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Abstract

The objectives of this study are: 1. to develop an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, 2. to compare the performance of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things with commonly used irrigation control systems in the market, and 3. to demonstrate and transfer knowledge on the development of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things to a group of farmers. The sample group used in the research consists of 30 tomato farmers from the Agricultural Production Efficiency Learning Center (ALC) in the Muang Sri Kai Subdistrict Network, Warin Chamrap District , Ubon Ratchathani Province The population was obtained by purposive sampling . The research tools used include: A questionnaire to evaluate the performance of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet, employing Black Box Testing methods conducted by 5 experts who assessed the system's effectiveness and A questionnaire to evaluate farmers' satisfaction with the training. Statistical analysis involved calculating the mean and standard deviation.

The research findings are:

1. The development of the irrigation control system using an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, controlled by the NodeMCU ESP8266 microcontroller, which manages sensors to detect temperature, humidity, water flow, and water usage, and can report environmental conditions of the greenhouse and handle error cases where no water is flowing through a developed web application, showed overall system performance at the very high level.

2. A comparison of the performance of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things with commonly used irrigation control systems revealed that the developed system offers additional functions: 1) a notification system via LINE to alert users when there is no water flow, 2) an automatic shutdown of the water pump if no water is flowing, 3) the ability to set the daily water rate, 4) a display of electricity usage, and 5) a report on daily and cycle water usage.

3. The results of the training demonstration and knowledge transfer on the development of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things show that the farmers' overall satisfaction with the training across all aspects is at a very high level.

Keywords: Drip Irrigation System, Internet of Things, Automatic Adapted, Tomato Plat, Modern farmers

Introduction

Tomatoes are economically and industrially important vegetables in Thailand. The majority of the cultivation areas are located in the northeastern and northern regions.

Tomatoes are crops that are often affected by water shortages, especially during the growth and fruiting stages, resulting in low yield and quality. Farmers, therefore, prefer to cultivate tomatoes under a drip irrigation system, which is part of a Precision Agricultural System and Smart Farm that utilizes Internet of Things (IoT) technology. IoT involves devices around us that can communicate and connect through the Internet, enabling Machine-to-Machine (M2M) communication, which is a widely used communication technology today. It has been applied to household appliances, industrial equipment, and agricultural devices, allowing users to control various equipment through the Internet from anywhere with an Internet connection (Jiamklin et al., 2021). This technology is used to address the aforementioned issues. Precision agriculture is a modern agricultural approach that uses production inputs in precise amounts necessary for plant growth (Low-External Input Agricultural: LEA) or maximizes the efficiency of production inputs. This approach involves monitoring various factors in the cultivation fields and rapidly transmitting data to processing systems for decision-making to control equipment in the fields. Therefore, various measuring devices, including computer programs for data transmission, display, and control of necessary cultivation factors, will assist in monitoring and managing the optimal cultivation conditions. This reduces the risk of crop damage and inconsistency in yields, leading to lower production costs due to reduced input usage while increasing yields, preserving the environment, and enabling the monitoring of plant growth.The primary importance of cultivation under drought conditions is an accurate and efficient irrigation system, especially for large-scale crop fields, where the yield is directly related to the soil moisture level. Therefore, controlling soil moisture levels

within the beneficial moisture range for plants (Available Moisture Capacity: AMCA) is a challenging task for farmers. An automatic irrigation control system with accuracy and precision is necessary for large-scale crop cultivation with limited water sources. Proper water management, including the amount and accuracy of water applied to the required areas, will help maintain sufficient and appropriate soil moisture levels for plant growth, resulting in higher yield and quality. Moisture measurement and control can be achieved by applying locally available electronic devices to develop a soil moisture measurement kit. The moisture readings from the fields are processed by a microcontroller, which then controls the water valves to open or close water supply to specific areas with precision. The main components of this system include soil moisture sensors, a microcontroller, and an automatic water control system. The various components work together systematically and continuously. The system can display real-time soil moisture levels in the cultivation fields and the status of the valves on a monitor, and all data is stored in a database. The database includes temperature, humidity, and water usage data throughout the cultivation season. This data can be analyzed alongside other cultivation factors measured by the sensors and used to forecast future yields. All data from each cultivation season is stored as a database for planning future cultivation. This research focuses on studying how to implement an automatic drip irrigation system To ensure that tomatoes have suitable yields and are beneficial for both existing and modern farmers.

Objective

1. To develop an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

2. To compare the performance of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things with commonly used irrigation control systems available in the market.

3. To demonstrate and disseminate knowledge on the development of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things to a group of farmers.

Literature Review

This development project has developed an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. The following documents were studied and Related Research.

1. Critical Soil Moisture Levels

Soil moisture can be categorized into several types, each with distinct properties. Therefore, utilizing soil moisture effectively requires considering different moisture levels, which are classified into five types as follows:

1.1 Saturation Point or Water Saturation: This is the condition where all the pore spaces between soil particles are filled with water. There might be a small amount of air in the tiny pore spaces, but it is minimal. If the soil has good drainage capacity, the water in the larger pore spaces will move downward due to gravity in a short period.

1.2 Field Capacity: This is the amount of moisture left in the soil after the free-draining water has been removed from the larger pore spaces. It represents the maximum amount of water the soil can retain against gravitational pull. In this condition, the small pores are fully saturated, but the large pores contain air. Field capacity is typically observed 2-3 days after heavy rainfall or irrigation ceases. Generally, the moisture tension at this point is about 1/3 atmosphere, although this value varies with soil texture. For example, coarse soils have a moisture tension of around 1/10 atmosphere, while clayey or sticky soils have about 0.6 atmosphere. Field capacity is considered the upper limit of soil moisture beneficial to plants, meaning plants can absorb moisture at this level, and it remains available long enough for plant uptake. Moisture levels higher than this, such as free water, are less useful to plants because they drain away quickly from the root zone. (Sutthiboribarn et al., 2011)

2. Internet of Things

The Internet of Things (IoT) is a network of objects, devices, or things embedded with electronic equipment, software, sensors, and connectivity that can be connected. It enables the collection and exchange of data between these entities. IoT allows these objects to be monitored and controlled remotely through existing networks, creating opportunities for integration between everyday objects and computer systems. This integration can enhance efficiency, accuracy, and economic benefits. Each object in IoT has a unique identifier and can be recognized through embedded devices, allowing them to interact over existing networks such as LAN, Wi-Fi, 3G, and 4G. Experts predict that by 2020, there will be approximately 50 billion IoT devices (Saaid M.F. et al, 2013). Using IoT in agriculture can address various problems faced by farmers, leading to highly precise and plant or animal-specific farming. Furthermore, farmers can use available resources more efficiently and appropriately for their farming area. Additionally, they can monitor and manage their operations closely via computer devices, with data transmitted through accessible networks. This will ensure that the yield meets the farmers' needs as they can control and adjust variables according to their requirements.

3. Microcontroller Board

The Arduino microcontroller board is an open-source project developed from another open-source project called "Wiring." The original "Wiring" project used the ATmega128 AVR microcontroller, which has a large amount of memory and input/output capabilities, and importantly, the ATmega128 is an SMD chip, making it challenging for beginners to build their own boards and circuits. Additionally, the board is relatively large, which might seem excessive for beginners, leading to less popularity. However, after Arduino adapted the "Wiring" code to work with smaller AVR microcontrollers like the Mega8 and Mega168, it became easier to create and use circuits and significantly reduced the cost of building the boards. This adaptation led to Arduino gaining widespread popularity in a short time (Nishimura, et al., 2016). The Arduino Esp8266 microcontroller board uses the ATmega328 chip with a 16 MHz clock, 32 KB flash memory, and 2 KB RAM. The board operates on a power supply of 7 to 12 V, with operating voltage and signal pins at 5 V (TTL). It includes 14 Digital Input/Output pins, 6 Analog Input pins, 1 Serial UART, 1 I2C, and 1 SPI For programming Arduino, the C++ language is used, which is a variant of the C language with a structure similar to standard ANSI-C. However, it has been simplified to reduce complexity, making it easier and more convenient for users to write programs compared to using standard C directly. In reality, Arduino programming can utilize commands that conform to the ANSI-C standard, and the programming style and command usage can be referenced directly from ANSI-C textbooks for NodeMCU is an open-source IoT platform. Consisting of hardware in the form of a system on a chip (SOC) Wi-Fi microchip from ESP8266 made by Espressif System as well as firmware used using the Lua scripting programming language. Node MCU itself refers to the firmware used in the hardware development kit. Node MCU is just like Arduino, but the difference is the MCU. The Node ESP 8266 module is equipped with WIFI, so it can be used for internet-based or IoT hardware requirements. (Firmansyah et al., 2019)

In this research, the NodeMCU ESP8266 is a popular device used in Internet of Things (IoT) applications. The research team chose the NodeMCU ESP8266 due to its compact size and sufficient number of input and output pins for general-purpose use. This device is utilized to control various equipment, such as light bulbs, solenoid valves, and irrigation valves. It is also used for tasks such as opening and closing irrigation valves based on water flow detection and monitoring humidity levels in cultivation areas.

4. Firebase

Firebase is a real-time database and also acts as a Backend-as-a-Service(BaaS). It allows to store a list of objects. Google Firebase is Google-backed application development software which allows developers to develop applications for Android, iOS, and Web apps. Firebase is a grouping of Google's many services in the cloud, including instant messaging, user authentication, real-time database, storage, hosting, etc. (Li et al., 2018)

In this research, Firebase is a schemaless database platform that enables backend management and operates faster than structured databases. The research team chose Firebase for controlling irrigation systems, scheduling, and setting water quantities. It acts as an intermediary between the web application and the ESP8266 board, facilitating communication between them.

5. MySQL

MySQL is the most widely used open-source database software in the world, with more than 100 million users worldwide. MySQL has become the preferred database for many software and application developers on both online and desktop platforms due to its

dependability, speed, and ease of use. Individuals and small businesses aren't the only ones that use MySQL; Yahoo!, Alcatel-Lucent, Google, Nokia, YouTube, WordPress, and Facebook are all MySQL users (Michael & Andreas, 2023).

In this research, MySQL is a structured database system that organizes data into tables. The research team chose MySQL for storing data on water usage rates and electricity consumption rates. This allows PHP and JavaScript to retrieve the data and create statistical graphs.

6. No Structure Query Language

Boonrom (2023) discussed unstructured databases, noting that they were first used in 1998 with the rapid expansion of the internet, driven by the increasing popularity of databases for websites. This was due to the need for a data management system capable of handling massive amounts of data. In unstructured databases, Structured Query Language (SQL) is not used to manage data. Generally, unstructured databases are used to handle large volumes of data, also known as Big Data, which have schemas and metadata. Data is accessed using reference principles that allow for quick retrieval, efficient recovery and recording, and synchronized operations for multiple users, along with indexing and high database security. NoSQL databases have become very popular, especially for developing applications to manage large data structures due to their rapid data access and the variety of data management formats. Applications of unstructured databases include the Internet of Things (IoT), hardware control in smart farms, and intelligent human agent systems. The characteristics of unstructured or NoSQL databases are as follows: 1) They do not use a relational database model. 2) They focus on distributed processing. 3) There are no requirements for schema or data structure. 4) Replication and backup are easy to perform. 5) Data access is achieved through an API: Application Program Interface. Unstructured databases are commonly used in formats similar to JSON and BSON data exchange. From an application development perspective, unstructured databases are often used in conjunction with JSON and BSON data exchange.

In this research, the research team utilized an unstructured database or NoSQL Database with Key-Value Store and Document Store capabilities for controlling the system through the developed web application. This was used to manage drip irrigation commands, where commands were stored in NoSQL Database using Firebase Realtime Database. Temperature, humidity, and water usage data for each irrigation event were temporarily stored in Firebase Firestore, a cloud-based database, before being recorded in the MySQL relational database management system at 11:00 PM each day. After the data was recorded, it was then deleted from Firebase Firestore. This process is executed daily following the use of the control system.

7. Related Research

7.1 Mohanad et al. (2020) developed research on designing an automated irrigation system to control water quantity using the Arduino Uno R3 microcontroller and soil moisture sensors. The system controls irrigation and schedules water delivery based on the type of plant, aiming to reduce costs such as water and labor expenses while increasing agricultural productivity. This proposed system is a sustainable solution for enhancing water use efficiency in agricultural areas according to plant needs. The system operates using a drip irrigation method, with the irrigation sensors connected to the Arduino Uno R3, allowing real-time monitoring via a computer. It also allows selection of plant types according to the system's program based on soil conditions and root zone moisture. The automatic irrigation system for farmers helps determine the required water quantity at scheduled times, reports the water status for each agricultural plot, and allows tracking of soil moisture levels and pump operation. It includes a database on plants and displays suitable water quantities for different plant types.

7.2 Rossy et al. (2020) developed research on the design and implementation of an automated tomato irrigation system using IoT with the ESP8266 microcontroller. The system considers factors such as the required soil moisture, air conditions, and temperature necessary for growing tomatoes, which should be between 60% and 80% humidity and temperatures between 24°C and 28°C. The research team utilized IoT technology to develop an innovative agricultural technology solution to address issues and enhance irrigation precision based on soil moisture levels and air temperature. The system, which includes ESP8266, soil moisture sensors, and DHT11, can be controlled remotely via an internet connection. The program is integrated with the Telegram Messenger application to receive data from the sensors and automate tomato watering. Experimental results showed that the soil moisture sensors functioned well, accurately reading soil moisture levels, and the temperature sensors provided suitable air temperature readings. Users receive all sensor data through the Telegram Bot, which sends notifications, allowing farmers to easily monitor and control tomato irrigation remotely. The system also manages and tracks the condition of tomato cultivation.

Research Methodology

The development of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things was conducted by the researcher following the steps of the SDLC model, which includes the following stages:

1. Planning Requirements

1.1 Studying the Problem: Due to the large amount of agricultural land in Thailand, farmers need to use a significant amount of water for their crops. This requires them to spend a lot of time watering their plants, and they are also unable to accurately monitor the amount of water being used. To help farmers work more efficiently, it is necessary to apply technological and innovative solutions to reduce the workload of cultivating field crops and garden plants.

1.2 Studying the Hardware Tools

1.2.1 Studying the Working Principles of NodeMCU ESP8266: NodeMCU ESP8266 is a small, low-cost Wi-Fi enabled microcontroller that is widely used in Internet of Things and smart home devices. It is unique in that it can be programmed to perform various tasks.

1.2.2 Studying the YF-S201 Water Flow Sensor Module: This sensor module is utilized to measure the flow rate of water. Generally, its operation is based on detecting and measuring the flow of water using the principles of pressure change or water flow within a pipe. Equipped with a fan, the sensor module measures the water pressure passing through it. It must be installed on a water pipe and measures the flow of water through the pipe by detecting changes in water pressure.

1.2.3 Studying the operational principles of a relay: relay is an electrical control device with a crucial component known as a coil. It functions similarly to a switch, utilizing electrical voltage to open and close the electrical current, thereby controlling various electrical devices. Relays are essential components in automated control circuits.

1.2.4 Studying the Solenoid Valve: A solenoid valve has the ability to control the flow of water or other substances using electrical energy as the medium for operation. It utilizes electrical energy to either open or close the flow of water, allowing for efficient control over the fluid's movement.

1.2.5 Studying the Temperature and Humidity Sensor (SHT31): The SHT31 module combines both temperature and humidity measurement capabilities while being water-

resistant. It is capable of measuring temperatures ranging from -40 to 125°C with high accuracy and can measure humidity levels from 0 to 100% RH. The sensor operates with an electrical voltage of 3.3V or 5V and connects using the I2C communication protocol. Additionally, it features a water-resistant design for added durability.

1.3 Studying the Software Tools

1.3.1 Studying the operation of the Arduino IDE involves understanding the programming aspect of controlling Arduino boards. Programming for Arduino boards is done using the C language, and the entire process is open source, allowing users to work with it without incurring any costs. The Arduino IDE enables users to write programs that control the functions of Arduino boards, making it a versatile and cost-free solution.

1.3.2 Studying the operational principles of Firebase Firebase Realtime Database is a NoSQL cloud database that stores data in JSON format. It enables real-time synchronization across all connected devices, offering faster performance compared to relational or structured databases (Boonrom, 2023). It supports offline functionality by storing data locally until the device reconnects to the internet, at which point it automatically synchronizes the data. Additionally, it includes Security Rules, allowing the configuration of access conditions for both reading and writing data. The database is compatible with Android, iOS, and web applications, as well as the ESP8266 board used in this research

1.3.3 Studying the principles of relational databases relational database stores data in the form of two-dimensional tables, where information is presented in rows and columns. Each row is referred to as a record, while each column is called a field or attribute (Boonrom, 2023). The research team will use a relational database to store daily drip irrigation data, including moisture levels, temperature, and water usage. The data will then be compiled into statistical graphs for reporting to users

2. Analysis System

2.1 Steps of Analysis

The research team has gathered data to study the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. This process involves the following steps:

Analyzing the Automatic Adapted Drip Irrigation Systemfor Tomato Plat Using Internet of Things

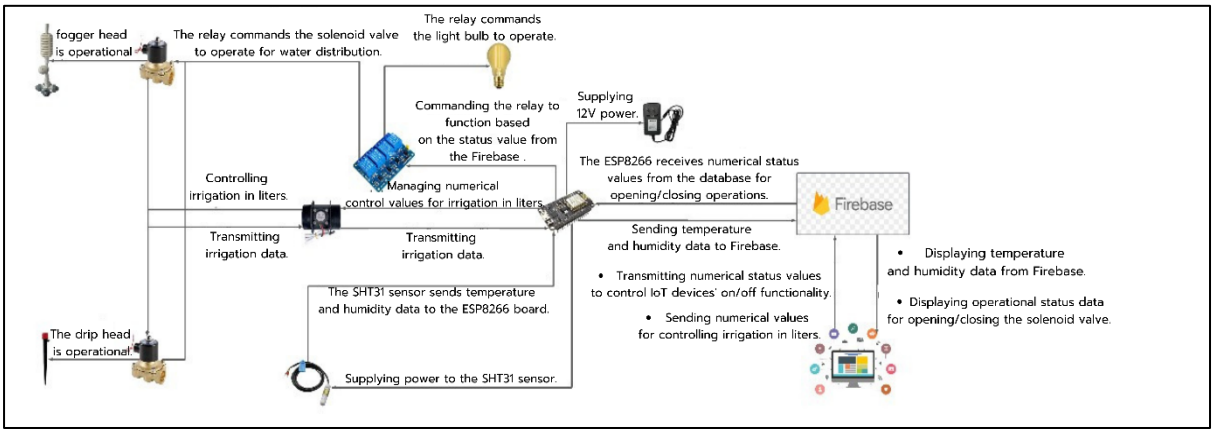


Figure 1: Analyzing the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

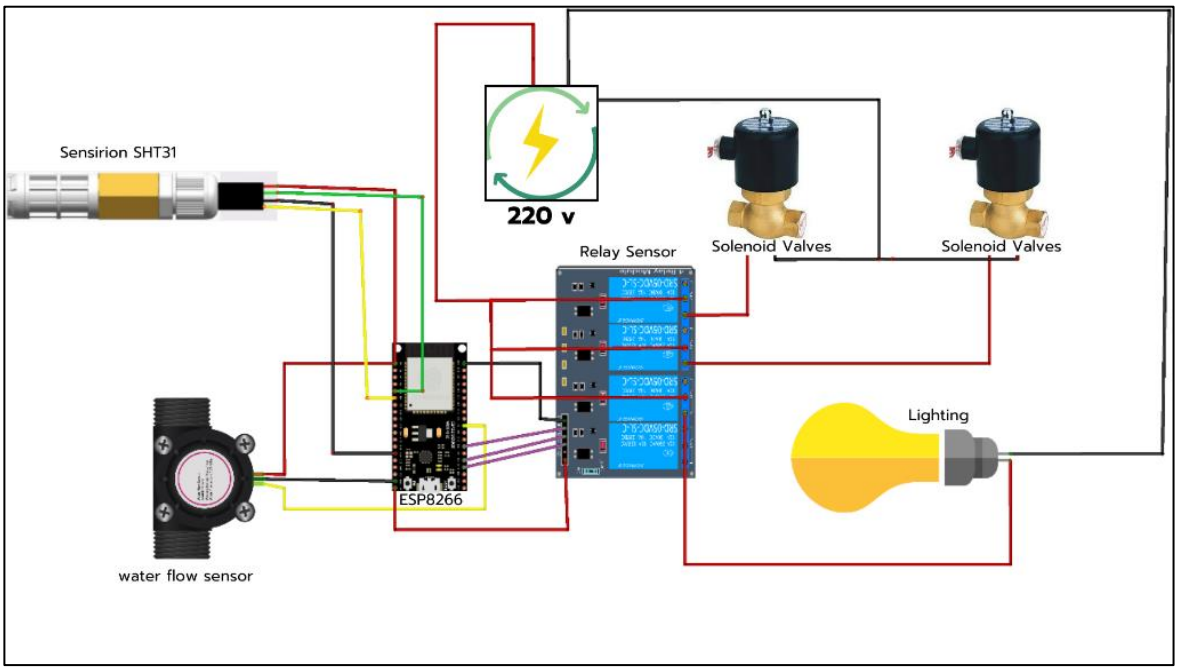


Figure 2: Circuit Analysis

Figure 1 and 2 depict the analysis of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. Users interact with the system through a web application to issue commands. The web application then sends status values as numerical data to Firebase, and the ESP8266 board retrieves these status values from the Firebase database. The ESP8266 board acts as a control unit, sending commands to the relay to activate or deactivate devices. The devices include light bulbs and solenoid valves. Moreover, the ESP8266 board transmits temperature and humidity data obtained from the SHT31 sensor to Firebase, allowing the web application to display sensor readings. This feature informs users about temperature and humidity levels in the cultivation area. Additionally, users can remotely control the irrigation schedule through the web application, utilizing the YF-S 201 Water Flow sensor module to measure the water flow rate in liters. When the specified water quantity is reached, the solenoid valve stops the water supply, effectively halting the irrigation process in the cultivation area.

2.2 Design System

Based on the study of the irrigation problems and system planning, the research team has designed an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. The system is divided into 3 main components as follows

1) Designing the overall system operation.

The research team has designed the overall operation of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things in the form of algorithms. The algorithms are as follows.

Control system for fogger, lights, and drip irrigation
Check control conditions for fogger, lights, and drip irrigation:
If true, activate RELAY1 to turn on the lights.
If true, activate RELAY2 to start drip irrigation.
If true, activate RELAY3 to turn on the fogger.
The variables are received as follows: RELAY1 = 1, RELAY2 = 1, RELAY3 = 1.
    Check if the board received RELAY1 = 1:
        If true, start the operation of the light bulb.
        If false, stop the operation of the light bulb.
    Check if the board received RELAY2 = 1:
        If true, start drip irrigation.
        If false, stop drip irrigation.
    Check if the board received RELAY3 = 1:
        If true, start the fogger operation.
        If false, stop the fogger operation.
If none of the above conditions are true, stop the operations of RELAY1, RELAY2, RELAY3.
Display the status of operations (on/off) through a web application.
End of operation.
Display the opening/closing status via a web application.

Figure 3: The program controls the on-off operation of the misting system, lights, and drip irrigation.

Water volume control program
If true, activate RELAY2 to start drip irrigation.
Receive variables: controlled volume data and current usage volume data.
Check if the current usage volume is less than the controlled volume
        If true, start drip irrigation.
        If false, stop drip irrigation.
If not true, stop the operation of RELAY2.
Display the opening/closing status via a web application.

Figure 4: The system is programmed to control the specified water quantity

Humidity control program
If true, activate RELAY3 to start the fogger.
Receive variables: target humidity and current humidity.
    Check if the target humidity is less than the current humidity
        If true, start the fogger.
        If false, stop the fogger.
If not true, stop the operation of RELAY3.
Display the opening/closing status via a web application.

Figure 5: The programmed system controls the specified humidity level.

Control system for program to send cumulative water and electricity usage data
Check the condition for sending cumulative water and electricity usage data:
If true, activate RELAY1 to calculate and sum up electricity usage.
If true, activate RELAY2 to calculate and sum up drip irrigation water usage.
If true, activate RELAY3 to calculate and sum up fogger water usage.
Receive variables: RELAY1 = 1, RELAY2 = 1, RELAY3 = 1.
Check if the board received RELAY1 = 1
If true, calculate and sum up electricity usage.
If false, stop calculation and send cumulative electricity usage data to the database. Check if the board received RELAY2 = 1
If true, calculate and sum up drip irrigation water usage.
If false, stop calculation and send cumulative drip irrigation water usage data to the database.
Check if the board received RELAY3 = 1
If true, calculate and sum up fogger water usage.
If false, stop calculation and send cumulative fogger water usage data to the database
If not true, deactivate RELAY1, stop calculation, and send cumulative electricity usage data to the database.
If not true, deactivate RELAY2, stop calculation, and send cumulative drip irrigation water usage data to the database.
If not true, deactivate RELAY2, stop calculation, and send cumulative drip irrigation water usage data to the database.
Display the opening/closing status via a web application.

Figure 6: The control system manages the program that sends cumulative data on water and electricity usage.

Figure 3 to 6 represent the overall design of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. The system incorporates the design of the program to control the on-off operation of the misting system, lights, and drip irrigation. The program checks the conditions to ensure that the board receives the values of variables for Relays in Channels 1 - 3 . Additionally, the system is designed to control the program for regulating the specified water quantity, activating Relay in Channel 2 when meeting the conditions. Furthermore, the program controls the humidity level as per specifications, activating Relay in Channel 3 under the defined conditions. The design also includes a program to control and send cumulative data on water and electricity usage, checking conditions to ensure the board receives the values of variables for Relays in Channels 1-3.

2) Designing a greenhouse for cultivating tomatoes using Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

After studying the issues and planning the development, the research team selected Queen Sirikit tomatoes as the sample crop. They examined the results of implementing the Automatic Drip Irrigation System Using Internet of Things. The greenhouse for growing Queen Sirikit tomatoes was designed using the SketchUp program, as shown in Figures 7-8.



Figure 7: Designing the interior layout of the greenhouse.

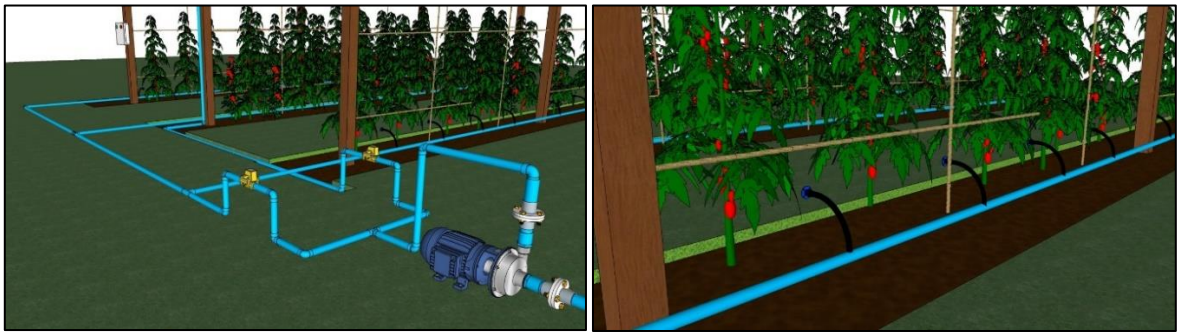


Figure 8: Designing the water pipe system.

3) Designing the operational principles of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

The research team has developed the operational principles of an intelligent agricultural irrigation system via the Internet of Things, as shown in Figure 9.

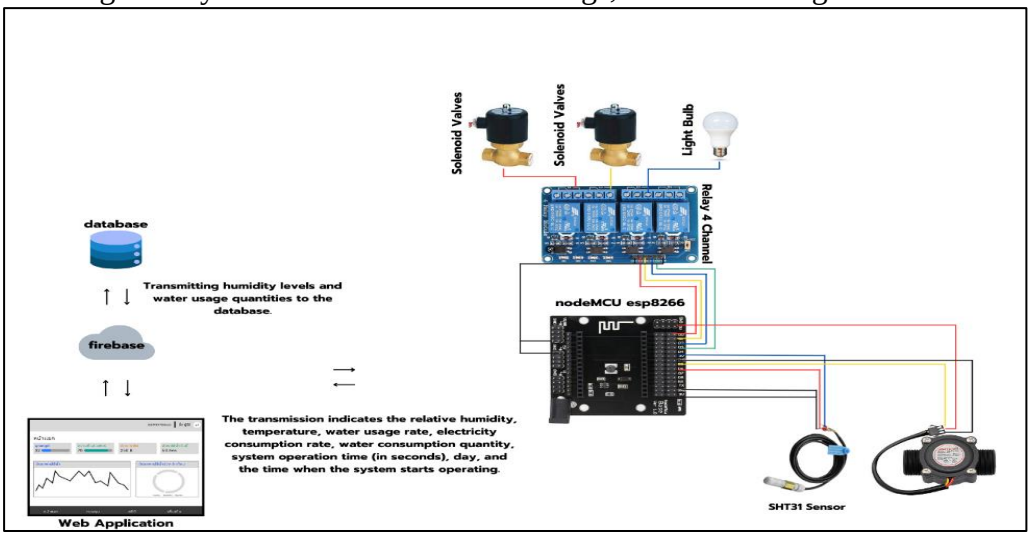


Figure 9: Designing the operational framework of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

From Figure 9, the system design involves using a web application to control an ESP8266 board, which commands the on-off status of a 4-channel relay to control two solenoid valves and one light bulb. It also regulates water usage rates using a water flow sensor. The board sends temperature and humidity data from an SHT31 sensor and displays the results in the web application. Data transmission occurs via Firebase, serving as an intermediary, and stores information on water usage, electricity consumption, temperature, and humidity in the database.

3. Development System

Developing an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things for nurseries and farms involves the following steps.

3.1 Preparation of land for planting crops.



Figure 10: Preparation of land for planting crops.

3.2 Designing a Water Pipe System for Plant Irrigation.

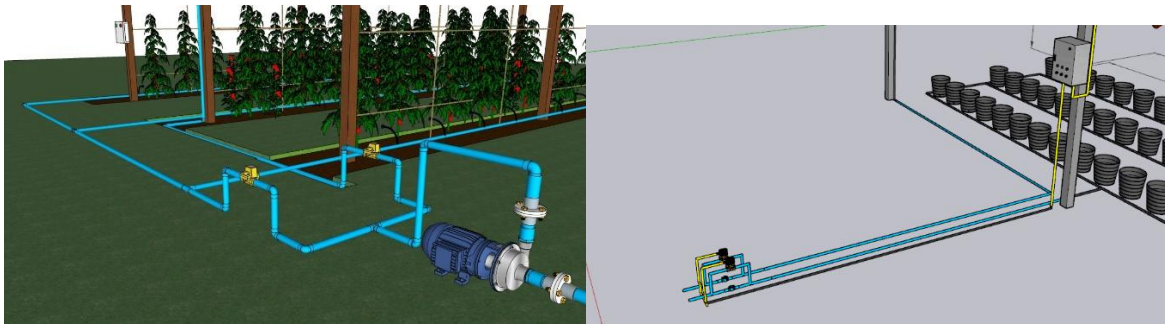


Figure 11: Laying the water pipe system.

3.3 Developing and installing a control box inside the plantation plot.



Figure 12: Development and installation of control boxes

Figure 1 2 the step-by-step process for installing the control box within a crop cultivation facility to manage the operations of equipment is depicted. This control box is essential for controlling the overall system and consists of the following 1) Control of Solenoid Valves 2) Flow Rate Monitoring 3) Moisture Level Sensing 4) Control of Light Tubes

3.4 This article discusses the programming of a system for controlling the operation of a plant cultivation plot. The system can be divided into 4 parts.

1) Development of the home page.

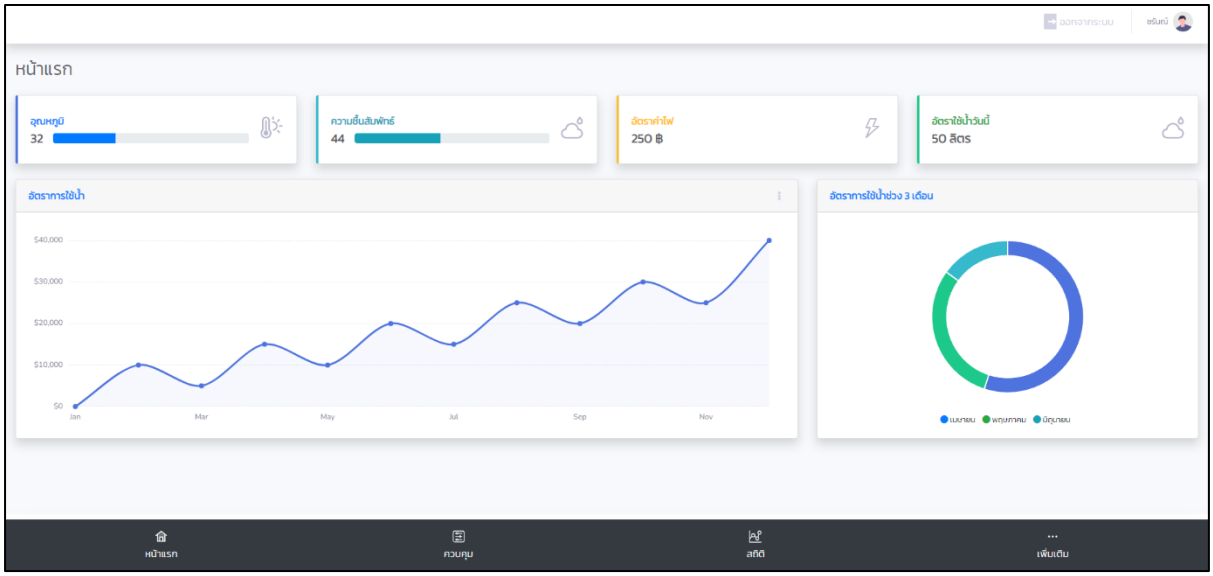


Figure 13: Development of the home page.

Figure 13 depicts the use of a web application to access information within a crop cultivation area. The displayed data includes temperature, relative humidity, electricity consumption rate, daily water consumption rate, a graph illustrating the water consumption rate, and the water consumption rate over a 3 month period0

2) Development in the control panel section.

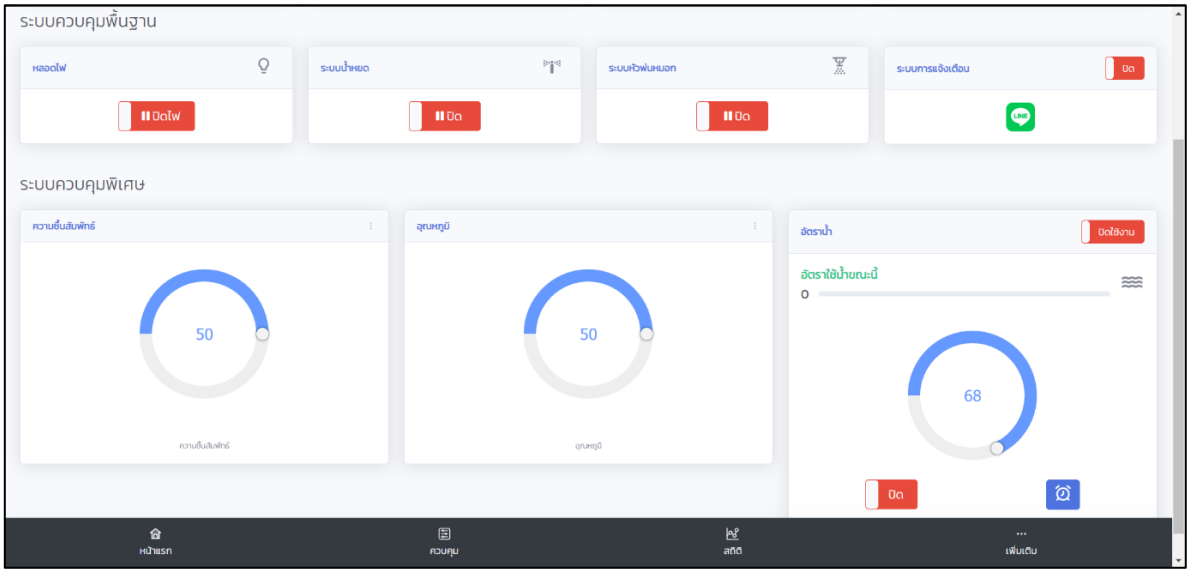


Figure 14: Development in the control panel section.

Figure 14 showcases the utilization of a web application for accessing information and controlling operations within a crop cultivation area. The displayed data and control features include temperature, relative humidity, electricity consumption rate, daily water consumption rate, and various fundamental operational controls. These controls encompass the management of light tubes, drip irrigation systems, misting systems, Line notification alerts for water flow without irrigation, and specialized controls such as humidity and temperature regulation. Additionally, the system allows for scheduled time settings and daily water consumption rate configuration measured in liters.

3) Development of the statistics page.

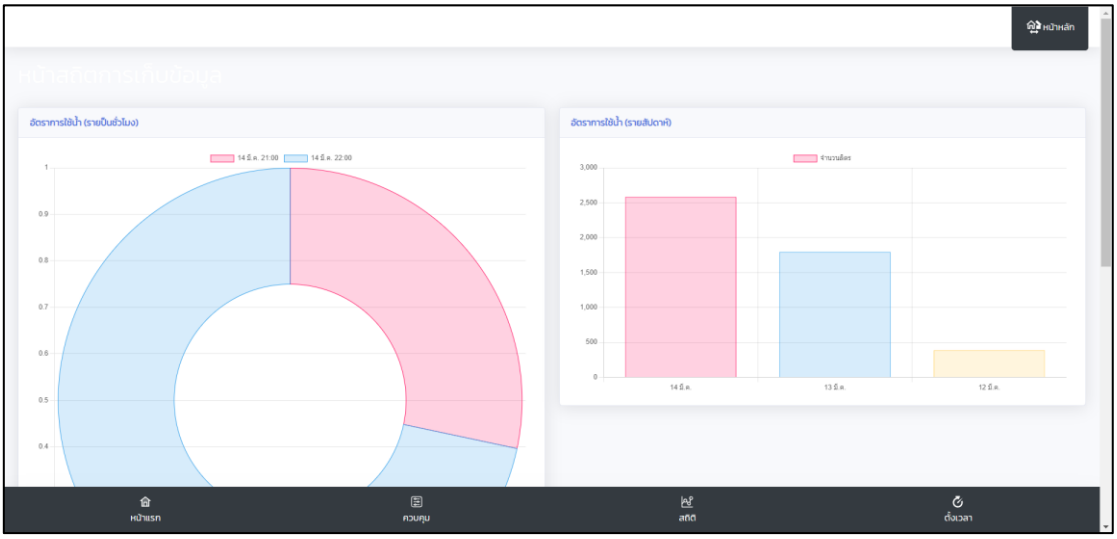


Figure 15: Intelligent Agricultural Irrigation System Controller Statistics Page.

Figure 15 it is a statistical data display page in the form of a bar graph for water usage rates over different time intervals. The data to be displayed includes hourly data showing the date, month, and time, weekly data showing the date, month, and monthly data showing the month. The statistical data in this bar graph format is measured in liters.

4) Development in the section of scheduling.

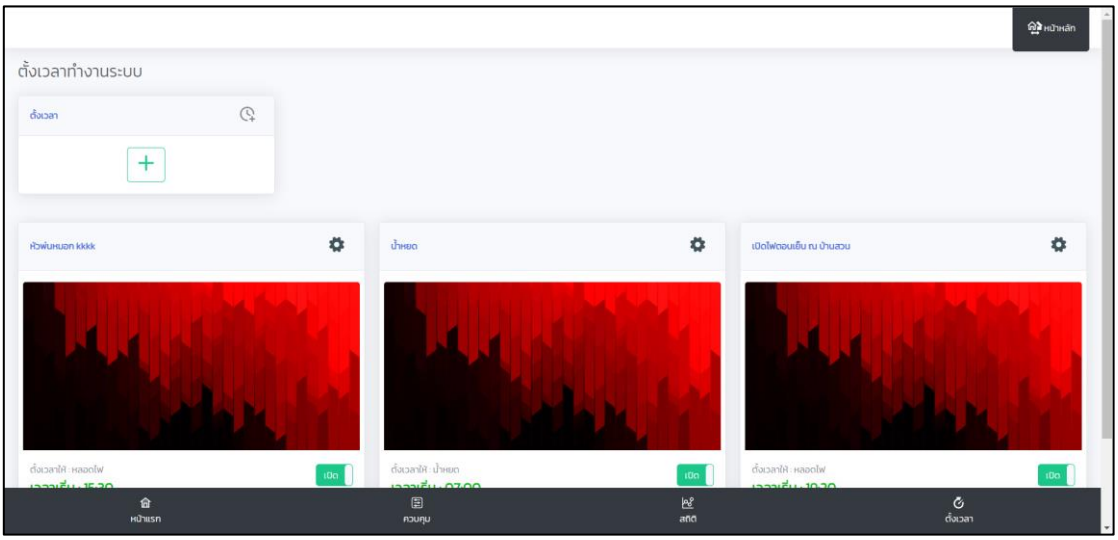


Figure 16: Development in the section of scheduling**.**

Figure 16 it is a section allows users to schedule watering times for Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. Users can set titles, start times, end times, select devices for activation, and choose days for operation. Users can add multiple scheduling entries, each with its own set of details, and edit the details of each entry as needed.

4. Testing

The research team conducted performance evaluation tests using an assessment form for the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. These tests aimed to assess the overall system performance to determine if the processes align with the predefined objectives. Additionally, the tests were conducted to identify any system errors or discrepancies. Following the evaluation, the research team made improvements and adjustments to enhance the system. The evaluation process involved the participation of five experts in the field.

5. Evaluation System**.**

The system evaluation process involved the creation of an efficiency assessment form. 5 expert assessors were enlisted to conduct a thorough evaluation of the system's performance

The outcomes derived from the assessment process will be subjected to statistical principles to aid in summarizing the efficiency of the developed system. Statistical calculations, including mean (average) and standard deviation (S.D.), will be employed for each dimension of the assessment. This statistical approach aims to provide a comprehensive overview of the system's efficiency and quality across various aspects. (Boonchom, 1998)

4.51–5.00 mean The performance and quality of the system is very good
3.51–4.50 mean The performance and quality of the system is good
2.51–3.50 mean The performance and quality of the system is medium
1.51–2.50 mean The performance and quality of the system is Low
1.00–1.50 mean The performance and quality of the system is Very few

The statistical data shows as follows:

1.Arithmetic mean

$$\overline{X} = \frac{\Sigma^{x_i}}{n}$$

When $\overline{X}$ is arithmetic mean
Σ_i^x is Sum of data
n is Amount of data

2. standard deviation

$$SD. = \sqrt{\frac{\Sigma(X_i - \overline{X})^2}{n}}$$

When $S.D.$ is standard deviation
X_i is Personal data
$\overline{X}$ is arithmetic mean
n is Amount of data

6. Assessing farmers' satisfaction with the training.

Assessing farmers' satisfaction with the training for demonstrating and transferring knowledge on the development of an automatic drip irrigation system for tomato farms using the Internet of Things according to the evaluation criteria in stage 5.

Research Findings

A team of researchers has developed Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. The system can be divided into the following four parts.

1. The result of developing an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

1.1 Results of the software development for the web application component to store data on temperature, humidity, watering times, drip irrigation duration, and daily water volume in the automatic drip irrigation system for tomato farms using the Internet of Things.

1) The first page of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

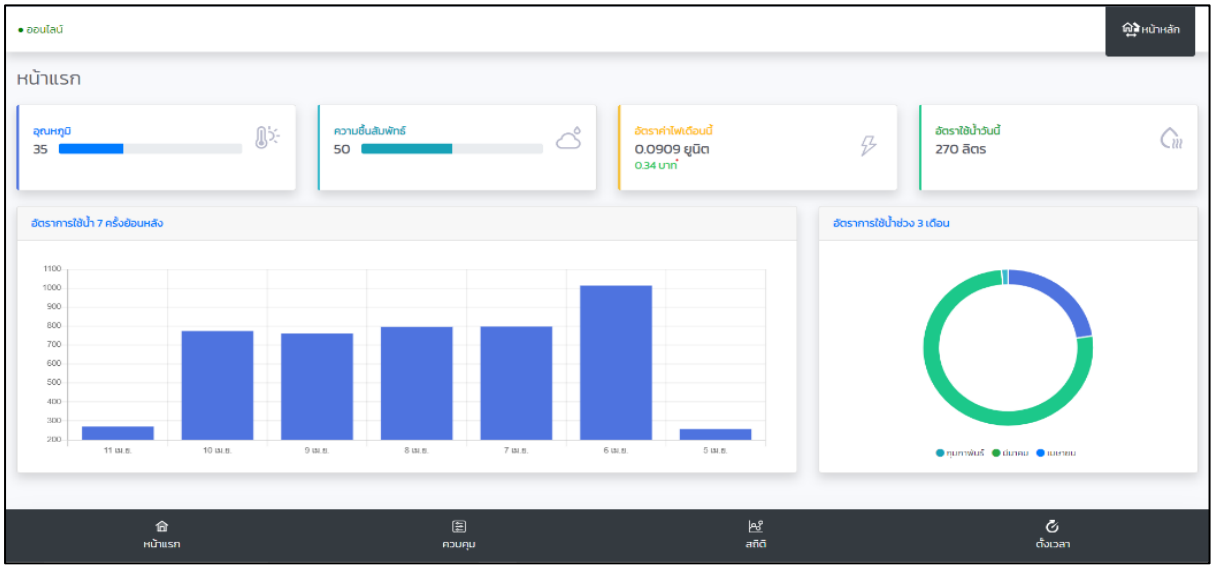


Figure 17: Home page.

Figure 17 illustrates the home page of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, which can display real-time temperature, humidity, electricity usage rate, and water usage rate for the current day. It also presents graphical representations and pie charts of the water usage rate over a three-month period.

2) Control Panel of the Automatic Adapted Drip Irrigation System for Tomato Plat. Using Internet of Things Thing.

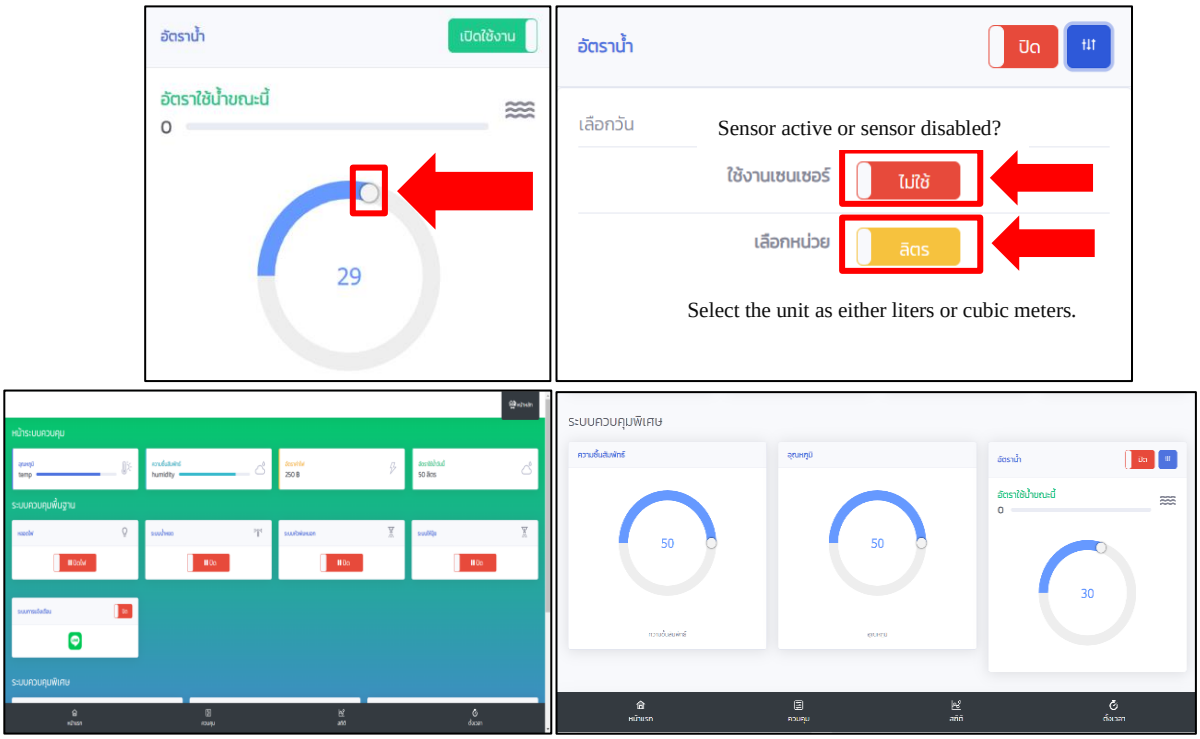


Figure 18: Control Panel

Figure 18 this is the control panel page of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things. Users can view various data such as temperature, humidity, electricity cost for the current month, and water usage rate for today. Additionally, users can control basic operations such as turning light bulbs on/off, controlling drip irrigation systems, misting systems, and receiving line notifications in cases where the water system is activated but no water flow is detected. Moreover, there's a special control system for managing humidity and temperature, allowing users to adjust settings according to their preferences. Importantly, users can control water flow rates by setting the desired volume in liters or cubic meters, and the system will stop operation when the set volume is reached.

3) Data Statistics Page

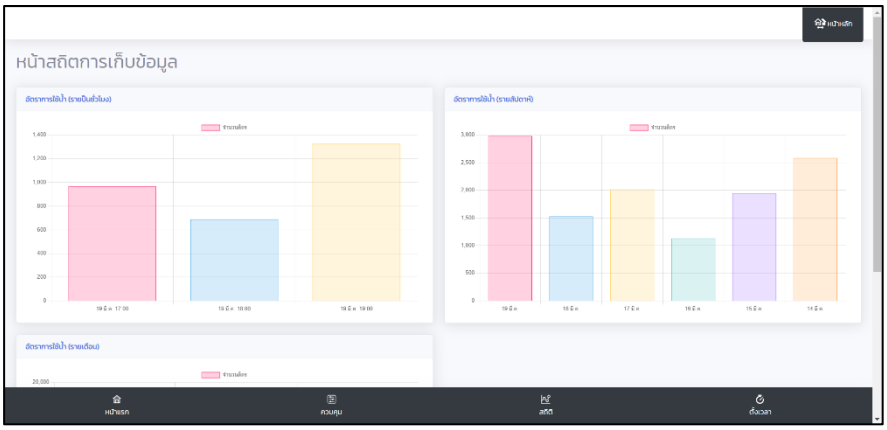


Figure 19: Data Statistics Page

Figure 19 depicts the data statistics page of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, which showcases statistics of water usage rates on an hourly, weekly, and monthly basis. The data is presented in bar graph format, with the unit of measurement being liters.

4) System Scheduling

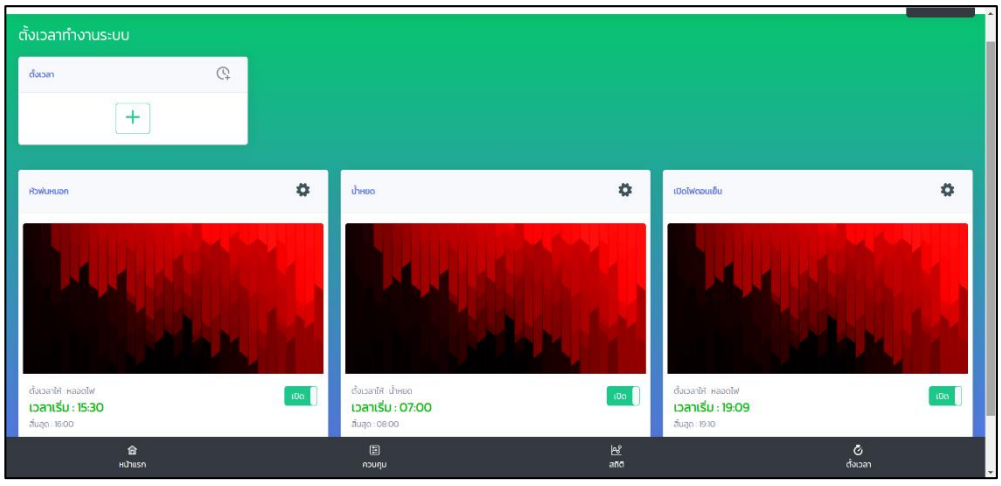


Figure 20: System Scheduling.

Figure 20 this is the system scheduling page of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, where users can schedule multiple system operations. Users can add more than one schedule entry, specifying a title, start time, end time, and selecting the days for scheduling. The system allows users to choose both desired and undesired days for scheduling. Users can also assign devices for activation and set their status. After configuring the system, users can edit the settings. Editing options include modifying the title, start time, end time, selected days, device activation time, and status adjustment.

1.2 Results of the development of the control device box for the automatic drip irrigation system for tomato farms using the Internet of Things.

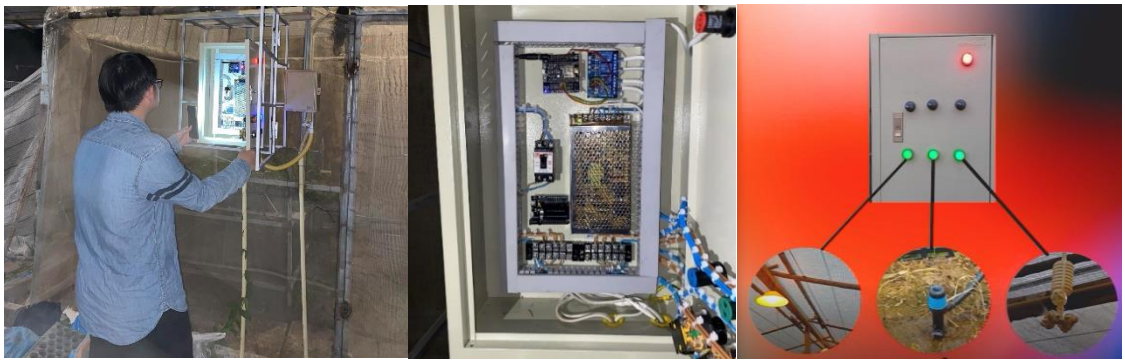


Figure 21: Results from the Development an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things.

Figure 21 shows the development of the Automatic Drip Irrigation System Using Internet of Things, resulting in a control box that plays a pivotal role in managing the system's operations. The control box comprises essential components, including an ESP8266 board for sensor control (measuring humidity and temperature), a solenoid valve for regulating water flow, a Water Flow Sensor module for monitoring the rate of water flow, and a Relay acting as a switch to control various electrical devices.

2. Evaluation results of Smart Irrigation Systems using Internet of Things

After five experts conducted tests on the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, the system's performance was evaluated across four dimensions, as shown in the following table.

Table 1: The results of the functional evaluation meet the needs of the user.

Evaluation list	Performance and Quality		
	$\bar{x}$	S.D.	Results
1. The system excels in its ability to control various aspects of plant cultivation, efficiently managing the operation of light tubes, drip irrigation, and a misting system in a responsive manner.	4.80	0.45	Very good
2. The system effectively employs rate limiting functionality, showcasing its ability to optimize and control water usage efficiently	4.60	0.55	Very Good
3. Line notification when water is not flowing	4.60	0.55	Very Good
4. Reporting of temperature, humidity, electricity consumption, and water consumption	4.80	0.45	Very Good
5. Fast and efficient control	4.80	0.45	Very Good
Overall Average	**4.72**	**0.49**	**Very good**

From Table 1 , the evaluation results indicate that the system's performance in meeting user requirements has an overall average rating of 4.72 with a standard deviation of 0.49 This shows that the developed system is very effective in meeting user needs.

Table 2: The results of the evaluation findings correspond with the features of the system.

Evaluation list	Performance and Quality		
	$\bar{x}$	S.D.	results
1. Accuracy of Data Storage	4.80	0.45	Very Good
2. Accuracy of Data Presentation	4.60	0.55	Very Good
3. Accuracy of Alerts	4.80	0.45	Very Good
Overall Average	**4.73**	**0.48**	**Very Good**

From Table 2 , the evaluation results indicate that the system's performance in fulfilling its designated functions has an overall average rating of 4.73 with a standard deviation of 0.48. This demonstrates that the developed system is very effective in performing its assigned tasks.

Table 3: The results of the evaluation on user-friendliness.

Evaluation list	Performance and Quality		
	$\bar{x}$	S.D.	Results
1. Appropriate Use of Text Colors	4.80	0.45	Very Good
2. Appropriate Use of Background Colors	4.80	0.45	Very Good
3. Effective Use of Descriptive Language on Screen	4.80	0.45	Very Good
4. Text Clarity on the Screen	4.60	0.89	Very Good
5. Overall System Layout Appropriateness	4.60	0.55	Very Good
6. User-Friendly System Development	4.80	0.45	Very Good
Overall Average	**4.73**	**0.54**	**Very Good**

From Table 3, the evaluation results indicate that the system's ease of use has an overall average rating of 4.73 with a standard deviation of 0.54. This shows that the developed system is very effective in terms of usability.

Table 4: The results of security aspects assessment of the electrical system.

Evaluation list	Performance and Quality		
	$\bar{x}$	S.D.	results
1. System Access Security	4.60	0.55	Very Good
2. Data Security within the System	4.80	0.45	Very Good
Overall Average	**4.70**	**0.50**	**Very Good**

From Table 4, the evaluation results indicate that the system's data security has an overall average rating of 4.70 with a standard deviation of 0.50. This shows that the developed system is very effective in terms of data security.

Table 5: Overall Evaluation of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things

Evaluation list	Performance and Quality		
	$\bar{x}$	S.D.	Results
1. The results of the functional evaluation meet the needs of the user	4.72	0.49	Very Good
2. The results of the evaluation findings correspond with the features of the system	4.73	0.48	Very Good
3. The results of the evaluation on user-friendliness	4.73	0.54	Very Good
4. The results of security aspects assessment of the electrical system	4.67	0.50	Very Good
Overall Average	**4.71**	**0.50**	**Very Good**

From Table 5, the evaluation results show that the overall average rating of the system is 4.71 with a standard deviation of 0.50, indicating that the developed system has a very high level of overall effectiveness.

3. Comparison of the Performance of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things with Commercially Available Irrigation Control Systems

The comparison results show that the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things has more functions than commercially available irrigation control systems, as follows: 1) A notification system via LINE alerts the user when there is no water flow in the system. 2) A system that automatically shuts down the water pump if there is no water flow. 3) The system allows setting the daily water application rate. 4) The system displays electricity costs. 5) The system can report daily water usage and water usage during the cultivation cycle for the following benefits: 5.1) To provide information on adequate daily water supply for the plants. 5.2) To provide data on water usage during the harvest cycle. 5.3) To support water management in the cultivation area.

4. The results of the training for demonstrating and transferring knowledge on the development of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things to a group of farmers.

Table 6: The results of the training for demonstrating and transferring knowledge from the developed system to farmers

Evaluation list	Performance and Quality		
	$\bar{x}$	S.D.	results
1. The relevance of the training topic	4.86	0.35	Very Good
2. The knowledge and ability of the trainer (knowledge transfer appearance/presentation style)	4.60	0.49	Very Good
3. The appropriateness of the content relative to the duration of the training	4.44	0.50	Good
4. The knowledge gained can be practically applied	4.76	0.43	Very Good
5. To what extent is the venue suitable for conducting the activity	4.43	0.50	Good
Overall Average	**4.61**	**0.45**	**Very Good**

From Table 6, the results of the training for demonstrating and knowledge transfer on the development of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things showed that overall satisfaction with the training was at a very high level, with an average rating of 4.61 and a standard deviation of 0.45 When considering individual aspects: The relevance of the training topic had an overall average rating of 4.86 with a standard deviation of 0.35, indicating a very high level, The applicability of the knowledge gained had an overall average rating of 4.76 with a standard deviation of 0.43, indicating a very high level, The knowledge and ability of the trainer had an overall average rating of 4.60 with a standard deviation of 0.49, indicating a very high level, The appropriateness of the content relative to the duration of the training had an overall average rating of 4.44 with a standard deviation of 0.50, indicating a high level, The suitability of the venue for conducting the activity had an overall average rating of 4.43 with a standard deviation of 0.50, indicating a very high level.

Discussion

The development of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things was carried out according to the five-step SDLC Model, which includes: 1) Problem study and system planning, 2) Analysis, 3) System design, 4) System development and testing, and 5) System evaluation. The performance of the automatic drip irrigation system was evaluated by experts, and the results showed that the system's overall performance is at the highest level. This is because the system can control the moisture in the cultivation area according to the settings in the web application. The system can store control data on a cloud database, which is an unstructured database, allowing for rapid control of

electrical devices. It also stores cultivation data in the cloud database at various times, and when the scheduled time arrives, the data is transferred to a relational database on a daily basis. The data stored in the relational database includes temperature, humidity, electricity usage rate, and daily water usage up to the harvest cycle. This information will later be analyzed and processed into information to be used in agricultural science and shared with farmers. Additionally, the system controls errors in case of no water flow through the developed web application, alerts users via LINE, and shuts down the water pump. This aligns with the research of Choeichom (2019) and Rungruangnattakul (2019), which studied guidelines for developing smart farming models and found that adopting a smart farming management model reduces labor and costs in the long term. It also aligns with the research of Fongnern et al. (2018) and Saetang et al. (2017), which focused on designing and developing temperature and humidity control systems suitable for mushroom growth. These studies identified issues with inconsistent mushroom yields due to temperature and humidity conditions, and that consistent mushroom production can be achieved with controlled temperature and humidity in the cultivation greenhouse.

Conclusion

1.The research on the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things can be summarized as follows:

The development of the irrigation control system using an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things, controlled by a NodeMCU ESP8266 microcontroller, which manages sensors to detect temperature, humidity, water flow rate, and water usage, as well as reports environmental data of the greenhouse and controls errors in case of no water flow through a developed web application, shows that the overall system efficiency is at the highest level

2. The comparison of the performance of the Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things with commercially available irrigation control systems found that the developed system offers more functionality as follows: 1) A notification system via LINE alerts users when there is no water flow in the system. 2) A system that automatically shuts down the water pump if there is no water flow. 3) The system allows setting the daily water application rate. 4) The system displays electricity costs. 5) The system can report daily water usage and water usage during the cultivation cycle for the following benefits: 5.1) To provide information on adequate daily water supply for the plants. 5.2) To provide data on water usage during the cultivation cycle. 5.3) To support water management in the cultivation area.

3. The results of the training demonstration and knowledge transfer on the development of an Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things show that the farmers' overall satisfaction with the training across all aspects is at a very high level.

Suggestion

The Automatic Adapted Drip Irrigation System for Tomato Plat Using Internet of Things cannot yet be used in cultivation areas without electrical access. If further development occurs, the system could be enhanced to include environmental control that works with solar power in conjunction with electricity. This would make the system suitable for cultivation areas based on their specific context

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