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IOT BASED WATER PUMP MONITORING & CONTROL SYSTEM

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ABSTRACT

Electric water pumps are used everywhere, from domestic overhead tank filling to agricultural borewells and small municipal supply schemes. In most of these installations the pump is switched manually or through a simple float switch, and the motor has only a fuse or a basic starter for protection. As a result, tanks overflow, pumps run dry when the source level falls, and motors burn out because of low voltage, single phasing, or overload, often in locations where no operator is present. This paper presents an IoT Based Water Pump Monitoring and Control System that automates pump operation, protects the motor against common electrical and hydraulic faults, and allows remote supervision through a mobile application.

The system uses an ESP32 microcontroller as the main controller. Water levels in the overhead tank and the sump or source are measured with ultrasonic and float sensors, flow in the delivery pipe is measured with a Hall effect flow sensor, and the electrical condition of the motor is measured through ZMPT101B voltage sensors on each phase and ACS712 or current transformer based sensing of motor current. A DS18B20 sensor on the motor body records winding temperature. The pump is started and stopped through a relay that drives the contactor coil of the existing direct-on-line or star-delta starter, so the high power switching remains with standard switchgear.

The controller starts the pump when the tank level falls below a lower limit and stops it when the upper limit is reached, provided the source has enough water and the supply is healthy. Protection functions include dry-run detection from low current combined with zero flow, over-voltage and under-voltage trip, single phasing and phase imbalance detection, overload trip with an inverse time delay, locked rotor detection at start, and thermal trip on high motor temperature. Each trip is followed by an automatic restart attempt after a cooling interval, with a limit on the number of restarts.

Operating data such as tank level, flow rate, supply voltage, motor current, power, running hours, and energy is sent over Wi-Fi to a cloud platform using MQTT, with a GSM module used as a fallback in rural areas without broadband. A dashboard and mobile application display live status, allow the user to switch the pump remotely or set a schedule, and deliver alerts for faults, overflow, and low source level. Pumping history helps estimate water delivered and energy consumed per day. This record also shows the owner how the supply voltage and the pump current vary over the day.

A prototype was built with a 0.5 HP single-phase pump for testing and a simulated three-phase supply board for fault studies. The system maintained the tank level

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between the set limits without overflow, detected dry-run within about five seconds, and tripped on single phasing and under-voltage within the programmed delay. The results show that a low-cost IoT controller can make pumping safer, save water and energy, and reduce motor failures.

I. INTRODUCTION

Water pumping is one of the largest uses of electricity in rural India, where millions of agricultural pump sets draw power from the grid, and it is also a routine daily task in urban homes and apartment buildings that rely on sumps and overhead tanks. Much of this pumping is done inefficiently. Farmers often leave pumps switched on because supply is available only at uncertain hours, and residents forget to switch off the motor until the tank overflows. Both situations waste water and energy and increase the load on the distribution network. Unmanaged pumping also lowers groundwater levels faster, which in turn forces pumps to work against a greater head and draw more power for the same quantity of water.

Pump motors also fail far more often than they should. Induction motors driving pumps are sensitive to low voltage, which increases current and heating, and to single phasing, in which the loss of one phase causes the motor to run on two phases with very high current in the remaining windings. When the water source runs dry the pump continues to run without load, and the lack of water flow damages seals and impellers in submersible and monoblock pumps. Traditional starters with fuses and bimetal overload relays give only partial protection, and in remote fields nobody may notice a fault for hours.

Embedded controllers and IoT connectivity offer a practical way to address these problems. A microcontroller can measure water levels, flow, voltage, and current continuously, decide when the pump should run, and trip it as soon as an abnormal condition appears. Wi-Fi or GSM connectivity lets the owner see the status of the pump from anywhere and control it without travelling to the site, which is especially useful for agricultural pumps located far from the farmer's home.

This paper describes an IoT Based Water Pump Monitoring and Control System that automates pump operation based on tank and source levels, provides electrical and hydraulic protection for the motor, and reports status and faults to a cloud dashboard and mobile application. The aim is to reduce water wastage, save energy, extend motor life, and remove the need for constant manual attention to the pump.

II. LITERATURE SURVEY

Automatic water level control has been studied for many years, beginning with float switches and electrode-based level sensors that open and close a contactor when the water reaches fixed points. These methods are simple and cheap, but electrodes corrode and scale over time, float switches stick, and neither gives a continuous reading of the level. Later research introduced ultrasonic distance sensors mounted at the top of the tank, pressure transducers at the bottom, and capacitive probes, which provide continuous level measurement and allow the controller to calculate the volume of water stored. Studies comparing these sensors note that ultrasonic sensors

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are non-contact and easy to install, but their readings can be affected by condensation, foam, and narrow tank openings, so averaging and range checks are required in the firmware. Some authors also report that wireless tank nodes using low-power radio are preferred in tall buildings where running a sensor cable from the terrace to the pump room is inconvenient.

Motor protection for pump sets has been a major theme in electrical engineering research. Induction motors are commonly protected by bimetal thermal overload relays, which respond to the heating effect of current, and by single phasing preventers that detect loss or imbalance of phases. Researchers have shown that microcontroller-based protection can combine these functions and improve their accuracy by measuring the actual voltage and current of each phase. Negative sequence voltage and current imbalance percentages have been used as indicators of unbalanced supply, and several works suggest trip limits based on recommendations for motor derating under imbalance. Under-voltage protection has received attention in rural feeders, where voltage at the tail end can fall well below the rated value during peak irrigation hours and cause motors to overheat. It has also been observed that frequent starting of large pumps on weak feeders causes voltage dips that affect other consumers on the same line.

Dry-run protection is particularly important for submersible and monoblock pumps. Research has examined several ways to detect dry-running, including water presence sensors in the suction pipe, flow sensors in the delivery line, and indirect detection through the motor current and power factor. When a pump runs without water, the load on the motor falls, so the current and power factor drop noticeably compared with normal pumping. Studies have shown that a combination of low current and zero flow over a short time window gives reliable detection while avoiding false trips during priming. Automatic restart after a delay, with a limit on the number of attempts, has been recommended so that the pump resumes once the source recovers.

IoT-based remote pump control has become common in academic projects and commercial products, largely driven by the needs of farmers. Early systems used GSM modules to allow the farmer to switch the pump on or off by sending an SMS or making a missed call, and to receive a message when power returned or the pump tripped. More recent work uses Wi-Fi or cellular data with cloud platforms and mobile applications, adding live dashboards, schedules, and historical records. Studies report that remote control reduces the number of trips farmers make to the field, particularly at night, and that scheduling pump operation according to supply hours and soil moisture can save both water and electricity. MQTT has been widely adopted for its low bandwidth and ability to handle intermittent connections.

Energy efficiency and condition monitoring of pumps form the final strand of related work. Researchers have used measured power and flow to estimate the efficiency of a pump set and to identify problems such as worn impellers, clogged foot valves, and oversized motors. Logging of running hours, number of starts, and winding temperature has been proposed as a basis for predictive maintenance. Some studies apply simple machine learning methods to current signatures to identify bearing faults and cavitation. The system in this paper draws on these findings by combining level-based automation, multi-parameter motor protection, flow and energy measurement,

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and cloud-based monitoring in one controller suitable for both domestic and agricultural pumps.

III. SYSTEM ANALYSIS

The system is analysed as a field unit at the pump starter, a communication link, and a cloud application. The field unit contains an ESP32 controller, an ultrasonic sensor on the overhead tank connected through a long cable or a small wireless node, a float or electrode sensor in the sump or well, and a YF-S201 type Hall effect flow sensor on the delivery pipe. Electrical sensing includes ZMPT101B modules for phase voltages and current sensors for motor line currents, with a DS18B20 probe fixed to the motor body. The controller drives a relay that energises the coil of the existing contactor, so the motor is switched by standard starter hardware with its own isolation. Local indication is provided by an LCD showing level, voltage, current, and status, and by LEDs for run and fault. The communication link uses Wi-Fi with MQTT and a SIM800L module for SMS where data coverage is weak. The cloud stores readings and applies alert rules, and the mobile application offers remote control and scheduling.

Existing System

In most homes and apartment buildings the water pump is switched on and off by hand, or through a simple float switch that has no knowledge of the sump level. The motor runs until someone notices overflow, and it continues running even when the sump is empty, which damages the pump. In agriculture, farmers visit the field to start the pump whenever power is available, often at night, and leave it running for long periods because they cannot predict when supply will return. Motor protection is usually limited to fuses and a thermal overload relay in the starter, which do not detect single phasing quickly, do not respond to dry running, and cannot distinguish between different causes of a trip. Supply voltage is not measured at all in most installations, so motors are regularly operated at low voltage. When a motor trips or burns out, the owner learns of it only after returning to the site, and there is no record of running hours, water pumped, or energy consumed.

Disadvantages of Existing System

- Pumps are switched manually and tanks frequently overflow.
- Simple float switches do not check whether the source has water.
- Dry running damages seals, bearings, and impellers of the pump.
- Single phasing is not detected quickly by basic thermal overload relays.
- Motors are often run at low supply voltage, which causes overheating.
- Farmers must travel to the field, often at night, to switch pumps.
- No alert is sent to the owner when the motor trips or fails.
- The cause of a trip is not recorded, which makes diagnosis difficult.
- Running hours, water delivered, and energy used are not measured.
- Water and electricity are wasted because pumping is not scheduled.

Proposed System

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The proposed system is an IoT controller fitted beside the existing pump starter that automates pumping and protects the motor. An ESP32 reads the overhead tank level through an ultrasonic sensor, the source level through a float sensor, and the delivery flow through a Hall effect flow meter, and it measures phase voltages and motor currents through ZMPT101B and current sensors. The pump starts automatically when the tank falls below the lower limit and stops at the upper limit, and it is not started if the source is low or the supply is unhealthy. The firmware provides dry-run trip based on low current and zero flow, over-voltage and under-voltage trip, single phasing and imbalance trip, inverse time overload trip, locked rotor detection at start, and thermal trip from winding temperature. After a trip the controller waits for a cooling period and retries a limited number of times. All readings and events are published through MQTT to a cloud dashboard, with GSM SMS as backup, and the mobile application allows remote switching, schedules, and review of pumping history.

Advantages of Proposed System

- Maintains tank level automatically and prevents overflow.
- Stops the pump when the source is empty and prevents dry running.
- Detects single phasing and phase imbalance before windings are damaged.
- Protects the motor against over-voltage, under-voltage, and overload.
- Monitors winding temperature and trips on overheating.
- Allows remote on and off control and scheduling from a mobile phone.
- Sends alerts for trips, power return, overflow, and low source level.
- Works over GSM in rural areas where Wi-Fi is not available.
- Records running hours, water delivered, and energy consumed.
- Uses the existing starter and contactor, so installation is simple.

IV. METHODOLOGY

The methodology begins with a survey of typical pump installations to fix the sensing points and the starter interface. The ultrasonic sensor is mounted on the tank lid and calibrated for empty and full distances, and the flow sensor is calibrated by timing the filling of a known volume. The ZMPT101B and current sensors are calibrated against a reference meter at several loads. The ESP32 firmware samples voltage and current over complete cycles, computes RMS values, power, power factor, and imbalance percentage, and runs a pump state machine with states for idle, starting, running, tripped, and lockout. Start is allowed only when source level and voltage are within limits, and a star-delta or DOL sequence is followed through the contactor relay. Dry-run is detected when current falls below a set fraction of the normal running current and flow stays near zero for five seconds. Faults are introduced by disconnecting a phase, lowering voltage through a variac, and closing the suction valve. Data is published through MQTT and the dashboard is tested for latency and alert delivery.

SYSTEM ARCHITECTURE

The architecture of the IoT Based Water Pump Monitoring and Control System is organised in layers. The Hydraulic Sensing Layer includes the ultrasonic tank level sensor, the sump float sensor, and the flow sensor on the delivery pipe. The Electrical

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Sensing Layer measures phase voltages, motor currents, and winding temperature. The Signal Conditioning Layer scales and filters these signals for the controller. The Edge Controller Layer on the ESP32 computes electrical quantities and runs the pump state machine. The Protection Logic Layer applies dry-run, voltage, single phasing, overload, locked rotor, and thermal rules. The Starter Interface Layer drives the relay and contactor that switch the motor. The Connectivity Layer carries data through Wi-Fi and MQTT with GSM as a fallback. The Cloud Layer stores readings, applies schedules and alert rules, and the Application Layer presents the live status, remote control, and pumping history on the mobile phone and web dashboard.

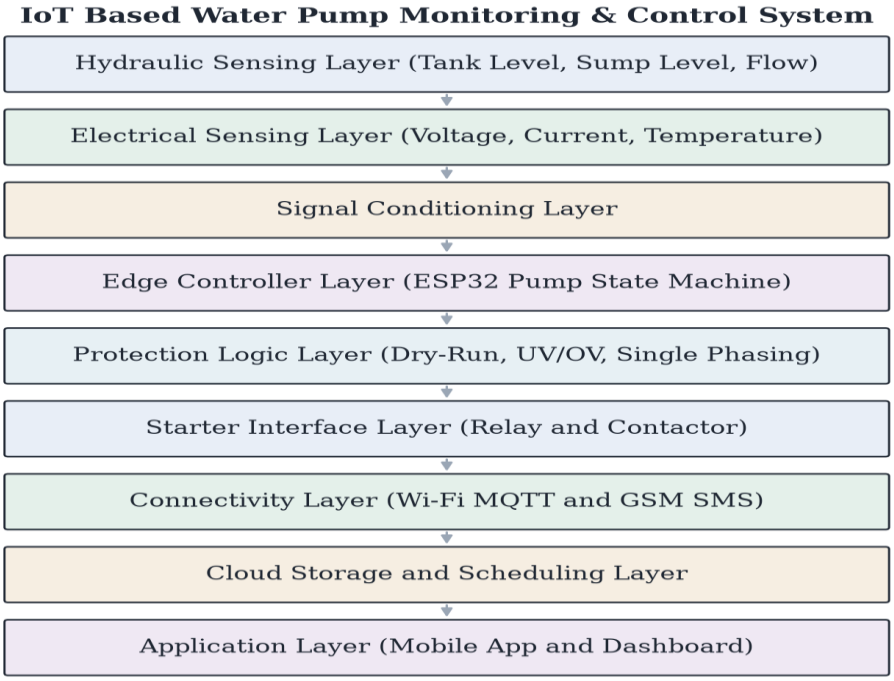


Fig. 1 System Architecture

V. RESULT AND OUTPUT

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VI. CONCLUSION

This paper presented an IoT Based Water Pump Monitoring and Control System that automates pumping according to tank and source levels, protects the pump motor against electrical and hydraulic faults, and allows the owner to supervise and control the pump remotely. The system uses an ESP32 controller with level, flow, voltage, current, and temperature sensors, and it switches the motor through the existing contactor so that it can be added to installed pumps without major changes.

The protection functions address the most common causes of pump motor failure. Dry running is detected from the combination of low current and zero flow, single phasing and imbalance from the measured phase quantities, low and high supply voltage from RMS values, sustained overload from an inverse time characteristic, and overheating from winding temperature. Tests on the prototype confirmed that these conditions were recognised within the programmed delays and that the pump restarted automatically when normal conditions returned, without repeated cycling.

The level-based automation prevented tank overflow and avoided starting the pump when the sump was empty, which saves both water and electricity. Remote control and schedules make the system especially useful for agricultural pumps, where farmers can start pumping when supply is available without travelling to the field at night. The recorded data on running hours, water delivered, and energy consumed also gives the owner a clear picture of pump usage and a basis for planning maintenance.

Future work will add soil moisture sensing so that irrigation pumps run only when the crop needs water, integrate solar pump controllers with maximum power point

tracking, and use motor current signatures to detect bearing wear and cavitation. A LoRa link between the tank node and the pump controller would remove the need for long cables in large buildings and farms. Field trials over a full irrigation season are planned to measure water and energy savings and to refine protection settings for different pump ratings.

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