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Microcontroller based Protection Unit for 3-PH Induction Motor

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Abstract: *In recent years, automation and remote monitoring have become essential in improving the reliability of agricultural water management systems. Operational issues are often faced by conventional pumping systems such as voltage fluctuations, overcurrent, overheating, vibration, and dry running. Such issues lead to frequent motor failures, energy losses, and high maintenance costs. The proposed "Microcontroller based Protection Unit for 3-ph Induction Motor" is designed to overcome these challenges and provide intelligent, automatic, and real-time protection for water pumps. The system employs multiple sensors to continuously monitor key parameters of motor such as voltage, current, temperature, vibration, and water level. The ESP32 microcontroller processes this data and takes immediate corrective action by controlling the relay to disconnect the pump during unsafe conditions and automatically restoring operation once normal conditions are re-established. The integration of IoT connectivity enables remote supervision and data visualization through cloud platforms without human intervention. This project aims to ensure reliable and efficient water pump operation with minimal human intervention, reduced energy consumption, and extended equipment lifespan. The proposed system achieves rapid fault detection within one second and operates with an accuracy of approximately 98%, making it a cost-effective and sustainable solution for modern smart agriculture*

Keywords: ESP-32 microcontroller, IoT-based Monitoring, Voltage Sensor, Current Sensor, Temperature Sensor, Water Level Sensor, Vibration Sensor, Buck Converter

I. INTRODUCTION

Water pumps play a vital role in agriculture, especially in rural and semi-urban areas where irrigation depends heavily on groundwater and stored water sources. These pumps are essential to water the fields, filling tanks, and maintaining a continuous irrigation supply. However, traditional pumping systems are often manually operated i.e. On-automated, and lack safety mechanisms, which makes the machine vulnerable to operational faults. In many agricultural settings, pumps frequently face voltage fluctuations, overcurrent, overheating, vibration, and dry running conditions. Such issues arise due to unstable power supply, prolonged operation without water, or mechanical wear and tear. These conditions lead to frequent motor failures, increased maintenance costs, and significant time loss for farmers leading to financial loss too. Replacing or repairing damaged pumps not only incurs heavy expenses but also interrupts irrigation, which directly affects crop yield and ultimately affecting farmer's income. With the advancement of embedded systems and IoT (Internet of Things) technologies, it has become possible to design intelligent systems that automatically monitor and control pump operation. Microcontrollers such as ESP32 offer built-in Wi-Fi and multiple input/output pins, making them ideal for real-time sensor integration and remote data handling. By using such technology, pumps can be monitored continuously and protected automatically without manual intervention. The Smart Water Pump Protection System is designed to overcome the limitations of conventional pumping systems by integrating automation, safety, and efficiency. It uses multiple sensors to track vital parameters like voltage, current, temperature, vibration, and water level. The ESP32 microcontroller processes this information and takes immediate corrective actions such as turning OFF the pump in case of unsafe conditions to prevent damage. Once the fault is cleared, the system automatically resumes normal operation. This project promotes sustainable farming practices by minimizing energy waste, extending pump lifespan, and reducing the need for human supervision. It provides a low-cost, reliable, and farmer-friendly solution, ensuring both equipment protection and efficient water utilization in agriculture.

II. LITERATURE SURVEY

A literature review provides an overview of previous research and existing technologies related to smart irrigation, water pump protection, and automation in agriculture. It helps in identifying current trends, methodologies, and limitations in existing systems. Over the past decade, several studies have explored the use of microcontrollers, IoT platforms, and sensor-based systems for agricultural automation. However, most of these systems are either high-cost industrial solutions or lack complete integration of electrical, thermal, and mechanical safety features for water pumps.
This chapter reviews selected works related to IoT-based agriculture, smart water management, and pump protection mechanisms, and highlights how the proposed system using ESP32 and low-cost sensors addresses the research gaps.
S. Gupta et al. [1] proposed an IoT-enabled smart irrigation system aimed at optimizing water usage in agriculture. The research integrated microcontrollers such as Arduino Uno and ESP32 with sensors for soil moisture, humidity, and temperature to automate irrigation schedules. I. Sultanov et al. [2] in this research work, developed an automated protection system for electric motors used in large pumping stations. Their approach involved continuous sensing of current, voltage, and temperature parameters using industrial sensors connected to a programmable logic controller (PLC). T. Todorov et al. [3] designed a comprehensive water flow management system focusing on the protection of pumping equipment against abnormal electrical conditions. Y. Zhang et al. [4] explored how ESP32 microcontrollers could be used for efficient data transmission and monitoring in agricultural water pumping systems. The researchers implemented a wireless communication framework where the ESP32 collected readings from various sensors including flow, voltage, and current and transmitted them via Wi-Fi to a centralized monitoring station. K. S. Krishnamoorthy [5] developed a smart pumping system that emphasized energy efficiency and intelligent control.

III. SYSTEM DESIGN

The circuit connects all sensors, the ESP32, relay, and display module in a structured manner to ensure stable performance.
Voltage Sensor → D21, Current Sensor → D22, Temperature Sensor → D19, Vibration Sensor → D18, Water Level Sensor → D5 and Relay → D4.
Each sensor is connected to the 5V power and ground lines. Data lines are linked to ESP32 GPIO pins

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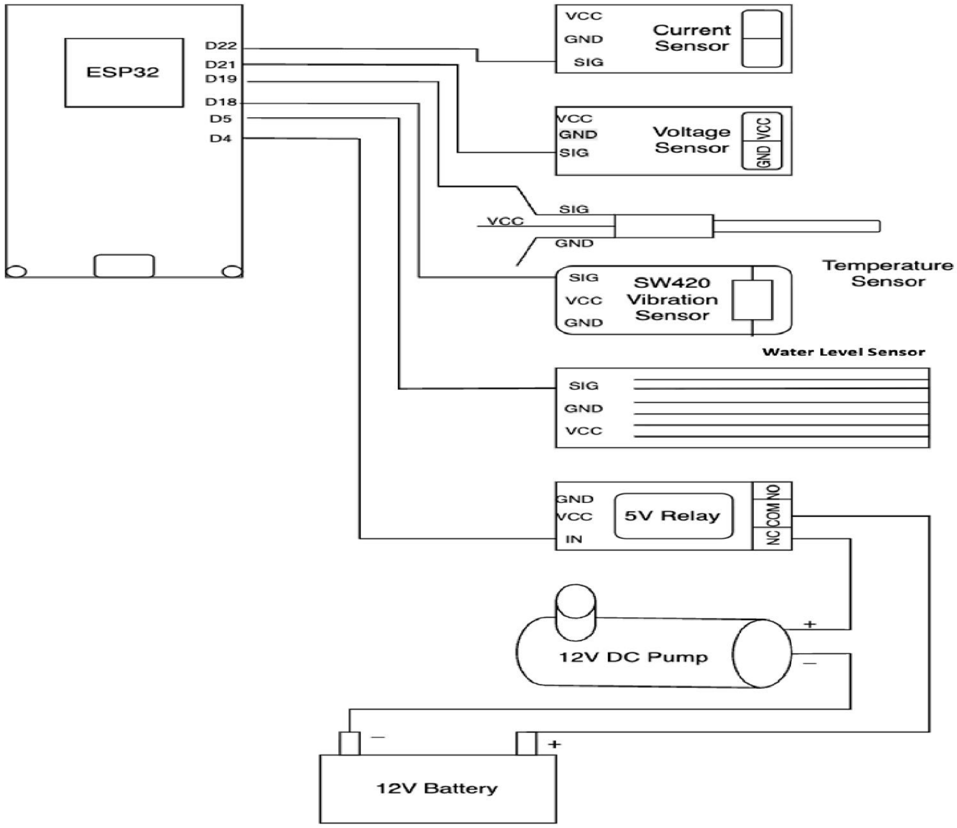

Fig. 1: Detailed Circuit Diagram of the system

Hardware Details:

The hardware components used in this project play a crucial role in ensuring the efficient operation of motor. This section provides an overview of the key hardware elements, including battery, ESP-32, Temperature sensor, Water Level sensor, Vibration sensor, Voltage sensor, Current sensor, DC motor, Relay Module, etc., along with their specifications and functions.

Sr. No.	COMPONENTS	SPECIFICATIONS
1	ESP32 Microcontroller	Operating Voltage: 3.3V, Build in Wi-Fi & Bluetooth, I/O: 30 Pins
2	Voltage Sensor Module	Operating Voltage Range :0-25 V DC, Accuracy: ±1%
3	Current Sensor (ACS712)	Operating Current Range: 0–5 A, Accuracy: ±1–2%
4	Temperature Sensor (DS18B20)	−55 °C to +125 °C, Accuracy: ±0.5°C
5	Vibration Sensor (SW-420)	Operating Voltage: 3.3–5 V DC Output: Digital
6	Water Level Sensor	Detection Range: 0 – 40 mm
7	12V DC Water Pump	Flow Rate: 1–5 L/min
8	Relay Module	1- Channel 5 V
9	DC-DC Buck Converter (LM2596)	Step Down 12 V DC to 5 V DC

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Fig1. ESP32 DevKit V1

Fig2. Voltage Sensor Module

Fig3. Current Sensor (ACS712)

Fig4. Temperature Sensor (DS18B20)

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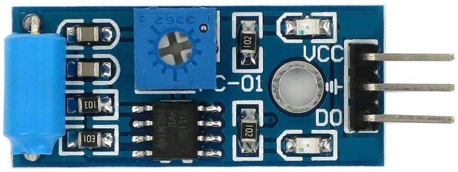

Fig5. Vibration Sensor (SW-420)

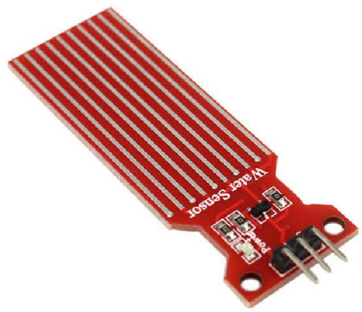

Fig6. Water Level Sensor

Fig7. 12V DC Water Pump

Fig8. Relay Module

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Fig9. Buck Converter

IV. IMPLEMENTATION AND WORKING

The Protection System works as a continuous monitoring and automatic control system. Sensors collect real-time data from the different sensors. ESP32 processes the data and compares it with safety limits. If readings exceed safe limits which is shown in the given table, the controller instantly cuts off power through the relay. Alerts are displayed on the mobile phone sent via IoT to the user's device. When normal conditions resume, the pump will automatically restart. This process operates in a loop, ensuring constant protection and minimal downtime.

Table for Automatic Motor Shutdown:

Sr. No.	Parameters	Condition for Motor Shutdown
1	Voltage	If Voltage > 8V
2	Current	If Current > 5A
3	Temperature	If Temperature > 45°C
4	Water Level	If Level < 15%
5	Vibration	If vibration > Threshold Value(Adjustable)

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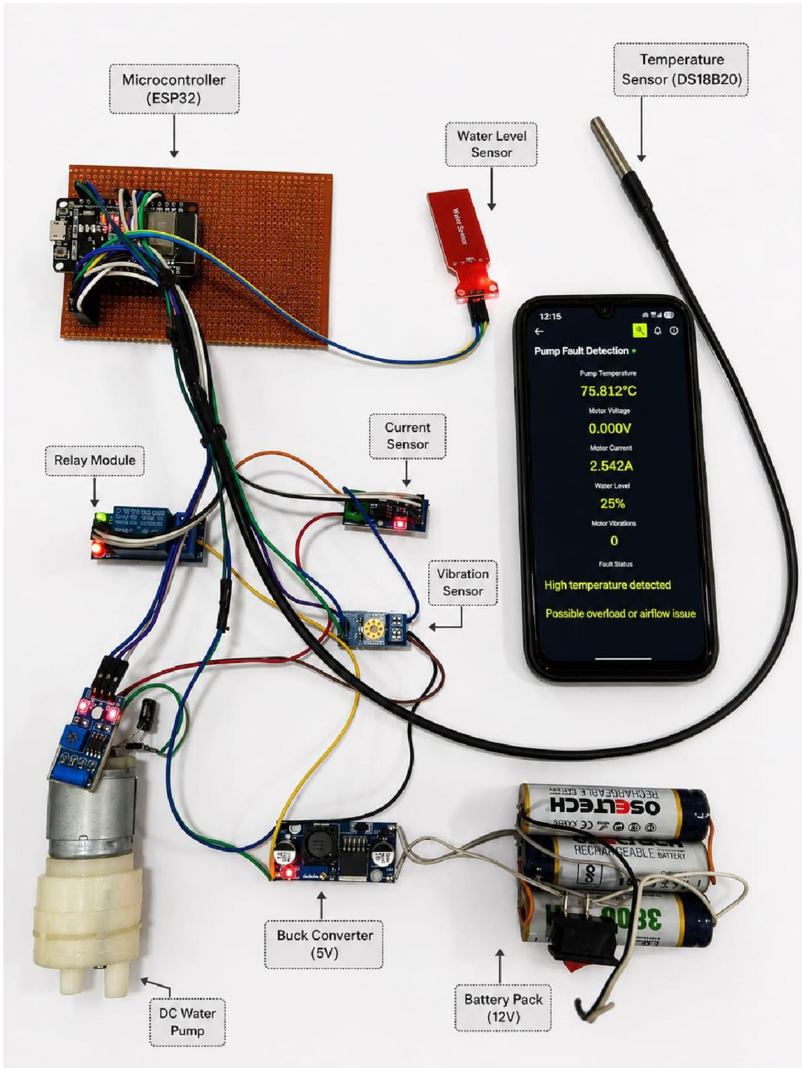

Fig9. Micro-controller based protection unit for Motor

V. RESULTS AND EVALUATION

The system effectively addresses problems such as dry running, overheating, and voltage fluctuations, ensuring both equipment safety and energy conservation. The results confirmed that the system is accurate (98%), responsive (<1s), and highly reliable for continuous operation.

In essence, this project demonstrates how embedded systems and IoT technologies can revolutionize conventional agricultural practices, improving productivity, efficiency, and sustainability. It lays the foundation for future smart irrigation and intelligent water management systems in developing regions.

The image shown below shows the fault condition i.e. 'High temperature detected' of the motor and the motor stops automatically.

Fig10. Blynk IoT app dashboard

VI. CONCLUSION

The Motor Protection System successfully achieved its objectives of developing a reliable, cost-effective, and automated solution for monitoring and protecting water pumps. The combination of ESP32, multi-sensor integration, and IoT connectivity enabled real-time supervision, fault detection, and automated control with exceptional accuracy and speed.

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