Solar Powered Automated Fertigation System (I-SIRAM)

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Abstract – *The use of digital agriculture, sometimes known as smart farming or e-agriculture is the new frontier to empower the agriculture sector by infusing IR4.0 in agriculture. The emergence of IoT technology has contributed to the progress of intelligent farming from manual and conventional farming through trial and error to precision agriculture through digital technology. Therefore, I-SIRAM has been created as a digital solution for precise and intelligent agriculture as a result. I-SIRAM is an Internet of Things (IoT)-based automated fertigation system that employs solar power to regulate the injection of fertilizer intake control and monitoring using mobile apps with the goal of preventing fertilizer and water overuse. I-SIRAM is a system designed to mechanically agitate fertilizer in the right quantity, water plants, and apply solar-powered automatic fertilizer to solve electricity accessibility difficulties. Pumps, motors, and sensors are utilised to start the agitation of fertilizer A, fertilizer B, and water into the mixer tank as the system is programmed using the Arduino UNO microcontroller. After several experiments conducted, I-SIRAM was found to be an efficient manner of isolating and blending the fertilizer mixtures in assisting users to optimize the amount of nutrients, water and also considering the pH and EC values are in the range for the farm operation.*

Keywords: *agriculture, fertigation, IoT, smart farming, solar energy*

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I. Introduction

An increasing population will cause various problems to agriculture in the 21st century in terms of producing enough food and fiber by 2050 [1]. Security of food, energy, and water resources is essential for a long-term, sustainable economy [2]. The agricultural industry uses a lot of water, and irrigation uses around 70% of both groundwater and river water [3]. In dry and semiarid regions, agriculture will always be one of the main consumers of water resources, thus it must continue to become more effective. Utilizing the more crop per drop technique, irrigation water management must carry out specific procedures that might boost food production [4].

In recent years, automation and IoT have been merged with traditional farming. Modern technology and intelligent irrigation systems may help to improve irrigation management. Remote sensing technologies, for example, Big Data, the Internet of Things (IoT), and Unmanned Aerial Vehicles (UAVs) are particularly promising [5]. They have the potential to provide new way of agricultural techniques. A wide range of agricultural parameters can be monitored to help with smart farming, increase crop yields, lower costs, and optimize process inputs such as environmental protection circumstances, growth status, soil quality, irrigation water, insect, and disease problems, and so on [6].

However, these technologies are a barrier for small farmers to improve their plant management. This is because the capital to use the technologies is high. In this era of modernity, everyone should experience the greatness of technology that can simplify daily affairs.

The increased demand for food, in terms of quality and quantity, has accelerated the need for agricultural modernization and intensive production techniques. Determining the exact amount of water and electrical conductivity (EC) necessary for the plant is a huge challenge.

A farmer will find it difficult to water and give enough nutrients to their plant. It is either the water is too much or too less. An EC meter, pH value, and temperature sensor is placed and operated by utilizing several IoT strategies to prevent those problems. EC meter monitoring also has been one of the most difficult task in agriculture for both cultivators and farmers. Soil testing raises a few environmental issues that have an impact on agricultural output. Soil management requires determining several soil properties including pH and EC values. These metrics can be easily computed with the help of IoT sensors [7].

Next, existing technology in agriculture is too expensive for a small farmer. Based on market price, a starter UAV can be around $850 [8]. In Malaysia, the cost of managing a Greenhouse structure can be around RM 20,000 per unit [9]. The price may increase from year to year. This amount of price is way too much for a small farmer. A low-cost technology must be proposed to help the small farmer. Next, the EC meter, pH value, and temperature of the plant are difficult to monitor without using the IoT. Nowadays, most of the technology is using IoT such as connected vehicles, traffic management, smart buildings and smart homes, smart cities, supply chain management, and more. Other than monitoring the plant, IoT also can enhance the productivity of the crop and provide better quality control.

After studying the development of an IoT in fertilization system for smart agriculture, previous articles states that the potential of the wireless sensor must be implemented into the agriculture sector. Farmers can connect to their farms from almost anywhere by using IoT technology [10]. Sensors and actuators are used to control farming processes the wireless sensor network is being used to monitor the farm. Wireless cameras and sensors were used to remotely monitor the farm and collect all the data [11]. The main principles of IoT technology includes the intelligent sensors, IoT sensor types, networks and protocols used in agriculture.

The researcher focuses more on the role of Unmanned Aerial Vehicle (UAV) technology in smart agriculture, by analyzing the applications of UAV in various conditions [12]. Next, the concept of solar fertigation is an IoT system that is designed specifically for smart agriculture. Lastly, sensors are used to collect real-time data and send it to the server to be deployed for extracting the information from sensor data [13]. Therefore, in this project, we proposed a smart system of agriculture that can be used by everyone that loves to cultivate.

II. Methodology

In general, there is a lot of smart system fertilization technology in agriculture but, not everyone can use the technology because it is not affordable for the small farmer or people who love to cultivate. Nowadays, we want to make sure that everyone can use existing technology in the cheapest way. For example, Apple produces a very good quality smartphone, but the price is too expensive for some people so, there is an option to use Android which offers an affordable smartphone. Because of that, this research will focus on developing affordable smart system fertilization using IoT in agriculture.

A. Proposed System

Fig. 1. shows the general flowchart of this proposed system and Fig. 2. shows the diagram block of this proposed system. The data from the plant will be continuously collected using three different types of sensors. The EC meter sensor will collect the EC value from the fertilizer solution. The data will be stored in the Arduino Uno and then transmitted to the data-based via Wi-Fi. From the database, the user can monitor the EC value through their smartphone. This working progress is also the same as the pH value sensor and temperature sensor. Fig. 3. below shows the overall design of the I-SIRAM.

B. Experimental Setup

This project presents affordable smart system fertilization in agriculture. Three types of sensors which are temperature sensor, pH sensor and EC meter are used to collect data which are EC value, pH value, and temperature. The data are sent to the cloud database via Blynk. The users can analyze the data through the apps on their smartphone. Subsequently, Fig. 4. shows the design of peristaltic pump in this project. With this, users can pump fertilizer with the desired value of EC which is less than 3 mS/cm to the plant by using a peristaltic pump.

To control the peristaltic pump, a relay module is connected. A relay module is an electromagnet switch that can open or close an electrical circuit. Fig. 5. shows the schematic diagram of the relay module powered by a solar panel.

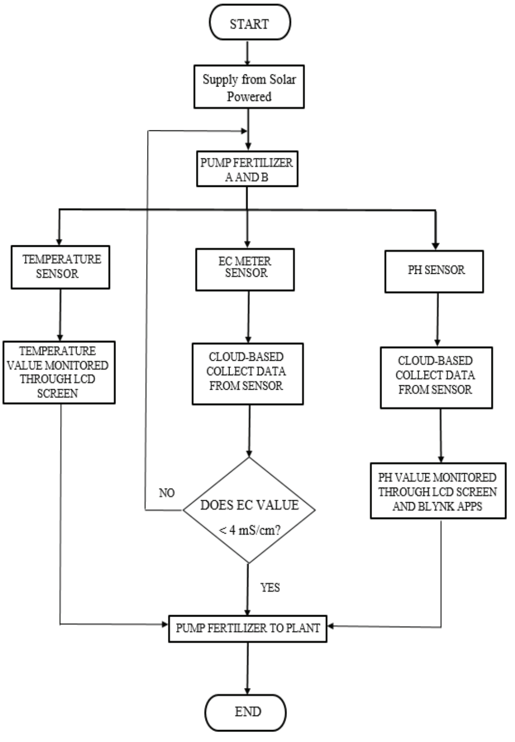

Fig. 1. Flowchart of the proposed system

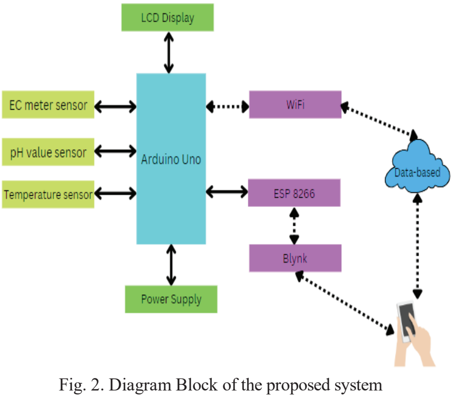

Fig. 2. Diagram Block of the proposed system

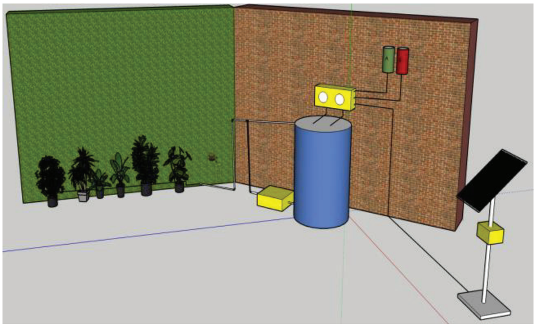

Fig. 3. Overall design of I-SIRAM

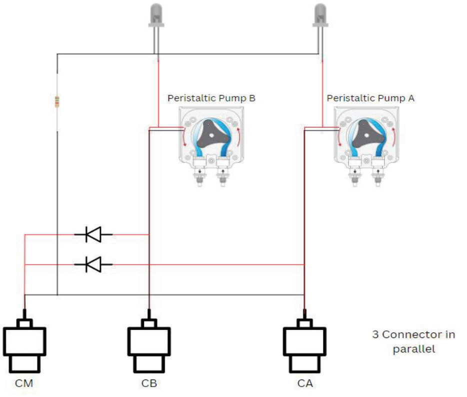

Fig. 4. Schematic diagram of Peristaltic Pump

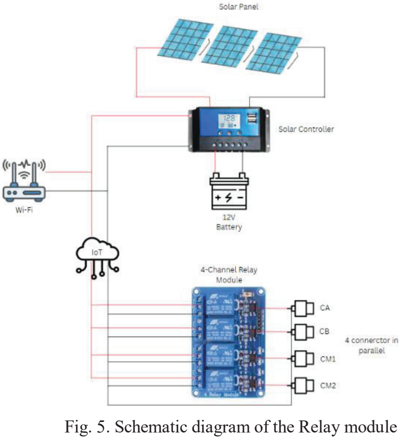

Fig. 5. Schematic diagram of the Relay module

An Arduino Uno, sensors such as a DS18B20 temperature sensor, EC meter sensor, pH value sensor and a NodeMCU (ESP8266) are used. The software comprises an android application that allows user to monitor their plant via Blynk. When the EC parameters measured fall below the threshold value, the user can run the peristaltic pump through their smartphone and fertilizer A and fertilizer B will be given to the plant. The Arduino Uno board functions as an IoT gateway and regulates all the operations on the board. All physical parameters are sensed by the sensor, which converts the analog value to a digital value. Fig. 6. below shows the Arduino Uno based circuit design fused or this project.

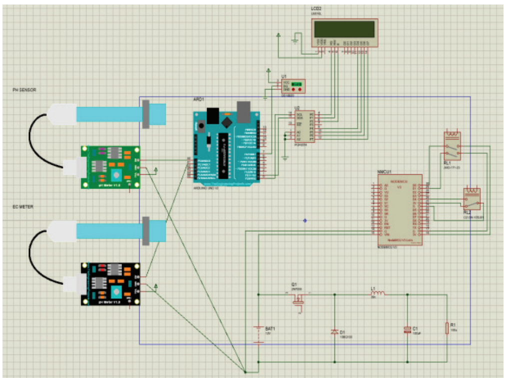

Fig. 6. Circuit design based on the Arduino Uno

C. IoT Implementation

A smart agriculture fertilization system based on the Internet of Things is used to make decisions based on real-time data. Firstly, the user will open the Android application on the smartphone. Users will see the data through the output of the sensor. Temperature, EC meter, and pH value are all measured. Arduino Uno Rev3 microcontroller board is attached to all these sensors because it has the capability to communicate data to the cloud. This board serves as an IoT gateway in this built system. A Wi-Fi ESP8266 module is used to transmit the data.

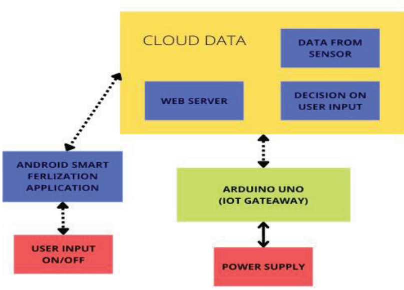

Fig. 7. Block diagram of IoT implementation

A Blynk application is used in this project. From the Blynk interface as shown in the Fig. 8, user can monitor their pH and EC values. The user also can turn on their peristaltic pump through their smartphone. It is very simple and convenient to be used.

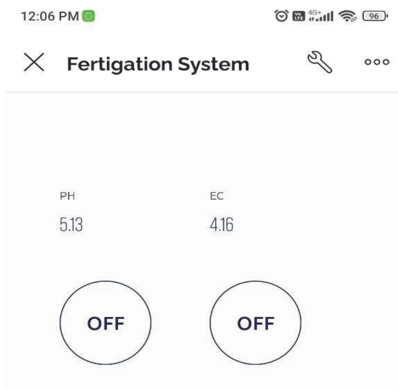

Fig. 8. Blynk interface

D. Parameters

To run this project, the EC value of fertilizer solution is the parameter to indicate that sufficient nutrients for the plant are applied. The EC value of the fertilizer is important to make sure that the plant gets enough nutrients. The type of the plant is chili pepper, or its scientific name is *Capsicum Annuum* which is extensively cultivated all over the world. Besides, the solution of the fertilizer is used to collect pH value and soil temperature data to be monitored. The type of fertilizer used is Fertilizer A and Fertilizer B as shown in Fig. 9. that contain a lot of multi-nutrients like Calcium, Iron, Magnesium, Manganese, Zinc, Copper and more. The role of fertilizer is important to the plant to maintain the water intake, increases the growth of roots and improve the seed formation.

Fig. 9. Fertilizer A and B

III. Hardware Development

Fig. 10. shows the complete development of I-SIRAM. For hardware development, I-SIRAM focuses on three main boxes of Box A, Box B, and Box C. Each of the box has a main function of itself. The supply voltage comes from solar power. Solar power is used to implement renewable energy and save energy costs.

Fig. 10. I-SIRAM

As shown in Fig. 10. three main boxes are connected to solar panel. I-SIRAM also provides a water tank to keep the water for the plant. The water is used to mix fertilizers A and B. The water tank can keep water at approximately 120L. Fig. 11 and Fig. 12 shows the outer look and inner look of Box A which consists of an LCD screen, Arduino UNO and NodeMCU ESP 8266. This box will control the main system including the reading of parameters and running the pump.

Fig. 11. Box A

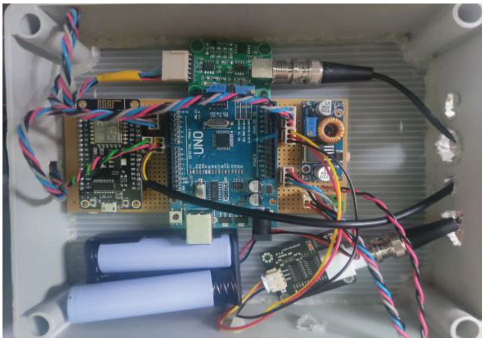

Fig. 12. Internal look of Box A

Next, Fig. 13 and Fig. 14 shows the appearance of Box B which contains the 12 V battery that is connected to the solar panel. It is the main supply voltage to run the water pump. To connect Box A to Box B, a relay module is used to control the running of the peristaltic pump. The double relay module controls the peristaltic pump and the single relay module controls the water pump.

Fig. 13. Outer look appearance of Box B

Lastly, Box C as shown in Fig. 15 and Fig. 16 contains the peristaltic pump that controls the intake amount of fertilizer A and B. Peristaltic pump is a mechanical pump that generates pressure by a constriction moving along a tube.

Fig. 14. Internal look of Box B

Fig. 15. Box C

Fig. 16. Internal look of Box C

IV. Software Development

To develop the system, Arduino IDE is used to write the coding. The program is divided into two which is to program Arduino UNO and another one is NodeMCU. Arduino UNO is programmed to store the parameter's library including temperature sensor, pH sensor, and EC meter sensor. This program will enable the values of the parameters to be shown on the LCD screen.

Meanwhile, NodeMCU is programmed to connect the hardware to Wi-Fi. The value of EC will be received from the sensor. From the value, it will state a condition if the value is less than 4 mS/cm or more. If the value is less, the water pump will be on but if its value is more, than the water pump will be off. Before that, this condition will be declared after the peristaltic pumps A and B is on. NodeMCU is also used to control the pump by using Blynk which is connected to the Wi-Fi through NodeMCU.

V. Discussions

By using an analogue pH meter with a temperature compensation feature designed for the Arduino controller, the pH value of the water is detected. The data from the sensor is sent to the cloud data in real time via Blynk. Most soils have pH values between 3.5 and 10. In higher rainfall areas the natural pH of soils typically ranges from 5 to 7, while in drier areas the range is 6.5 to 9. The neutral pH value for soil is 6.5 to 7.5, a value over 7.5 is alkaline and a value less than 6.5 is acidic [14]. If the soil is acidic, a notification is sent to the database and remind the user to add pulverized limestone to the soil to raise the pH value. If the soil is alkaline, a notification is sent to the database and remind the user to add elemental sulphur or iron sulphate to lower the pH value. The analogue pH meter comes with a temperature compensation feature. However in this project, the pH value focuses more on the fertilizer itself. The pH value of the fertilizer is important to be monitored because it indicates whether the solution is acidic or alkaline. Too much acidic or too much alkaline is not suitable for plant growth.

To make sure I-SIRAM is relevant to the community, a few statistical analysis is carried out in the project. The statistical analysis is done through research and findings. This analysis is to show the relationship between temperature and the voltage generated by the solar panel. In Malaysia, the average normal temperature is between 21°C to 32°C. The solar panel output current rises exponentially as its temperature rises, but its voltage output decreases linearly. As a result, heat can significantly lower the solar panel ability to generate electricity. The graph in Fig. 17 below shows the relationship between voltage and solar panel temperature.

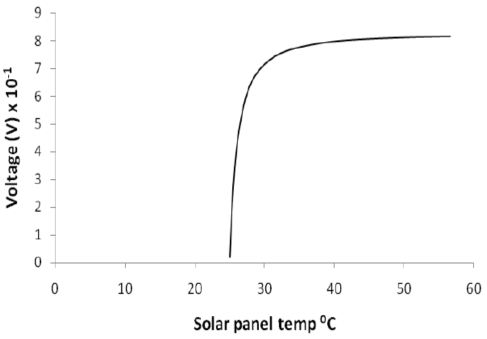

Fig. 17. Graph of voltage vs Solar Panel temperature

As mentioned in the previous discussion, the water pump will be activated when the EC value is less than 4 mS/cm. This is because it is a suitable EC value for the plants. The water pump will only activated when both peristaltic pumps are activated. Table I below shows the performance analysis of this project.

TABLE I
PERFORMANCE ANALYSIS OF I-SIRAM

Peristaltic Pump A	Peristaltic Pump B	EC value	Water Pump
On	On	3.71 mS/cm	On
On	On	4.40 mS/cm	Off
On	Off	3.71 mS/cm	Off
On	Off	4.40 mS/cm	Off
Off	On	3.71 mS/cm	Off
Off	On	4.40 mS/cm	Off
Off	Off	Either the value is less or more than 4 mS/cm	Off

VI. Conclusion

In conclusion, I-SIRAM as an affordable automated fertigation system which provides a monitoring and control method through the use of a mobile application is developed. The results successfully showed that the system could effectively manage and control the fertigation system anytime and anywhere remotely and alert users when there is a problem. Also, it increases efficiency where effective irrigation and fertigation scheduling require high manpower. The biggest aim of this project is to make every single house to own this fertigation system with the slogan of "1 House, 1 I-SIRAM". Thus, every single household can start to plant vegetables in their house and hopefully, this project can be a step solution for people who have problems in plant care.

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Conflict of Interest

The authors declare no conflict of interest in the publication process of the research article.

Authors Contribution

Author 1: data collection and draft editing; Author 2: data verification and draft review; Author 3: draft review; Author 4: project funding and administration; Author 5, 6 & 7: draft review and research collaboration.

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