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Implementation Of A Multi-Protection Pump Control Unit For Precision Farming

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Abstract: The increasing need for automation and resource optimization in agriculture has emphasized the importance of intelligent irrigation systems. This paper presents the design and implementation of a cost-effective and scalable Pump Control Unit for smart farming applications. The system employs an Arduino Uno microcontroller integrated with a GSM module to enable remote control and monitoring of a three-phase induction motor used for irrigation. Critical protection features such as overcurrent, overvoltage, dry-run detection, and thermal shutdown are incorporated to enhance equipment safety and reliability. The GSM-based communication interface allows farmers to operate and supervise motor functions via SMS, ensuring operability even in remote areas with limited internet access. Comprehensive testing demonstrates that the proposed system significantly reduces manual intervention, improves motor longevity, and supports efficient water management practices. The results affirm the system's potential to contribute to sustainable agricultural practices and serve as a foundational platform for future smart farming enhancements.

***Index Terms* -** Smart Farming, Arduino Uno, GSM Communication, Pump Automation, Motor Protection, Dry Run Detection, Remote Monitoring, Irrigation System, Agricultural IoT, Embedded Systems

I. INTRODUCTION

This project presents a low-cost, GSM-enabled Pump Control Unit designed to automate and protect irrigation systems commonly used in rural farming, where water pumps powered by three-phase induction motors are manually operated. These traditional systems pose challenges such as frequent physical visits—especially during odd hours or adverse weather—and are susceptible to faults like overcurrent, overvoltage, dry-run, and overheating, which can lead to equipment failure, crop damage, and increased maintenance costs. Built around an Arduino Uno microcontroller, the proposed system integrates a range of sensors to monitor temperature, water availability, and electrical parameters, ensuring timely detection and response to abnormal conditions. A GSM module facilitates remote control of the pump and provides real-time SMS alerts to farmers, eliminating the need for internet connectivity and enabling accessibility even in remote regions. The system also includes relay-based motor control, automatic cut-off mechanisms, and a user-friendly interface for seamless operation. By significantly reducing manual labour, minimizing downtime, and improving energy and water efficiency, this smart pump controller offers a scalable and farmer-friendly solution that supports the broader objectives of sustainable agriculture and rural development.

II. SYSTEM DESIGN/METHDOLOGY

The proposed system is a cost-effective, remote-controlled, and protective irrigation pump controller specifically designed to address the operational challenges faced in rural agriculture. It integrates an Arduino Uno microcontroller with a network of sensors and a GSM module to automate the control and safeguard a three-phase induction motor used for irrigation. The system architecture includes core components such as a GSM module (SIM800/900) for two-way SMS communication, enabling remote ON/OFF control and fault alerts, and multiple sensors including a DHT11 for temperature monitoring, a water level sensor to prevent dry-run, and ACS712 along with voltage sensors to ensure safe electrical conditions. The Arduino processes real-time sensor data to decide motor operation, ensuring the pump runs only under safe parameters. Upon detecting abnormal conditions like overheating, overcurrent, overvoltage, or insufficient water levels, the system automatically shuts off the motor and sends an SMS alert to the user, thereby preventing equipment damage and reducing unnecessary power consumption.

This smart solution not only enhances the reliability and safety of agricultural pumping systems but also significantly reduces the physical burden on farmers who would otherwise need to manually monitor and operate pumps located in distant fields. The use of GSM technology ensures compatibility with regions lacking stable internet infrastructure, while predefined SMS commands allow seamless manual override and status checks, even from basic mobile phones. Furthermore, the modular design makes it easy to upgrade or modify the system based on specific farm requirements or additional features, such as soil moisture sensors, solar integration, or IoT-based enhancements. By offering protection from multiple electrical and environmental faults, the system improves the motor's lifespan, conserves water, optimizes energy use, and supports sustainable farming practices. This methodology builds upon previous work in GSM-based automation systems but goes a step further by focusing on robustness, scalability, and practical usability, making it a viable and impactful solution for small and marginal farmers across developing agricultural regions.

II.I BLOCK DIAGRAM

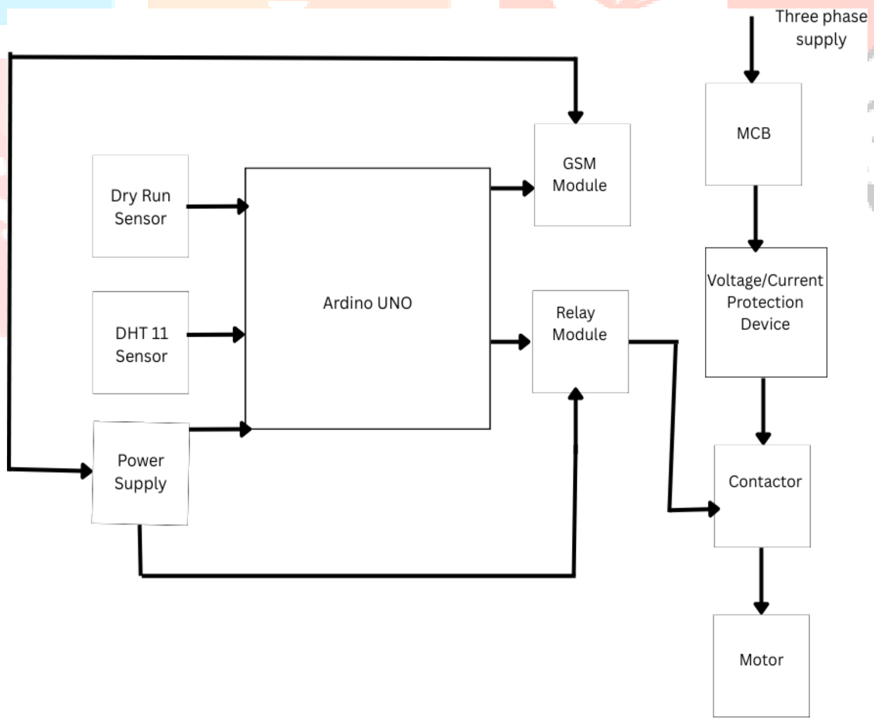

Figure 1: Block Diagram of Implementation of Pump Control Unit for Smart Farming

The Smart Motor Starter Control System developed in this project is specifically designed for smart farming applications, with the primary objective of automating and protecting the operation of a three-phase irrigation pump. The system enables remote motor control while ensuring protection against common electrical and environmental faults typically encountered in agricultural fields. By integrating a microcontroller, sensor modules, GSM-based communication, and control mechanisms, the system enhances the overall efficiency, safety, and convenience of irrigation operations, particularly in rural areas with limited access to infrastructure.

At the core of the system lies the Arduino Uno microcontroller, which acts as the brain of the unit. It acquires real-time data from the connected sensors, processes the input through decision-making logic, and controls the motor operation via a relay and power contactor. Additionally, the Arduino handles remote communication with the farmer through an integrated GSM module, enabling fault alerts and command execution using SMS, without the need for internet connectivity. This ensures accessibility and reliability even in remote farming locations.

The system uses a regulated DC power supply to convert AC mains voltage into appropriate 5V or 12V DC power for various components, ensuring uninterrupted and stable operation. To monitor the pump's environmental and electrical conditions, a set of safety sensors is employed. A dry run sensor detects the absence of water in the source, which could damage the motor, while a DHT11 sensor monitors temperature to prevent overheating. If abnormal conditions are detected, the system immediately stops the motor and sends an SMS alert to the user, ensuring timely intervention.

Electrical parameters are monitored using current and voltage sensing modules, which continuously feed data to the microcontroller. If issues such as overcurrent, overvoltage, or undervoltage are identified, the system performs an emergency shutdown and notifies the user. A Miniature Circuit Breaker (MCB) offers an added layer of manual protection and allows disconnection during maintenance or major faults. Motor switching is handled by a relay module coupled with a power contactor, which ensures isolation between control and power circuits and supports the high starting current of the motor.

The communication system is enabled by a GSM module (SIM7670C), which supports SMS-based control commands such as "START" and "STOP." It also sends real-time alerts when faults occur, keeping the farmer informed at all times. In addition to automated operation, the system includes a manual control option, allowing the pump to be operated directly in cases where the communication module fails or during setup and maintenance activities.

Overall, the system operates by continuously monitoring sensor data and making control decisions based on pre-defined safety conditions. When all conditions are within safe limits, the motor is allowed to run; otherwise, it is shut down to prevent damage. An SMS is sent to report the fault, providing the user with immediate status updates. This closed-loop, real-time feedback mechanism ensures optimal motor performance, enhances safety, promotes water conservation, and significantly reduces the manual burden on farmers, making it a practical and scalable solution for sustainable agriculture.

II.II Hardware Implementation

Figure 2: Working Prototype of Pump Control Unit for Smart Farming

The fully assembled and functional prototype of the Pump Control Unit is mounted on a wooden board for demonstration and testing purposes, with each component strategically placed for accessibility and clarity. The three-phase induction motor, located at the bottom right, serves as the system's main load, simulating a typical irrigation pump used in agricultural fields. The Arduino Uno, placed at the bottom left, functions as the central processing unit, interfacing with various sensors and control modules to execute real-time decision-making. Adjacent to it, the GSM module is integrated to enable remote communication via SMS, allowing the farmer to start or stop the pump and receive fault alerts without the need for internet connectivity.

In the centre of the setup lies the relay module, which acts as an intermediary between the microcontroller and the high-power switching components. It activates the power contactor situated at the top right, which handles the large currents required to operate the motor safely and reliably. Next to the contactor, a Miniature Circuit Breaker (MCB) is installed to offer overcurrent and short-circuit protection, ensuring manual disconnection capability in case of critical failures or maintenance requirements.

At the top left corner, power supply modules are used to convert AC mains into regulated 5V and 12V DC outputs, powering the Arduino, sensors, relay, and GSM module. The center of the board also features essential sensors, including a dry run sensor to detect water absence in the source and a current sensor to monitor the load drawn by the motor. These sensors play a vital role in preventing motor damage due to dry-run operation or overcurrent situations. During testing, the system was subjected to simulated fault scenarios, including dry run, overheating, and voltage irregularities. In each case, the Arduino responded accurately by shutting down the motor and sending real-time SMS notifications to the user.

This hands-on validation confirmed that the prototype not only functions as intended under normal conditions but also provides effective fault detection, protection, and remote operability. The modular design of the prototype also allows for easy troubleshooting, upgrades, and scalability. It reflects a practical solution tailored for farmers, especially in regions where physical access to irrigation systems is limited or infrastructure is underdeveloped. The successful testing of this prototype marks a significant step toward the implementation of affordable and intelligent pump control systems in smart farming environments.

III. RESULTS AND ANALYSIS

The experimental evaluation of the GSM-enabled Pump Control Unit demonstrated its effectiveness in automating and safeguarding irrigation systems under a variety of real-world conditions. The DHT11 sensor provided consistent and accurate temperature data, allowing the system to shut down the motor when overheating was detected, thus preventing thermal damage and prolonging equipment life. Similarly, the water level sensor responded promptly to low water conditions, ensuring that dry-run scenarios were avoided—one of the leading causes of motor failure in rural agriculture. Electrical safety was also robust, with the current and voltage sensors providing immediate feedback to the Arduino. The system reacted swiftly to anomalies such as overcurrent, undervoltage, and overvoltage by halting operation and sending SMS alerts to the user, ensuring that electrical faults were addressed without user delay.

The GSM module performed well under all tested conditions, proving to be an effective medium for real-time communication. SMS commands were executed with high accuracy, and alerts were received within seconds, even in low-signal areas. This functionality drastically reduces the need for physical site visits, especially during adverse weather or late-night irrigation cycles. Moreover, the system's manual override feature provided added flexibility, allowing operation during maintenance or communication failures.

Overall, the project achieved its goal of creating a cost-effective, remotely operable, and intelligent pump control system suitable for rural and semi-urban farming environments. It not only reduces operational workload and improves user safety but also promotes better resource management by minimizing water and power wastage. The modular design allows for future upgrades, such as solar power integration, IoT-based dashboards, and AI-powered irrigation forecasting, making it a future-ready solution for sustainable smart farming.

Figure 2: Motor On Condition Via SMS

The image depicts a straightforward chat-based motor control interface, where the user sends the command "MOT1" twice to operate the motor. Upon receiving the command, the system responds with "Motor is on," confirming that the motor has been successfully activated. This suggests that "MOT1" is a predefined SMS keyword used to trigger the motor's operation. The system likely utilizes a microcontroller or GSM-based platform to interpret this command, which then sends a signal to the motor control unit, activating the motor. After the motor is turned on, the system sends a confirmation SMS back to the user, providing real-time feedback. This setup allows for remote control and monitoring of the motor, eliminating the need for physical interaction with the hardware. The use of SMS commands offers a simple, accessible interface that is highly effective in rural or remote areas with limited internet connectivity, making it an ideal solution for agricultural automation. The system can be further enhanced by adding more command options, such as "MOT1 OFF" to turn the motor off, or integrating sensor-based triggers to automate the process based on environmental conditions like temperature or water level.

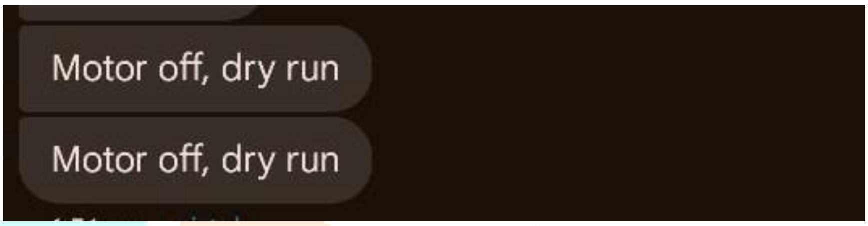

Figure 2: Motor Off Due to Dry Run

This message clearly indicates that the system has detected a dry run condition, which occurs when the motor is running without sufficient water supply a common and serious issue in irrigation pump systems. In this situation, the system automatically shuts off the motor to prevent potential damage caused by overheating and excessive wear. This confirms that the smart farming project incorporates dry run protection, a vital feature for ensuring the longevity and efficiency of irrigation pumps. The inclusion of such protection not only safeguards the motor from costly damage but also reduces maintenance costs and downtime. By detecting dry run conditions in real time, the system helps optimize pump performance and ensures that the motor operates only under safe conditions. This feature contributes to more sustainable farming practices by minimizing the risk of equipment failure, promoting energy efficiency, and reducing unnecessary water wastage. Additionally, integrating this protection mechanism with remote SMS alerts further empowers farmers to respond promptly, even when they are far from the pump site, enhancing operational convenience and safety.

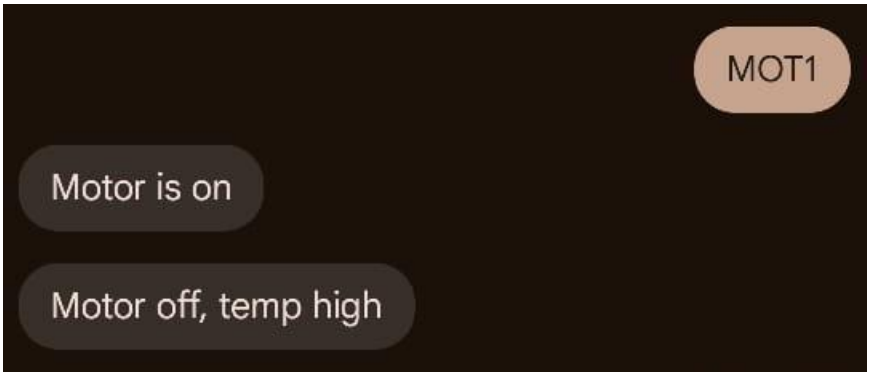

Figure 2: Motor Off Temp. High

The system is equipped with a temperature sensor that continuously monitors the motor's operating temperature in real time. When the temperature exceeds a predefined safety threshold, the system automatically shuts off the motor to prevent overheating, which could cause serious damage to the motor's components. This proactive protection mechanism ensures that the motor operates within safe temperature limits, thereby enhancing its lifespan and reliability. Upon detecting an over-temperature condition, the system promptly sends an SMS alert to the farmer, notifying them of the issue. The alert may read something like: "Motor temperature too high. System shutdown for safety." This immediate feedback allows the farmer to take timely corrective actions, such as inspecting the motor or addressing environmental factors contributing to the overheating, without the need for manual checks or on-site visits. This feature not only protects the motor but also helps optimize operational efficiency and safety in the farming environment.

IV. CONCLUSION

In conclusion, the GSM-enabled Pump Control Unit for smart farming represents a significant advancement in agricultural automation, offering a reliable, cost-effective, and scalable solution for irrigation management. By integrating a range of safety mechanisms such as dry run protection, temperature monitoring, and electrical fault detection, the system ensures the protection of both the pump and the motor, thereby reducing the likelihood of costly repairs and system failures. The real-time SMS alerts and remote control functionality provide farmers with the flexibility to manage their irrigation systems efficiently from any location, which is particularly valuable in remote farming environments where access to technology and internet connectivity may be limited.

The system's ability to automatically shut down the motor when fault conditions are detected ensures that the pump operates within safe parameters, reducing both energy consumption and water wastage. Additionally, the system's modular design allows for easy integration of additional sensors and functionalities, such as soil moisture sensing, weather forecasting, or even integration with renewable energy sources like solar power, further improving its effectiveness and sustainability.

This smart farming solution not only improves operational efficiency and convenience but also promotes sustainable agricultural practices by optimizing water and energy use, key resources in farming. It also empowers farmers with greater control and autonomy over their irrigation systems, contributing to enhanced crop productivity and lower operational costs. Looking ahead, the potential for future enhancements could further transform this system into a fully autonomous, intelligent irrigation management tool that supports precision farming techniques and fosters sustainable agricultural development on a larger scale.

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