and maintenance scheduling, minimizing unexpected failures. By leveraging IoT connectivity, users can monitor and control motors remotely, making it especially beneficial for industries and households in remote areas. The system's scalability and efficiency make it a promising solution for improving motor performance, reducing maintenance costs, and promoting sustainable energy use. Future advancements can incorporate cloud-based analytics and mobile integration for even more enhanced monitoring and control.

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