A Web-based Computerization Tool Environment for Smart Motor controller Deployment with Flash Encryption

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Abstract— **The science involved in tilling land, producing crops, and rearing animals is known as agriculture, or farming. Agriculture has always relied on technology, dating back more than ten thousand years, to the time when the first plow was made from sticks. The extent to which farming was feasible increased along with advances in science and technology. There are even more opportunities for technology to improve agriculture and support farmers worldwide as a result of the Internet of Things' (IoT) recent rise and popularity. In order to automate the watering process, we created and tested a smart IoT-enabled drip irrigation system utilizing an ESP32. The MQTT protocol is used by the ESP32 to connect with the client devices. It is used for gathering irrigation data, manually watering plants, turning off automated watering, and creating graphs based on sensor readings. A soil moisture sensor, temperature sensor, air humidity sensor, and water flow sensor were all linked to the ESP32. The ESP32 periodically assesses the soil's dryness. The ESP32 activates a solenoid valve to irrigate the plants when the soil is dry and the temperature is suitable for doing so. The water flow sensor's measurement of the flow rate determines how long the drip irrigation system should operate. The microcontroller is implemented with flash encryption for better security for over-the-air (OTA) updates. When the humidity is too high or too low, the ESP32 detects the data from the humidity sensor and alerts the user.**

Keywords— **autonomous sensor interface, internet of things (IoT), smart irrigation system, monitoring and control, smart motor, mqtt protocol**

I. INTRODUCTION

These days, farmers often labor on huge plots of divided land used to cultivate several crops. In the arid months, they engage in irrigated farming. There is not enough water available for irrigation, and it is impossible for someone to constantly check or monitor the soil's moisture level, which is necessary to keep plant roots wet. With the provision of an autonomous sensor interface for the remote monitoring and management of the water supply to the soil, this research seeks to alleviate the issue of water scarcity that farmers often have when using irrigation systems. This will reduce the amount of labor that farmers must expend on the matter.

Farmers who engage in irrigated agriculture have recently paid a great deal of attention to the use of sophisticated sensory approaches. These methods have been used in agriculture to efficiently schedule a variety of chores and activities while reducing the amount of human involvement and making better use of scarce resources. Across the globe, aeroponics is a popular contemporary agriculture technique. With this technique, the soil medium is replaced with a gentle mist of nutrient solution, and plants are grown in a growth chamber under strict supervision. Periodically, these nutrition mists are released by atomization nozzles. In order to maximize plant development, a number of characteristics are regulated throughout the plant culture period, such as temperature, humidity, light intensity, pH and EC levels, water nutrient solution level, CO_2 concentration, atomization duration, and atomization interval time [1].

The current wave of technological progress has increased the need for specific knowledge about farming methods. This is due to the fact that a large portion of agricultural research is based on small-scale exploratory experiments that utilize a single remote sensor to collect ground data. Furthermore, the majority of the techniques used rely on local understanding of biological materials, environments, and management techniques. These restrictions need a shift in strategy toward intelligent irrigation [2].

The Internet of Things may be used for any application that requires control, automation, or data collection (IoT). The growing popularity of IoT has coincided with a growth in the notions around smart agricultural technologies. In this study, we created an intelligent Internet of Things irrigation system using an ESP32 microcontroller. The system consists of an ESP32, a solenoid valve, and an online application for remote access. To control the valve's opening and closing as needed, we developed a mobile application with a dashboard. When the valve is opened, water may seep into the roots of the plants.

Our objective was to grow crops in a Coimbatore, India, agricultural region. After a week of using the irrigation system, the crops had increased dramatically in size. The farmers used the technology to remotely control the irrigation for the whole week.

II. RELATED WORKS

An intelligent irrigation system is the result of several investigations. The technology used in food production has to advance quickly due to the increased demand for food. A lot of study has gone into trying to figure out how to do irrigated farming. These initiatives, however, have not yet produced a workable fix for the issues with the current irrigation system.

Imran et al.'s review study [3] makes a substantial contribution to our understanding of the use of wireless sensor networks for early defect diagnosis and detection in aeroponics. Using the Aeroponics approach, a farmer may remotely operate the whole system and monitor several parameters without the need for laboratory tools. Furthermore, this method offers important data that is crucial for plant scientists to know and a deeper comprehension of the relationship between the main Aeroponics parameters and plant development in the system.

Agnés et al.'s review article [4] offers a thorough analysis of remote sensing techniques for crop mapping. The writers stress the need of having specific knowledge about agricultural methods. Three categories of activities are used to classify the study: crop succession, crop pattern, and cropping methods. The bulk of research, according to the authors, were based on exploratory investigations that were evaluated locally utilizing ground data obtained via the use of a single remote sensor. Furthermore, the majority of the techniques used are based on local understanding of biological materials, environments, and management techniques. Future research directions, such as the use of land stratification, multi-sensor data combination, and expert knowledge-driven approaches, may be identified using these restrictions. In their conclusion, the authors suggested that new spatial technologies—especially the sentinel constellation—will likely improve the management of agro-environmental concerns and cropping practices monitoring in the context of food security. A wireless sensor network was used in an intriguing method that was proposed for the best irrigation of agricultural crops [5]. The application user may manually or automatically regulate crops with the help of the suggested system.

To monitor the moisture level of citrus soil, ZigBee technology, artificial intelligence, and decision support technologies have also been used [6]. This research shed light on the use of IoT in agricultural activities, namely in the integration of fertilization, irrigation decision support systems, and monitoring of citrus soil moisture and nutrients. Some notable innovations include wireless sensor nodes, citrus precision fertilizing, single-point multi-layer citrus soil temperature and humidity sensing, and an irrigation management decision support system. The device may assist a farmer in optimizing the application of nutrients in an irrigation system, according to the study's findings. Furthermore, the technique improves citrus production accuracy while lowering labor costs and pollutants from chemical fertilizer application to the land.

In order to assess the water content of soil, a self-powered and autonomous fringing field capacitive sensor was designed and built [7]. The sensor that was employed was made using a traditional PCB that included a porous ceramic substance. The authors employed a circuit consisting of an AC amplifier, precision rectifier, micro-controller, and a 10-kHz triangle wave generator to produce the sensor readout. By combining the sensor, an energy-harvesting module made consisting of a micro-generator mounted atop a micro-sprinkler spinner, and a DC/DC converter circuit that charges a 1-F supercapacitor, this method produced a comprehensive irrigation control system. The energy-harvesting module may function as long as the soil is irrigated by the micro-sprinkler spinner and the supercapacitor is completely charged to 5 V within around three hours of the first watering, according to the design. After that, the super-capacitor was completely charged, and the system used it to generate electricity for around 23 days without using any energy harvesting.

The transient information sent by the watering system controller is shown by the Yogesh et al. research [8]. It displays the sensor's output as well as the option to configure it to improve system performance. The moisture sensor uses a remote network connection to link to devices and sends the information it has detected, synced to the Internet in a certain amount of time, along with instructions on how the system should be used. If the solenoid valve is open, the watering system regulates the soil moisture sensor. The main constituents of irrigation system control are these two elements. As a result, it is best to employ a systematic irrigation field control system. The moisture sensor, for example, need to function within a restricted range. Specifically, the solenoid valve should open or close in response to variations in the moisture value, which should not exceed the predetermined threshold.

The Arduino board, which has an ATmega 328 microcontroller, was used in [9, 10]. The microcontroller has been configured to detect the plants' moisture content. The design was created to provide the plants the necessary quantity of water. The whole agricultural field is monitored and plant upkeep is handled by the system. As a result, you may water the plants twice a day, in the morning and the evening. As a result, using a microcontroller is essential for regularly watering and checking on the plants.

A moisture sensor may provide sensed data on the amount of water content in the soil, and Marie et al. [11] found that this data can greatly increase agricultural productivity. This would encourage scientists to do in-depth research in several relevant disciplines of study that are connected to irrigation systems. Reducing irrigation management expenses is a big step forward in monitoring plant growth progress, especially when using a computerized watering system. This strategy would drastically cut down on water waste and the amount of labor needed to continuously check the irrigation system's water supply source. Using a feedback-based system would assist monitor and manage resources more effectively, but at a greater cost of complexity, than open-loop systems. As a result, it is challenging to accurately assess soil moisture and difficult to maintain the desired moisture content levels.

The need for agricultural goods and raw resources is always rising, which has made it necessary for food technology to advance quickly [12]. Therefore, the only way to solve this issue is via agricultural methods. The ongoing need for agricultural farm goods has been precipitated by the use of automated irrigation systems. There are few water resources accessible, and the world's water volume has decreased as a consequence of insufficient land and water. During the dry season, farmers often use irrigation systems. Information on the soil's fertility and moisture content are two crucial factors to take into account in irrigation agriculture. Farmers have used a variety of strategies and tactics in their irrigation systems to lessen the reliance on rainfall as the primary source of water for the land. The method most often used is powering the irrigation system with electrical energy and an on-and-off schedule control system. Other methods that are now in use function according to the state of the atmosphere. An essential component of a smart irrigation system is the use of smart microcontrollers, which detect weather and supply of water in real-time. This strategy makes use of a worldwide mobile communication system, a generic packet radio service modem, servers for Internet-based monitoring, a global system for mobile communication, and wireless monitoring via Bluetooth and WSNs.

In order to develop their agricultural techniques, many farmers need financial assistance. There are a lot of master frameworks available to help farmers increase agricultural output. However, these foundational frameworks rely on a base-learning methodology. Consequently, it is strongly advised to implement a master system structure that incorporates IoT technology, as this will allow it to take use of the constantly created real-time data [13].

The majority of farmers cannot afford to adopt modern technology for agricultural techniques, as Gabriel et al. [14] pointed out. The necessity to adopt more affordable and efficient alternatives has become critical. The research suggested creating virtual groups of bots that may converse with one another and keep an eye on farmed produce. Simple and inexpensive sensor design reorganizes the amount of resources crops need at each developmental stage, enabling farmers to monitor and maximize crop growth. To get over hardware and processing capacity constraints, the method makes use of the Platform for Automatic Construction of Organizations of Intelligent Agents (PANGEA) architecture. The suggested system may use sensors for temperature, sun radiation, humidity, pH, wetness, and wind to gather heterogeneous data from its surroundings. Their approach's key discovery is that the system can combine diverse sensor inputs and provide a response that is tailored to each circumstance. To support the suggested system, the authors provided a case study. Its disadvantage is that, in this situation, using a TV screen to keep an eye on crop conditions is not financially viable.

Furthermore, the real-time presentation of the monitored data may have an impact on crop moisture level monitoring, which might lead to low crop production.

In [15], the architecture of SmartFarmNet—an Internet of Things infrastructure that offers data collecting services for soil, irrigation, fertilizer, and the environment—was described. In order to assess crop performance, provide forecasts, and provide suggestions for a particular acreage, the system independently correlates this data and eliminates irrelevant data. Virtually any IoT device, including commercially available sensors, cameras, and weather stations, may be integrated with the suggested SmartFarmNet. The collected data can also be stored in the cloud for performance monitoring and suggestion purposes. Finally, it was said that SmartFarmNet was the world's first and biggest system at the time to provide suggestions and analysis of crop performance.

An intelligent irrigation system is presented by Chandan and Pramitee [16]. Farmers in the middle class can afford and benefit from the system. Automation technology is a defining feature of the twenty-first century and is integral to human existence. With the use of this technology, equipment may be programmed to operate automatically, saving time, energy, and discomfort. Local farmers cannot employ the machine automation and control used by contemporary industry since it is not cost-effective. On the other hand, their research offers an inexpensive irrigation technique that Indian farmers may afford. The primary goal of the study is to use a soil moisture sensor to automatically operate a water motor that determines which way water flows in a pipe. Users' mobile phones get an SMS with information on how the motor is operating and which way the farmland's water flow is flowing.

Karthikeswari and Mithraderi [17] used a GPRS module and wireless sensor network to build an inexpensive automated watering system. The project's objectives were to decrease the amount of manual agricultural monitoring and increase user information delivery using GPRS technology. The technology can identify if electric motors are being used to pump water to the farms or whether free power supplies are being used. By doing this, improper usage of the power source for pumping mechanisms will be avoided. Consequently, less water is wasted.

III. METHODOLOGY OVERVIEW

An overview of the IoT-capable smart drip irrigation system's data flow is shown in Figure 1. The ESP32 is the source of system intelligence. The ESP32 has a number of sensors and a relay connected to it. The water flow sensor gives information about the rate of water flow. The system opens the solenoid valve that watered the plants by using relays. Through the use of the MQTT server, the ESP32 establishes a Wi-Fi connection to the mobile dashboard. We have been use the online application to operate the valve. The ESP32 board is in charge of the complete system's functioning and is configured to mimic the actions of other system parts. The eight components of the system are the water pump, power supply, WiFi module, ESP32 board, soil moisture sensor, temperature, pH, and humidity sensors, user interface, and 16 x 2 liquid crystal display (LCD). The combination of these elements offers the best performance and facilitates simpler system integration debugging. At intervals of five minutes, the sensor readings are posted online. Through the use of a relay circuit and a 5 V transformer, the power supply unit continuously supplies energy to the smart irrigation system. The system powers the board and the water pump using a generic AC 220 V to 5 V DC step down power supply module for ESP32 generic PCs. The water pump is regulated and controlled using a 5 V relay circuit. The USB connection (5 V), the DC power jack, or the board's VIN pin may all be used to power the device. The ESP32 board and the water pumping device get electricity from the output. A system for supplying the plants with enough water in the right amounts is provided by the water pumping unit. The ESP32 board is used to program, regulate, and keep an eye on this mechanism. The primary device used for monitoring and controlling is the ESP32 board. The ESP32 microcontroller is designed to deliver the required control signals to operate the irrigation system as a whole. It is developed using embedded C language. The soil moisture content and water level are determined by the moisture sensor unit, which employs a capacitance sensor to detect the soil's water content. This is crucial to smart farming methods since it enables farmers to monitor and manage the intelligent irrigation system. The versatile and adjustable sensor is really placed into the irrigated field, or the soil that has to be tested, and the percentage of the soil's volumetric water content is given. The user interface unit offers a practical way to access and configure the sensors. Through desktop, laptop, and smartphone devices, system users may communicate with the system. The microprocessor and the LCD unit interact with each other via this channel.

Sensor data readings that have been detected are shown on the LCD screen. The WiFi module unit is a stand-alone system-on-a-chip (SoC) that gives users access to a wireless network using an integrated transmission control protocol/internet protocol (TCP/IP) stack. Either all WiFi networking tasks can be offloaded from another application processor, or it can host an application. The module is an IEEE standards-based wireless local area network (WLAN) module equipped with devices. Moreover, wireless access points and WLANs may be used by WiFi-capable devices to connect to the Internet.

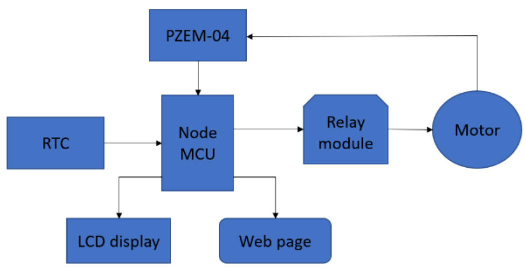

Fig. 1 Data Flow Chart

For optimal plant watering, water them in the morning or early evening. If the water becomes too hot due to afternoon crop irrigation, plants could burn. Water stagnation from late night irrigation of crops might encourage insect growth, crop rot, and fungal development [18, 19]. Five and eight hours, respectively, are allocated for our irrigation windows in the morning and evening. The temperature and soil moisture content will be tracked by the ESP32 using real-time data throughout these periods, and the plants will be watered as necessary.

Utilizing an air humidity sensor, humidity data was gathered. In a very hot, low-humidity environment, there will be an excessive amount of water evaporation via transpiration. Wet plants will attempt to absorb more water, which will also increase their nutrient uptake. A surplus of nutrients will cause the tips of the leaves to burn, causing them to wilt [20]. Watering the soil in an excessively dry climate may not be a smart idea. The ESP32 will notify us in the event that the relative humidity is excessively high or low. Based on the humidity readings and other sensor data, we may turn on or off the automatic watering feature.

In case it becomes necessary, we may use the app to manually open the valve. The reason irrigation data is retained in the app is because it may be used to find trends and eventually improve the system. The irrigation data includes the time, date, and soil temperature at irrigation time, as well as the water flow rate via the drip line.

IV. PROPOSED METHODOLOGY AND MODULES

A. Overview of the Methodology

The smart IoT-based irrigation monitoring and control system's low-cost autonomous sensor interface is implemented to confirm the system's functionality and meet the user's operational requirements for measurement and assessment. The key metrics that the smart system will be measuring are well-defined and established. The moisture sensors are placed two centimeters below the surface of the earth. The sensors alert the microcontroller to shut off the relay circuits that drive the water pump when the soil achieves the appropriate moisture content. The specified location may be used to test the implementation. One of the experiments involves placing the built system prototype in a key farming region so that the sensors can keep an eye on the environmental factors. The processed sensor data are sent to the web server via www.hivemq.com, the website where users may access the control and monitoring information. The embedded moisture sensor, which is buried in the soil, monitors the moisture level and relays the data to the microcontroller. The components are connected by a smart interface. The water pump supplies water to the plants when the soil's moisture content falls below normal. Subsequently, the WiFi module uploads the data that has been observed and controlled to the web server and sends it to the LCD screen.

The low-cost autonomous sensor interface of the smart IoT-based irrigation monitoring and control system is built to fulfill the user's operational needs for measurement and evaluation and to verify the system's functioning. The smart system will be monitoring certain, well-established important parameters. Two centimeters below the earth's surface is where the moisture sensors are located. When the soil reaches the proper moisture level, the sensors notify the microcontroller to turn off the relay circuits that power the water pump. You may test the implementation at the given location. In order for the sensors to monitor the environmental conditions, one of the trials is putting the constructed system prototype in a strategic agricultural area. The processed sensor data are delivered to the web server via a MQTT service provider, allowing users to see and work with the data. The control page of the web application is shown in Figure 2. Buried in the ground, the embedded moisture sensor senses the moisture content and transmits the information to the microcontroller. A clever interface connects the various parts. When the moisture content of the soil drops below the ideal level, the water pump provides water to the plants. The data that has been watched and managed is then uploaded by the WiFi module to the web server and sent to the LCD panel. Figures 3, 4 and 5 show the prototype that was implemented along with the jet pump motor.

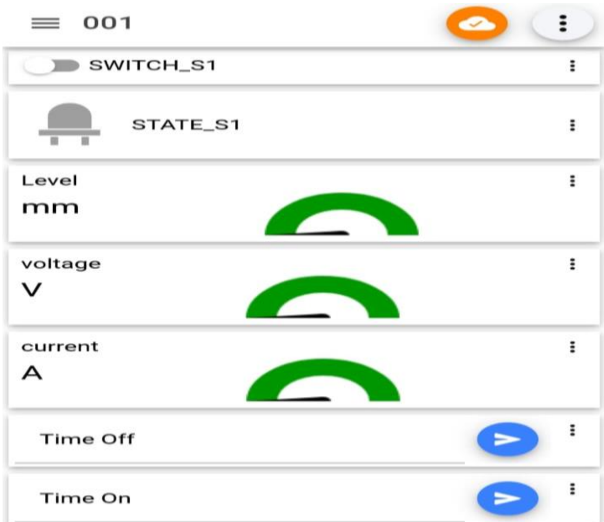

Fig. 2 Motor Control and Monitor Page of Mobile Application

Fig. 3 Valve Setup of the System

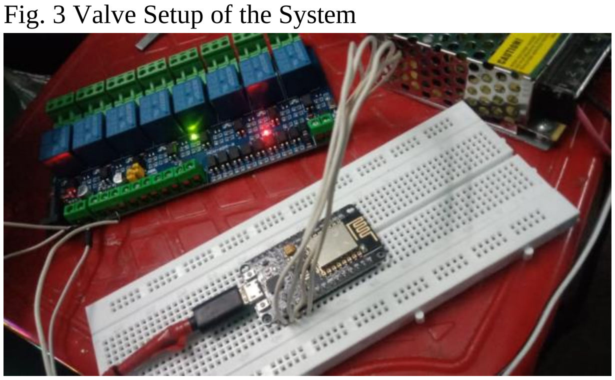

Fig. 4 Relay Setup of the System

Fig. 5 Jet Pump Motor

B. Flash Encryption in ESP32

An essential feature of ESP32 microcontrollers is flash encryption, which guards against tampering and unwanted access to the flash memory contents, hence enhancing the security of embedded applications. As more and more ESP32s are being used in embedded and Internet of Things systems, it is crucial to protect the integrity and confidentiality of firmware and stored data. The ESP32's flash encryption techniques provide reliable means of protecting firmware code and private data.

Hardware-accelerated flash encryption is supported by the ESP32 microcontroller, offering a major speed and security boost. The Advanced Encryption Standard (AES) serves as the foundation for the main flash encryption technique used in ESP32. Symmetric encryption works using the AES algorithm, which is well-known for its effectiveness and security. ESP32 makes use of AES-256, which encrypts and decrypts data using a 256-bit key, offering strong protection against brute force assaults.

The creation of an encryption key, which is essential to guaranteeing the security of the data, starts the encryption process. The flash encryption key for the ESP32 is kept in the eFuse, a special area of the hardware key storage. The encryption key may be stored in a tamper-resistant manner in the eFuse, a one-time programmable memory. By prohibiting key extraction, the programmed key offers an added degree of protection as it cannot be read back. In order to improve security by guaranteeing that every device has a distinct encryption key, the eFuse further permits the production of a random encryption key during the first configuration. Figures 6 and 7 show the ESP-IDF flash encryption tools and configuration.

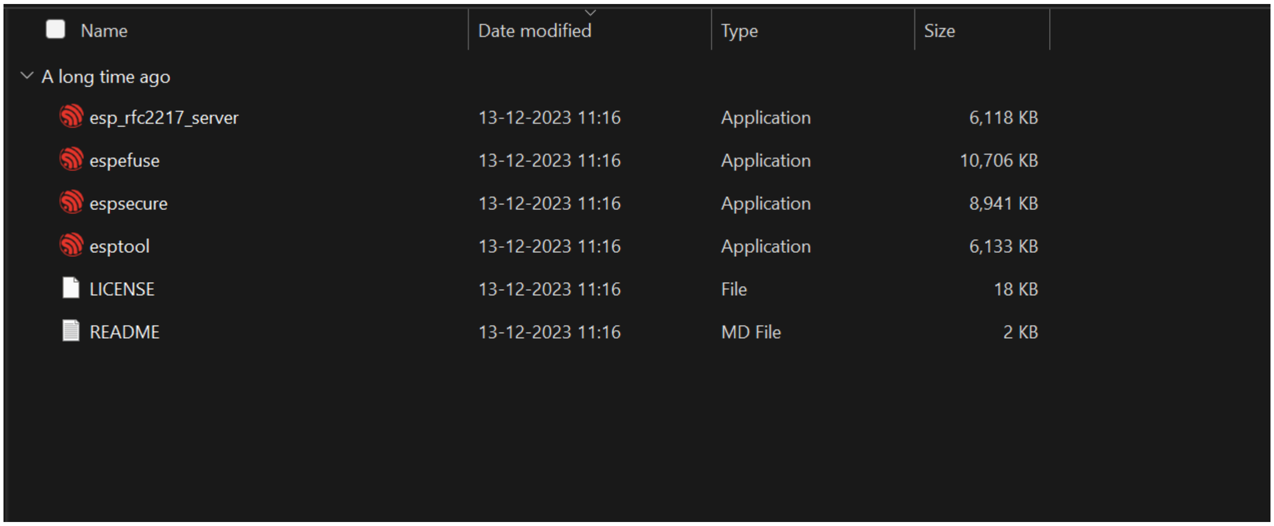

Fig. 6 Flash Encryption Tools

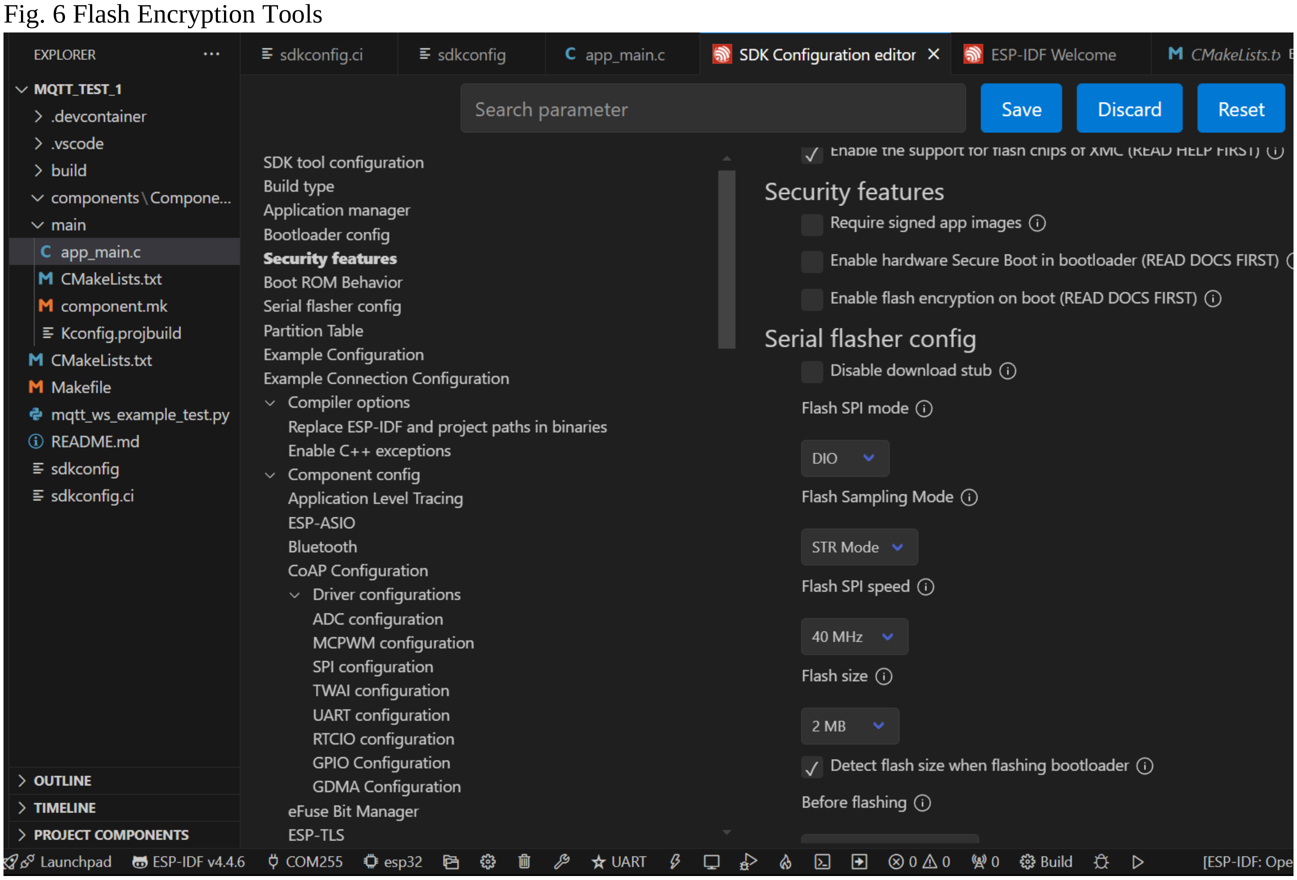

Fig. 7 ESP-IDF SDK Tool Configuration

In ESP32, flash encryption is part of the bootloader procedure. The bootloader loads the application software from flash memory and initializes the hardware when the ESP32 device powers up. Using the AES-256 key kept in the eFuse, the bootloader decrypts the encrypted firmware that is placed in flash memory throughout this procedure. Thus, malicious code cannot be installed into the device and only approved and authenticated firmware may be run.

The application firmware is intended to be able to see right through the ESP32 flash encryption mechanism. Developers may take use of flash encryption without changing the code of their applications. Performance is not much affected since the hardware handles the encryption and decryption procedures. An important benefit of this hardware acceleration is that it makes the encryption process quick and effective, making it appropriate for real-time applications. Figure 8 shows the flash encrypted microcontroller used in this research.

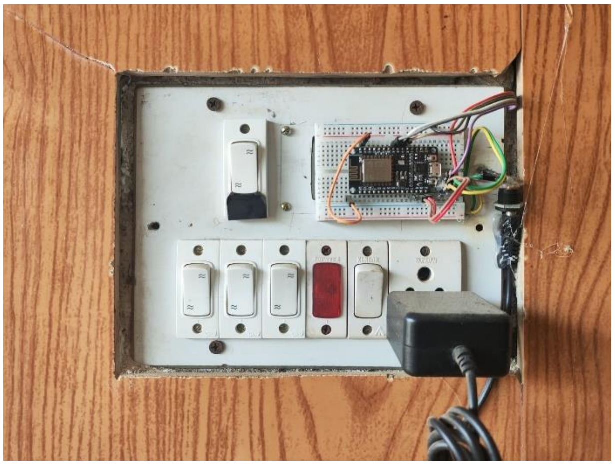

Fig. 8 Flash Encrypted Microcontroller

Because ESP32 supports many flash encryption modes, developers may choose the amount of security that best suits their needs. Full Flash Encryption is a popular option in which everything of the flash memory is encrypted, including the data partitions, application firmware, and bootloader. This mode ensures that no portion of the flash memory may be accessed by unauthorized parties and offers complete security for the data contained in it.

Partition-Level Encryption is an additional option that encrypts just certain flash memory partitions. By enabling developers to encrypt only the firmware or data that is sensitive, this mode provides flexibility while lowering the complexity related to the encryption and decryption operations. For example, developers may decide to leave certain data partitions unencrypted and only encrypt those that include important data, such user passwords or configuration settings.

Additionally, OTA (Over-The-Air) updates with flash encryption are supported by ESP32. For deployed devices to maintain and upgrade their firmware, over-the-air (OTA) updates are crucial. The OTA update procedure makes sure that the new firmware is encrypted before it is copied to flash memory when it uses flash encryption. The security and integrity of the system are preserved even while upgrades are being performed since the new firmware is first encrypted and checked before being implemented.

An essential component of flash encryption in the ESP32 is key management. To avoid unwanted access, the encryption key kept in the eFuse has to be treated carefully. Mechanisms for safe key creation, storage, and use are provided by ESP32. Physical assaults on the key are prevented by the tamper-resistant architecture of the eFuse key storage. To further guarantee that every device has a distinct and safe key, the encryption key may also be produced by the bootloader or during the manufacturing process.

Strong security protections are offered by the flash encryption techniques in ESP32 to guard against unwanted access and manipulation with the contents of the flash memory. Through the use of secure key storage in the eFuse and hardware-accelerated AES-256 encryption, ESP32 guarantees the integrity and confidentiality of firmware and stored data. The security of ESP32-based apps is further improved via secure OTA updates, support for several encryption modes, and the incorporation of flash encryption into the bootloader process. Modern IoT and embedded systems based on the ESP32 microcontroller need flash encryption as a crucial component for security due to its transparent encryption mechanism and efficient key management.

V. CONCLUSION

The paper presents a low-cost autonomous sensor interface that may be used to build an Internet of Things (IoT) smart irrigation monitoring and control system. A workable prototype was designed and implemented. This project's primary goal was to increase crop productivity by giving farmers the autonomy to monitor and manage remote agricultural property. In order to provide the plants with the appropriate amount of water, this study used a water pump, a moisture sensor to determine the soil's water content, and a WiFi module to allow users to view the sensed data online. The web server serves as the main base station and stores sensor information. The data that was kept on the web server was carefully examined. The Internet received real-time sensor readings. The information gathered allows a farmer to precisely monitor the water content of the soil on their land. The system's performance evaluation is reliable in terms of the data gathered, speed, accuracy, and integrity of the sensed data obtained from the sensors. Plotted graphs are descriptive tools that farmers may use to evaluate a plant's health in relation to the quantity of water in the soil underneath it. Depending on the moisture level, the water pump is switched on or off, and the technology immediately notifies farmers whether there is too much or too little water delivered. The low-cost solution that has been proposed might help large-scale farmers reduce the stress that comes with delivering water to their land. The recommended strategy and the experiment results will be very helpful to farmers and other decision-makers in appropriately monitoring and regulating agricultural farm commodities.

We were successful in developing a smart drip irrigation system with Internet of Things capabilities. With its enhanced automation feature, if the soil is dry, the temperature is within the ideal range for maximum water absorption, and the time falls within the designated morning or evening irrigation windows, the ESP32 will open the solenoid valve and water the plants. We put in safety precautions to prevent things like overwatering, forgetting to water, or not watering the plants at all.

Using the IoT dashboard mobile application, we can also monitor temperature, humidity in the air, and moisture in the soil. If the humidity is too high or too low, the admin user receives a notification on the mobile application. Through the web application dashboard, we may manually open the valve or stop the automatic function based on the recorded data.

The intelligent drip irrigation technique is now being used to cultivate rose plants from rose bushes. Future study will examine the usage of a field programmable gate array (FPGA) and system-on-chip (SoC)-based architecture, namely the Xilinx Zynq 7000 FPGA-SoC device utilizing the Python programming language for Zynq devices, despite the system's outstanding performance. When used in expansive agricultural farms, this will improve the monitoring and management of high performance devices.

REFERENCE

[1] What is Water Level Indicator: Circuit Diagram and Its Applications (2019, September 24). Retrieved from https://www.watelectronics.com/simple-water- level-alarm-circuit/ on June 15, 2020.

[2] Mallikarjun G. Hudedmani, Nagaraj. S. N, Shrikanth B. J., Ali AdilSha, Pramod.G (2018). Flexible Automatic Water Level Controller and Indicator, World Journal of Technology, Engineering and Research, Volume 3, Issue 1 (2018), 359-366.

[3] Imran, A.L.; Gao, J.; Tabinda, N.S.; Farman, A.C.; Noman, A.B.; Waqar, A.Q. Monitoring and Control Systems in Agriculture Using Intelligent Sensor Techniques: A Review of the Aeroponic System. J. Sens. 2018, 18, 8672769.

[4] Bégué, A.; Arvor, D.; Bellon, B.; Betbeder, J.; De Abelleyra, D.; Ferraz, R.P.D.; Lebourgeois, V.; Lelong, C.; Simões, M.; Verón, S.R. Remote Sensing and Cropping Practices: A Review. Remote Sens. 2018, 10, 99.

[5] Jirapond, M.; Nathaphon, B.; Siriwan, K.; Narongsak, L.; Apirat, W.; Pichetwut, N. IoT and agriculture data analysis for smart farm. Comput. Electron. Agric. 2019, 156, 467–474.

[6] Zhang, X.; Zhang, J.; Lin, L.; Zhang, Y.; Yang, G. Monitoring Citrus Soil Moisture and Nutrients Using an IoT Based System. Sensors 2017, 17, 447.

[7] Da Costa, E.; De Oliveira, N.; Morais, F.; Carvalhaes-Dias, P.; Duarte, L.; Cabot, A.; Siqueira Dias, J. A Self-Powered and Autonomous Fringing Field Capacitive Sensor Integrated into a Micro Sprinkler Spinner to Measure Soil Water Content. Sensors 2017, 17, 575.

[8] Yogesh, G.G.; Devendra, S.C.; Hitendra, C.C. A Review on Automated Irrigation System Using Wireless Sensor Network. Int. J. Adv. Res. Electron. Commun. Eng. 2016, 5, 1725–1731.

[9] Sumeet, S.; Sandhya, U.; Piyali, S.; Yatin, J. Arduino Based Automated Watering System. IJIRT 2015, 2, 419–420.

[10] Sumeet, S.B.; Manoj, A.M. IoT Based Automated Irrigation System. Int. J. Mod. Trends Eng. Res. 2015, 2, 1532–1538.

[11] Marie, F.L. Design of an Automated Irrigation System: Student Paper Competition; McGill University: Montreal, QC, Canada, 16 May 2005.

[12] Deweshvree, R.; Indurkar, P.R.; Khatri, D.M. Review Paper Based on Automatic Irrigation System Based on RF Module. IJAICT 2015, 1, 736–738.

[13] Raheela, S.; Muhammad, T.; Javed, F.; Muhammad, A.S. Internet of Things based Expert System for Smart Agriculture. Int. J. Adv. Comput. Sci. Appl. 2016, 7, 341–350.

[14] Gabriel, V.; Juan, F.D.P.; Daniel, H.; De La Iglesia, D.H.; Javier, B. Combining Multi-Agent Systems and Wireless Sensor Networks for Monitoring Crop Irrigation. Sensors 2017, 17, 1775.

[15] Prem, P.J.; Ali, Y.; Dimitrios, G.; Ahsan, M.; Arkady, Z. Internet of Things Platform for Smart Farming: Experiences and Lessons Learnt. Sensors 2016, 16, 1884.

[16] Chandan, K.S.; Pramitee, B. A Low-Cost Smart Irrigation Control System. In Proceedings of the International Conference on Electronics and Communication System, Coimbatore, India, 26–27 February 2015; pp. 1146–1152.

[17] Karthikeswari, M.; Mithraderi, P. Automated Irrigation System in Agriculture Using Wireless Sensor Technology. Int. J. Adv. Res. Electr. Electron. Instrum. Eng. 2014, 3, 13622–13627.

[18] Carberry, A. How to Choose the Best Time for Watering a Garden: 7 Steps. Available online: https://www.wikihow.com/Choose-the-Best-Time-for-Watering-a-Garden (accessed on 9 June 2024).

[19] When to Water—Southern Living Plants. Available online: https://southernlivingplants.com/planting-care/when-to-water/ (accessed on 9 June 2024).

[20] What Humidity Do Houseplants Need?—Be.Green. Available online: https://be.green/en/blog/what-humidity-houseplants-need (accessed on 9 June 2024).