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 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 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 the 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 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 on 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).

Both IoT and automation are interconnected and used to provide highly efficient and cost-effective solutions for agricultural systems [[11].](#Eleven)

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 water level reaches full in tank, continuous usage of the motor wastes water and electricity. So that IoT turns off the engine by reducing human interfernce. The relay that connects 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 Bore well 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.

# METHODOLOGY

This project serves as an extension of the preceding study [12], which focused on forecasting crop yield using Sentinel-2 data. The dataset can be accessed through the USGS Earth Explorer website at: https://earthexplorer.usgs.gov/. The variables investigated in this research encompass vapor pressure, maximum and minimum temperatures, cumulative precipitation, surface shortwave radiation, runoff, wind speed, evapotranspiration, Palmer Drought Severity Index, actual evapotranspiration, climate water deficit, soil moisture, snow water equivalent, and vapor pressure deficit

An image with six bands, one for each depth (0–5, 5–15, 15–30, 30–60, 60–100, and 100–200 cm), makes up each asset of a soil grid data set. However, soil data only included bands with a depth of 5 to 15 cm in this work.

The crop yield model's accuracy is influenced by four significant soil-related attributes: the average Cation Exchange Capacity at pH7, Silt content, Total Nitrogen level, and organic carbon density.

The process encompasses the subsequent stages:

## Sentinal-2 Data

Retrieve Sentinel-2 data, accessible through the European Space Agency (ESA). https://drive.google.com/uc?id=1uK-hU99aZHa40HlCfgaolGR-\_iPYfXfW

## Calculate ARVI

ARVI (Atmospherically Resistant Vegetation Index) stands as the initial vegetation index that exhibits a degree of immunity to atmospheric elements (such as aerosols) and terrain-related impacts. This characteristic renders it valuable for monitoring tropical mountainous areas, frequently plagued by the presence of soot due to slash-and-burn farming practices. "Equation (1)" depicts the modified NDVI formula, aimed at mitigating the influence of atmospheric scattering by duplicating measurements from the red spectrum and introducing blue wavelengths, as described by Kaufman and Tanré.

(1)

“Eq. (1)” B8 stands for Band 8 (Near-Infra Red (NIR)). B04 is a Band 4 (Visible Red color) B02 is a Band 2 (Blue color) in addition to some adjustment factors are included in the equation.

## Calculate NDMI

The water content of vegetation is calculated using NDMI. In line with traditional techniques, it is calculated as the ratio between Near Infrared (NIR) and Short-Wave Infrared (SWIR) values (USGS, 2019).

(2)

“Eq. (2)” B08 stands for Band 8 (Near-Infra Red (NIR)). B11 is Band 11(Short Wave Infrared (SWIR))

## Calculate NDWI

Water body analysis employs the NDWI technique, which relies on remote sensing information from the green and near-infrared spectral bands. In the majority of cases, the NDWI proves highly valuable in enhancing water-related data. However, its responsiveness to urban expansion can lead to an overestimation of water bodies. For assessing the circumstances of noticeable changes in specific areas, it is beneficial to combine NDWI outputs with NDVI change results.

(3)

“Eq. (3)” B08 stands for Band 8 (Near-Infra Red (NIR)). B3 is Band 3(Green color)

## Calculate MSI

The assessment of canopy stress, productivity forecasting, and biophysical modeling all utilize the Moisture Stress Index (MSI). Elevated index values indicate heightened plant water stress, indicating lower soil moisture content. In contrast to other water vegetation indices, the interpretation of the MSI is reversed. Index values vary from 0 to exceeding 3, with typically verdant vegetation frequently falling within the range of 0.2 to 2.

(4)

“Eq. (4)” B08 stands for Band 8 (Near-Infra Red (NIR)). B11 is Band 11(Short Wave Infrared (SWIR))

## Calculate BSI

For the purpose of quantifying soil variations, the Bare Soil Index (BSI) amalgamates information from the blue, red, near-infrared, and short-wave infrared spectral bands. These bands are normalized to facilitate effective comparison. The blue and near-infrared bands accentuate vegetation presence, whereas the short-wave infrared and red bands gauge the mineral composition of the soil.

(5)

“Eq. (5)” B08 stands for Band 8 (Near-Infra Red (NIR)). B11 is Band 11(Short Wave Infrared (SWIR)) B04 is a Band 4 (Visible Red color) B02 is a Band 2 (Blue color)

## Calculate GCI

The Green Chlorophyll Index is employed in remote sensing to assess the quantity of leaf chlorophyll present in various plant types. The concentration of chlorophyll in vegetation serves as an indicator of plant health. If the chlorophyll content is lower, it signifies stressed plants, making the Green Chlorophyll Index a valuable tool for evaluating plant well-being.

(6)

“Eq. (6)” B9 stands for Band 9 (Short Wave Infrared (SWIR)). B3 is Band 3(Green color)

## k-Fold Cross Validation

Cross-validation is among the various resampling techniques used in model evaluation. It involves partitioning a smaller dataset to resample through cross-validation. The number of folds required in the dataset is determined by the value of a parameter K. When a specific value of k is provided, such as k=5 for 5-fold cross-validation, K folds are created. Cross-validation, a machine learning approach, is employed to assess a model's performance with data. Essentially, it estimates how well the model would perform in a real-world scenario using a limited subset of the data. The model is applied to data that wasn't part of its training to conduct testing and generate predictions.

In k-fold cross-validation, the dataset is first randomly shuffled and then split into k groups. During each iteration of the process, k-1 groups are utilized as the training dataset, while one group is designated as the test dataset. The model is tested against this test dataset while being trained on the remaining groups. This procedure is repeated for all k groups, and the evaluation results are recorded for further analysis.

# 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.

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