Intelligent Submersible Pump for Irrigation Purposes

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***Abstract***— **India, with its villages and thriving agriculture sector, heavily relies on climate conditions for successful cultivation. Unfortunately, the insufficient availability of water sources during the monsoon season poses a challenge. To combat this issue, farmers have resorted to utilizing irrigation methods in their agricultural fields. Notably, bore well electric pumps and lift irrigation systems have become the go-to choices for irrigation in India. These electric pumps, ranging in capacity from 3HP to 15HP, are responsible for efficiently extracting and pumping water. However, many farmers in rural areas encounter multiple problems, such as unscheduled load shedding, under-voltage, over-voltage, dry run scenarios, and consequent motor failures. The high costs associated with motor replacements or repairs have raised concerns among farming communities. Consequently, ongoing research is focused on developing robust motor protection mechanisms to prevent these faults. An intelligent protection and control system is developed for safeguarding electric motors in agricultural environments, leveraging the Internet of Things (IoT) and cutting-edge sensors.**

Keywords— ***Internet of Things, Submersible Pump, Sensors, Agriculture Fields, Dry run, Under voltage, over Voltage***

# Introduction

India, being primarily an agricultural country, heavily relies on farming as the main occupation for a majority of its population. With approximately 70% of the people depending on agriculture, it contributes significantly to the nation's economy. However, despite the sector's crucial role, its share in the country's GDP has declined due to the growth of other sectors. To tackle various challenges faced by farmers, such as inadequate water supply and unreliable power sources, innovative solutions incorporating the Internet of Things (IoT) and intelligent pump control systems are being introduced.

In the latest interconnected environment, utilization of Embedded Internet of Things (IoT) devices has become increasingly prevalent. These devices are equipped with Wi-Fi communication modules, enabling seamless connection to the Internet. Within the realm of IoT, we encounter various embedded systems such as STM32L4, which assists in discovering IoT nodes, and Node MCU esp8266, a reliable IoT component. Gathering environmental data, particularly temperature and humidity, is made possible through the application of the advanced DHT11 sensor. Employing C++ and similar low-level programming languages, developers can effectively craft IoT devices and implement IoT Cloud software. In this context, the IoT Cloud assumes significance, as it has been specifically modified to handle data processing emanating from IoT devices. With the evolution of IoT, the Cloud has transcended geographical boundaries and can be leveraged from any part of the world. For seamless integration and exchange of information between IoT devices or with the IoT Cloud, access to the Internet is imperative[[1].](#One) In today's interconnected world, the utilization of Embedded Internet of Things (IoT) devices has become increasingly prevalent. In this context, the IoT Cloud assumes significance, as it has been specifically modified to handle data processing emanating from IoT devices. With the evolution of IoT, the Cloud has transcended geographical boundaries and can be leveraged from any part of the world. For seamless integration and exchange of information between IoT devices or with the IoT Cloud, access to the Internet is imperative [[2].](#Two)

In the revolutionary era of the IoT, sensors play a crucial part in the process of facilitating advanced environmental sensing, remote surveillance, and health monitoring. Through their sophisticated technology, sensors have become the instrumental link bridging physical objects with digital connectivity, ushering us into a new realm of transformative possibilities [[3]](#Three). We regularly interact with IoT technology due to the monitoring, measurement, and management of various objects through technologies like RFID, wireless, and WAN. In the field of electronic engineering, a significant number of commercial operations focus on embedded systems, and many embedded devices run code in C/C++. Common tasks in traditional C/C++ programming include providing text and graphics support for Windows and Linux. C/C++ API modules are used for sensor integration, particularly for monitoring liquid levels in tanks used for storage purposes and containers. Various techniques used for measuring the level of liquid such as magnetic, radar, and ultrasonic are employed based on factors like measurement range, constraints of installation, and type of liquid, each requiring specific sensor requirements Sensors measuring water level are important in tanks used in distribution of water supplied for drinking purposes [[4]](#Four).

# LITERATURE SURVEY

The Electric Submersible Pump (ESP) plays a vital role in achieving a high recovery percentage in the oil and gas industry. These pumps are commonly either low-speed progressive cavity pumps or multi-stage high-speed centrifugal pumps. Traditionally, an enclosed submersible induction motor (IM) is used to power the ESP. Typically, these pumps are utilized for process of removing gas and oil from underground geological formations, situated within wells underground of 100-1000 ft. Powering the ESP is achieved through long cables connected to variable frequency drive or adjustable frequency drive or VSD on surface installation or platform. Unfortunately, conventional IPM drives with position sensor-based speed controllers cannot be utilized by ESPs [[4]](#Four).

A range of straightforward drivers for file systems, networks, and easy-to-use APIs have been developed to enhance the input-output capabilities of the NXP1768 chip [[5]](#Five).

The submersible diaphragm pump finds extensive use in oil wells, but this utilization often leads to various issues such as wax deposition, corrosion of oil pipes, cable damage, and obstruction in monitoring pump parameters, results in expensive and easily worn pipe rods etc [[6]](#Six).

IMs have lower efficiency and thermal stability due to power losses in the rotor through slippage. The energy efficiency of ESP depends on the reduction of energy losses in the supply channel. Converters for energy-efficient SEM control are available in the country and abroad. The permanent Magnet Synchronous Motor (PMSM)-controlled Electric Submersible Pumps (ESPs) provide enhanced efficiency, reduced dimensions, expanded operating ranges, lower heat production, and superior performance compared to equivalently size Induction Motor (IM)-controlled ESPs. Nonetheless, PMSM-ESPs encounter control challenges attributed to the nonlinearity inherent in Permanent Magnet (PM) motors [[7]](#Seven).

Inductive loads such as AC and DC motors are considered common in industrial applications. In industry, three-phase induction machines are popular, for domestic use, single-phase induction motors are preferred for their low maintenance, low operating costs, robust construction, and also for their efficiency and reliability. Motors can face damage such as cooling, temperature and vibration, lubrication, stator, rotor, bearing, and winding failures. Even small problems will result in damages and financial losses. Monitoring of motors and their parameters is necessary to avoid damage. Thanks to IoT technology, engines can monitor and facilitate data communication between machines [[8]](#Eight).

It is important to identify errors while they are still being created. According to the literature, the most damaging faults in electrical equipment are stator and bearing abnormalities, which account for more than 80% of induction motor problems. Stator rotation faults are caused by aging and damage to the windings, as well as other insulation techniques used in the construction of new motors. Once thresholds are exceeded, the insulation continues to degrade, resulting in thermal hot spots that affect stator rotation. Similarly, the main causes of bearing-related failures include aging, lubricant and its viscosity diminishes over time. As a result, the rolling balls of the bearings begin to seize [[9]](#Nine).

The Internet of Things technology has lately received much study attention and has emerged as a very promising technological paradigm. The quantity of devices linked to the Internet of Things is projected to surge significantly, rising from 26 billion in 2020 to a remarkable 100 billion by 2030 .. Wireless sensor networks (WSNs) perform better when the IoT is used, especially in requirements which requires environmental and healthcare monitoring. IoT has made it easy for consumers to get continuously updated information about the conditions and characteristics of the environment and the physiological state data from anywhere, anytime through web browsers or mobile software application. The Internet of Things (IoT) enables seamless data collection, wireless networking, cloud storage, and analytics that are critical to the design and deployment of these systems. [[10]](#Ten).Wearable Body Area Network ,WSN type is widely used to monitor physiological signals and improve overall well-being and quality of life. For example, the study used WBANs to monitor safety-related variables such as temperature, humidity, and ultraviolet (UV) radiation levels. The design and deployment of a Wearable Sensor Network by utilizing the technology IoT has several advantages for the wearable technology industry, some of which are specified below: 1. Data collection 2. Wireless connectivity 3. Storage on cloud platforms also enables data processing, analysis, and long-term storage 4. Data analytics: Data analytics technologies that can process and analyse sensor-collected data are included in the IoT. Various machine learning algorithms can detect patterns and similarities in data to offer insightful information about people's health. [[10]](#Ten).

The effectiveness of IOT and automation is evident for the following reasons:

1. Diverse connectivity: IoT can connect and connect a wide range of devices, from mobile devices and tablets to stand-alone devices, enabling comprehensive monitoring and control

2. Reduced dependence on human labour: Both IoT and automation are essential to decrease the human interference and completely rule out the possibility of human error, leading to more reliable and consistent results.

3. Remote Monitoring: In agriculture, farmers can use a variety of equipment to remotely monitor crop and soil health from any location, enabling quick intervention and decision-making.

4. Time-saving: IOT and automation simplify the report generation and monitoring process, saving farmers valuable time and effort.

5. Advanced analytics: IoT and automation facilitate a wide range of analytics, such as monitoring average rainfall and evaluating soil condition gradients, providing valuable insights for informed agricultural decision-making.[[11].](#Eleven)

Arduino UNO: An open-source microcontroller board that features sets of analog and digital I/O pins, and devices.

16x2 Liquid Crystal Display: An electronic device generally used as a screen in TVs, PCs, and smartphones, which helps to control the device independently and displays moving images.

DHT11: The DHT11 is a combination of humidity and temperature sensor that provides a simple,easy-to-read interface for reading humidity and temperature. These can be used mainly in the fields to select a suitable environment for growing crops.

Soil Moisture Sensor: A device based on Ohm's Law that uses resistance to calculate soil moisture and display the moisture level in the crop.

GSM module: GSM modules are communication modules that use mobile networks to wirelessly receive and send data, creating a data transfer between the device and the network [[11].](#Eleven)

Ultrasonic sensor: An ultrasonic sensor is employed for distance measurement from a specific point or location. A high-frequency sound wave is emitted and at this point, an echo is picked up from the object.

Wi-Fi Module: A device that allows Wi-Fi signals to be transmitted to smart devices such as laptops and phones, allowing users to gain high-speed network access. A popular example of such a module is the ESP8266 module. It enables us to meet the demands of the IoT industry [[12]](#Twelve)

The system for calculating fault distance relies only on measuring original flash events and analysing the reflection pattern of traveling waves caused by the fault. Unlike other approaches that generally uses Rogowski coils for measuring step waves, this particular system explores the operation of Capacitive voltage detectors within a medium voltage substation [[13]](#Thirteen).

Water can be saved without being wasted with help of to the Internet of Things and sensors; this system shuts down the motor in situation when water reaches the top level in the tank, reducing water wastage. When the water level reaches full in the tank, continuous usage of the motor wastes water and electricity. So IoT turns off the engine by reducing human interference. The relay that connects the motor consists of an oscillator connected to the tank and an IC connected to the circuit that controls how the circuit turns on and off. [[14](#Fourteen)].

IoT can be used to manage water resources, bringing with it a reliable and affordable method of monitoring water levels. A system for controlling the level of water and the ability to act quickly and autonomously to prevent losses. Requirements for water level monitoring systems include residential areas. Pumps that can be completely submerged in water are referred to as submersible pumps, often known as electric submersible pumps. A 3-6V source is used for power supply [[15](#Fifteen)].

# ADVANCEMENTS

In this paper, it is planned to design a smart irrigation submersible pump :

• To automatically control the operations of the motor through mobile/tab etc using IoT.

• To detect the under-voltage, over-voltage, and phase-out faults during motor operations and automatically turn off the motor/pump and alert the user.

• To control the pump set from getting burned due to dry run issues, detect the Water level inside the Borewell using the water sensors, switch off the motor under no or low water conditions, and alert the user.

• To detect damages like winding worn-out issues and any winding issues using temperature sensors and alert the user when the issue is diagnosed.

• To have a safe operation of the pump set without any interruption.

• To detect the humidity of soil.

• Provide the user with the parameter values on the above-mentioned input and alert the user on the occurrence of any above-mentioned faults.

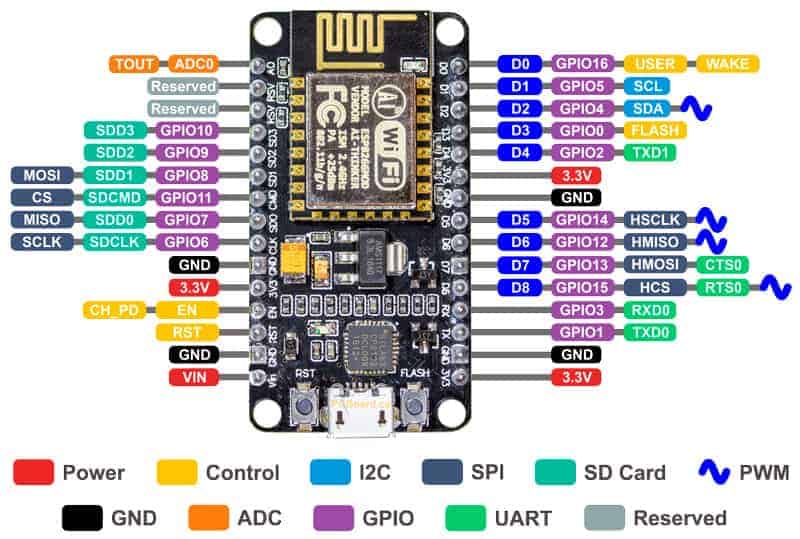
Recent studies have demonstrated that using machine learning algorithms on Satellite Sentinel-2 data may accurately estimate agricultural yields.

# METHODOLOGY

The main purpose of this project is to devise an Internet of Things (IoT) based system for controlling a water pump. This system will use specific parameters and analyze sensor data to implement safety measures in real-time. Our main focus is on creating a smart irrigational pump monitoring solution that is capable of gathering essential data for irrigation purposes, and then it will be transmitted instantly to the Thingspeak IoT platform for documentation and analysis. By showcasing the data in a graphical format on Thingspeak, individuals like botanists or knowledgeable farmers can effectively interpret the information to make necessary adjustments to optimize the irrigation process and ensure the safety of the water pump.

# HARDWARE USED

## NodeMCU ESP8266



The NodeMCU (Node Microcontroller Unit) is an open-source software and hardware development environment built around an inexpensive System-on-a-Chip (SoC) called the ESP8266. The ESP8266, designed and manufactured by Espressif Systems, contains the crucial elements of a computer CPU, RAM, networking (WiFi), and even a modern operating system and SDK. That makes it an excellent choice for Internet of Things (IoT) projects of all kinds.

## NodeMCU Specifications

The most common models of the NodeMCU are the Amica (based on the standard narrow pin-spacing) and the LoLin which has the wider pin spacing and larger board. The open-source design of the base ESP8266 enables the market to design new variants of the NodeMCU continually.

Power Pins There are four power pins. VIN pin and three 3.3V pins. VIN can be used to directly supply the NodeMCU/ESP8266 and its peripherals. Power delivered on VIN is regulated through the onboard regulator on the NodeMCU module – you can also supply 5V regulated to the VIN pin 3.3V pins are the output of the onboard voltage regulator and can be used to supply power to external components.

GND are the ground pins of NodeMCU

I2C Pins are used to connect I2C sensors and peripherals. Both I2C Master and I2C Slave are supported. I2C interface functionality can be realized programmatically, and the clock frequency is 100 kHz at a maximum. It should be noted that I2C clock frequency should be higher than the slowest clock frequency of the slave device.

GPIO Pins NodeMCU/ESP8266 has 17 GPIO pins which can be assigned to functions such as I2C, I2S, UART, PWM, IR Remote Control, LED Light and Button programmatically. Each digital enabled GPIO can be configured to internal pull-up or pull-down, or set to high impedance. When configured as an input, it can also be set to edge-trigger or level-trigger to generate CPU interrupts.

ADC Channel the NodeMCU is embedded with a 10-bit precision SAR ADC. The two functions can be implemented using ADC. Testing power supply voltage of VDD3P3 pin and testing input voltage of TOUT pin. However, they cannot be implemented at the same time.

UART Pins NodeMCU/ESP8266 has 2 UART interfaces (UART0 and UART1) which provide asynchronous communication (RS232 and RS485), and can communicate at up to 4.5 Mbps. UART0 (TXD0, RXD0, RST0 & CTS0 pins) can be used for communication. However, UART1 (TXD1 pin) features only data transmit signal so, it is usually used for printing log.

SPI Pins NodeMCU/ESP8266 features two SPIs (SPI and HSPI) in slave and master modes. These SPIs also support the following general-purpose SPI features: 4 timing modes of the SPI format transfer Up to 80 MHz and the divided clocks of 80 MHz Up to 64-Byte FIFO

SDIO Pins NodeMCU/ESP8266 features Secure Digital Input/Output Interface (SDIO) which is used to directly interface SD cards. 4-bit 25 MHz SDIO v1.1 and 4-bit 50 MHz SDIO v2.0 are supported.

PWM Pins The board has 4 channels of Pulse Width Modulation (PWM). The PWM output can be implemented programmatically and used for driving digital motors and LEDs. PWM frequency range is adjustable from 1000 μs to 10000 μs (100 Hz and 1 kHz).

Control Pins are used to control the NodeMCU/ESP8266. These pins include Chip Enable pin (EN), Reset pin (RST) and WAKE pin. EN: The ESP8266 chip is enabled when EN pin is pulled HIGH. When pulled LOW the chip works at minimum power. RST: RST pin is used to reset the ESP8266 chip. WAKE: Wake pin is used to wake the chip from deep-sleep.

## RELAY



Figure B: 5V Relay Module Pin Configuration

The pin configuration of the 5V relay module is shown below. This module includes 6 pins where each pin and its functionality are discussed below.

Normally Open (NO): This pin is normally open unless we provide a signal to the relay module's signal pin. So, the common contact pin smashes its link through the NC pin to make a connection through the NO pin

Common Contact**:** This pin is used to connect through the load that we desire to switch by using the module.

**Normally Closed (NC):** This NC pin is connected through the COM pin to form a closed circuit. However, this NC connection will break once the relay is switched through providing an active high/low signal toward the signal pin from a [microcontroller](https://www.elprocus.com/atmega16-next-generation-micro-controller/).

**Signal Pin:** The signal pin is mainly used for controlling the relay. This pin works in two cases like active low otherwise active high. So, in active low case, the relay activates once we provide an active low signal toward the signal pin, whereas, in an active high case, the relay will trigger once we provide a high signal toward the signal pin.

However, these modules generally work on an active high signal which will strengthen the relay coil to make contact with the common terminal with the normally open terminal.

**5V VCC:** This pin needs 5V DC to work. So 5V DC power supply is provided to this pin.

**Ground:** This pin connects the GND terminal of the power supply

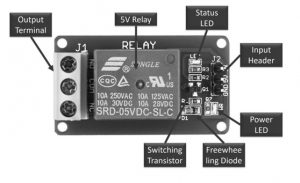


Figure C: 5Volts 1-Channel Relay Module Components

A 5V relay is coated with blue color plastic material. For both AC & DC loads, the utmost operating voltage & current are also displayed on the relay. This relay operates with 5V, so it is called a 5V relay.

Output Terminal

The output terminal of the relay module is located at the left-hand side, used to fix an AC/DC load & AC/DC i/p power source. Every o/p connector’s terminal is connected through NC, COM pins & NO of the relay.

The relay module consists of screws that are used to connect wires & cables. The max current supported by this module is 10A & the max contact voltage is 250V AC & 30V DC. Thick main cables are mainly used whenever high voltage & current load is used.

Status LED

Status LED is connected by using a current limiting resistor that is located on the top right side of the relay module. So this LED illustrates the relay status by activating the relay & coil through a signal pin. The DC supplies throughout a relay coil.

Power LED

Power LED shows the condition of the power source that is connected through the single channel module. If we provide the above 5V source toward both the pins of the module like Vcc & GND, the LED will be damaged due to high voltage.

Freewheeling Diode

The connection of this diode can be done across the coil to keep away from the back EMF effect, so-called a flyback diode. The type of coil used in the relay is the inductive type. Once the current supplies throughout an inductive load, then it generates a back EMF voltage, which may harm the circuit. So, this diode is mainly used to keep away from this effect.

Input Connector

The input connector is located on the right side of the module. This connector is mainly used to supply a 5V power supply & input signal. In addition, it also supplies power supply toward the power LED, relay coil & status LED.

Switching Transistor

Generally, the input signal which is given to a relay is from the I/O pins of microcontrollers like ESP32, TM4C123, Arduino, etc. However, the highest current sourcing capacity of GPIO pins is usually below 20mA.

Therefore, a switching transistor is used in this module to strengthen the current to the requirement of the minimum current level of the relay coil. A switching transistor is used to control the 5V relay from the microcontroller’s GPIO pin.

Specifications

The specifications of a 1- 1-channel relay module include the following.

* Voltage supply ranges from 3.75V – 6V
* Quiescent current is 2mA
* Once the relay is active then the current is ~70mA
* The highest contact voltage of a relay is 250VAC/30VDC
* The maximum current is 10A

## Buzzer Pin ConfigurationBUZZER

Figure D: Water Level Sensors

An audio signaling device like a beeper or buzzer may be electromechanical or [piezoelectric](https://www.elprocus.com/what-is-a-piezoelectric-material-working/) or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren.

The **pin configuration of the buzzer** is shown below. It includes two pins namely positive and negative. The positive terminal of this is represented with the ‘+’ symbol or a longer terminal. This terminal is powered through 6Volts whereas the negative terminal is represented with the ‘-‘symbol or short terminal and it is connected to the GND terminal.

Specifications

The **specifications of the buzzer** include the following.

* Color is black
* The frequency range is 3,300Hz
* Operating Temperature ranges from – 20° C to +60°C
* Operating voltage ranges from 3V to 24V DC
* The sound pressure level is 85dBA or 10cm
* The supply current is below 15mA

## Water Pump

Figure E: Water Level Sensors

Mini Pump, delicate and light, very perfect for experiment, aquarium, fish tank and fountain etc. Make the water level higher than the pump, too low water level may cause high temperature and noise of the pump. Item only includes the pump without power supply , please adapt it to 5V power supply.

Specifications:

* Operating Voltage: 5V DC
* Rated Current: 100mA – 200mA
* Flow rate: 80-100L / H
* Wire Length: ~22 cm
* Material: plastic
* Mode driving: brushless cc design, magnetic driving

## Introduction to DHT11 - The Engineering ProjectsDHT11

Figure E: DHT11 Voltage and Humidity Sensor

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). Its fairly simple to use, but requires careful timing to grab data. You can get new data from it once every 2 seconds, so when using the library from Adafruit, sensor readings can be up to 2 seconds old.

Comes with a 4.7K or 10K resistor, which you will want to use as a pullup from the data pin to VCC.

Specifications:

* 3 to 5V power and I/O
* 2.5mA max current use during conversion (while requesting data)
* Good for 20-80% humidity readings with 5% accuracy
* Good for 0-50 °C temperature readings +-2 °C accuracy
* No more than 1 Hz sampling rate (once every second)
* Body size 15.5mm x 12mm x 5.5mm
* 4 pins with 0.1" spacing
* Adafruit Learning Documentation for DHTxx Sensors
* RoHS compliant

# Software Requirements

## ARDUINO SOFTWARE (IDE)

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Figure F :Arduino Software 1

A program composed utilizing Arduino Software (IDE) is called portrays. These representations are composed in the content tool and are spared with the document expansion “. ino”. The proofreader has highlights for cutting/gluing and for looking/supplanting content. The message zone gives criticism while sparing and sending out and furthermore shows blunders. The comfort shows content yield by the Arduino Software (IDE), including complete blunder messages and other data. The base right hand corner of the window shows the arranged board and serial port. The toolbar catches permit you to check and transfer programs, make, open, and spare outlines, and open the serial screen.

## IOT PLATFORM:



Figure G: Thingspeak as IoT platform

In this project , we have used Thingspeak as IoT platform

According to its developers, "ThingSpeak is an open source Internet of Things (IoT) application and API to store and retrieve data from things using the HTTP protocol over the Internet or via a Local Area Network. ThingSpeak enables the creation of sensor logging applications, location tracking applications, and a social network of things with status updates.

# CONCLUSION

In this project, an intelligent protection and control system has been designed and developed for the protection of electric motors/pumps used for irrigation purposes using IoT and sensors. The prototype model has been developed, which protects the motor against under-voltage, over-voltage, temperature, and dry run. The project is designed for the detection of water levels, voltage levels, and temperature levels of submersible pumps and to perform safer operation and protection of the system against various faults. The usage of the Raspberry Pi system provides information to the user about the operating condition of the pump and also to control the submersible pump through wireless mode. The project aims to work efficiently by using magnetic fluid level sensors, voltage level sensors, and LM35 temperature sensors to reduce the interruptions for the working of submersible pumps.

# FUTURE WORK

For the same project idea, we can use different type of technologies like AI etc to apply it in the future on a large scale.

* Mobile applications can be developed for easier operations with advanced features.
* Advanced temperature sensors and motor vibration sensors can be used for high-rating pumps to detect mechanical faults in the pump.
* The idea for an autonomous pump system in the future with solar-powered irrigation systems, windmills, and natural energy usage systems that will not require any human intervention can be adopted.

Acknowledgment

We would like to thank REVA University for supporting in carrying out this research.

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