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SOLAR PHOTOVOLTAIC (PV) SYSTEM FOR SOIL MOISTURE LEVEL DETECTOR

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Abstract:

This paper is to aim in designing a system which is capable of detecting moisture level in the soil and capable of taking the decision of switching ON/OFF water pump in irrigation system. The microcontroller, Arduino forms the heart of the device for detecting the moisture in the soil and is programmed with the Arduino software. This project involves the development an automatic watering system that utilizes sensor that determines soil moisture level and water level designator additionally its pumping system that aims to distribute the needed water predicated on the assigned soil moisture value. The reading of the soil sensor is above 70%, the water pump will turn off, and when it is below 70%, the water pump will turn on until the soil sensor reading returns to normal. As a result of this project, the prototype successfully operated in line with the simulation. As the results at 1pm, 4th June 2024 with temperature 28°C, humidity is 73% the higher volume of water is 5.5ml with 5-minute water pumps was on. Next, the results for solar PV as main supply, the high output voltage is 14.8V at 2pm, 14th and 16th June 2024. As conclusion, this project has successfully achieved all the stated objectives and performs its desired functions, such as measuring humidity levels, temperature values, and soil moisture levels. This innovative system enhances plant care by providing users

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with real-time data and potential also ensuring optimal growing conditions and convenience for plant conditions.

Keywords:

Arduino, Soil Moisture Sensor, Solar Energy, Watering System

Introduction

Nowadays, solar energy has developed as a viable alternative for powering several industrial operations, including agricultural activities. Solar energy is plentiful, environmentally, not dangerous, and has the potential to drastically cut agricultural facility operating costs (Tasneem, 2019). The use of solar energy into fertilizer manufacturing is consistent with the agriculture sector's overall trend of adopting sustainable energy solutions (L. Pattison & J. Boisseau, 2010).

Agriculture is essential for fulfilling the demands of a growing global population by producing food, fibre, and bioenergy. Traditional agricultural practices, on the other hand, frequently result in excessive use of fertilizers, water, and energy, which can contribute to soil deterioration, water pollution, and increased greenhouse gas emissions. To addressing these difficulties, it requires a long-term plant growth control.

Therefore, the project will involve the deployment of solar panels to harness solar energy for both power generation and irrigation systems. Solar power is the most promising energy source due to its sustainability and ability to generate a large amount of energy (L.L. Hanna, 2019). This project is designed to utilize Arduino to manage the water flow of the water pump, as well as a soil moisture sensor to detect when to stop the water pump. By successfully developing and implementing a solar-powered application for monitoring and controlling plant growth, this project aims to revolutionize modern agriculture, making it more sustainable, efficient, and environmentally (S.A. Jumaat & M. H. Othman 2018). It serves as a model for precision agriculture practices and showcases the potential of renewable energy sources in transforming the agricultural industry.

The objectives of this project are to design a solar energy as a power supply to monitoring and controlling system for soil moisture level, to build a prototype that consist of the solar energy for the system and to evaluate a system that can detect the moisture level of soil.

Material and Method

In this part, it focuses on the material and method of the research. The aim is to focuses on how to create a model and design hardware for a system that monitors and controls soil moisture levels using solar panels. It will also explain the parts and software necessary for this project. These materials will be utilized to build a prototype of the project.

Theory of Solar Energy

Solar energy, harnessed from the sun's light, is considered a dependable and renewable power source as it consistently generates usable energy. This energy can be captured for various purposes like heating water or air in buildings or industries, and it can also be turned into electricity using photovoltaic cells (Shahid, 2023). In systems measuring soil moisture levels, this project just uses the solar electric energy. Usually, photovoltaic cells are utilized to convert

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sunlight into electricity. These cells use semiconductor components like silicon to capture solar energy and change it into electrical power. The electricity generated by photovoltaic cells can operate various components in the fertigation system, such as pumps and lights. Using solar electric energy in a fertigation system can be beneficial because it provides a clean and sustainable power source, potentially reducing the overall operational expenses (Ahsan & Hossan, 2015).

The energy carried by each sunlight particle (photon) changes based on its wavelength. A p-n junction is created by combining two distinct semiconductor materials, like silicon (Si) of n-type and p-type. As sunlight's photons hit a solar cell, they can either bounce off, pass through, or get taken in by the semiconductor material. When the semiconductor material absorbs photons, it contributes to generating electricity (Ramli & M. Mohamed, 2022). Figure 1 illustrates how the photovoltaic effect is used.

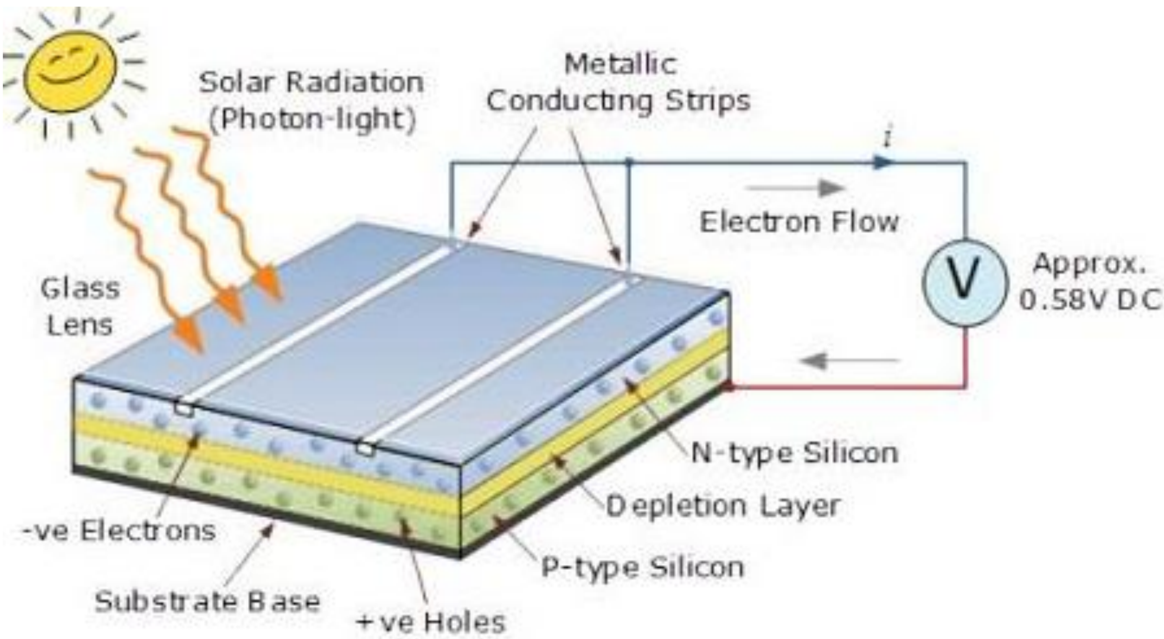

Figure 1: Application photovoltaic effect.

This happens because when the material absorbs a photon, it causes an electron, which has a negative charge, to be released from one of its atoms. During the design and manufacturing of solar cells, the front surface is intentionally made more sensitive to these released electrons so that they move toward the cell's surface. As these free electrons move towards the front surface, it creates an electrical charge difference between the front and back surfaces, resulting in the generation of voltage potential within the solar cell. Solar cells are connected to form a solar PV panel or module, and the size and capacity of the solar panel depend on the parameters of the solar cells and the number of cells used. By connecting solar PV modules electrically, a solar PV array is created. A PV cell generates direct current (DC) electricity, which can be used by devices that operate on DC power, or an inverter can convert it into alternating current (AC) electricity (Shahid M, 2023). The solar power system's size is an important factor to decide whether to install solar energy. The size of a solar power setup is calculated using the formula shown in Equation (1).

$$solar\ power\ system\ size\ = \frac{kWh\ per\ month}{hours\ per\ month} \tag{1}$$

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To apply the formula, you need to know the monthly kWh usage and divide it by the monthly sunlight hours. In Malaysia, the peak solar duration usually spans four hours, from 11 am to 3 pm. Using these data sets, one can estimate the required size of a solar power system. Apart from the system size, it's important to consider the efficiency of the solar panels because higher efficiency leads to more power output. The formula for solar panel efficiency is given as Equation (2). The efficiency can be used to predict the strategic location to get the maximum output power.

$$\text{Efficiency (\%)} = \frac{power\ panel\ (kW) panel\ length}{power\ panel\ (kW) panel\ length\ X\ panel\ width} \times 100\% \qquad (2)$$

Fertigation is the process of providing nourishment to plants by delivering a nutrient mixture with irrigation water through pipelines or sprinklers (R. Biswas *et al*, 2019). It is a modern agricultural technique extensively used in commercial agriculture and horticulture. However, effective fertigation is by default labour-intensive as it requires farmers to hire workers to seed the fertilizer. As a way forward, the project proposes an automatic fertigation water preparation system and has developed the necessary control system that is accessible via smartphone or tablet.

The Previous Research

(Saurabh Suman *et al*, 2019) focuses on developing a fully automated plant watering system. The primary aim is to conserve water while ensuring precise control over the amount of water plants receive. This is achieved through the utilization of solar panels to harness daytime energy, powering the system and charging batteries for nighttime operation. (Bimal Mahato *et al*, 2020) is centered around aiding farmers and gardeners in effectively managing soil moisture levels using solar energy, which offers a cost-effective and sustainable energy source once the initial setup is completed. The project employs a DHTI1 humidity sensor to continuously monitor and log moisture levels in the soil. An Arduino UNO functions as the central controller, facilitating irrigation only when necessary. They've integrated a system connected to GSM technology, enabling the transmission of results and actionable instructions to the farmer's mobile phone.

Next, (Ishtiak Ahmed Karim *et al*, 2019) focuses on developing a cost-effective Solar Charge Controller (SCC) using an ATmega8 microcontroller from Atmel Corporation for a 100 WP solar PV system. The study concluded that the designed SCC was both cost-effective and functional, making it suitable for commercial use to optimize energy utilization, particularly in rural areas. (Osaretin C.A. et al, 2021) presented the design and construction of a solar charge controller using mostly discrete components, aimed at varying its output to 12V for a 200Ah battery. The project focuses on creating a functional, durable, economical, and locally sourced controller.

(Kumar S. Santhosa *et al*, 2019) developed a system aims to reduce farmer effort, save time, energy, and costs by employing robotic technology to enhance agricultural efficiency. Objectives include developing a microcontroller-based Agribot that performs seeding, crop cutting, and furrowing at designated distances and depths, and operates using solar energy. (Yogesh R. Sonawane *et al*, 2020) describes a system for controlling and monitoring environmental parameters in a Polyhouse farm using internet-based technology, which can also integrate with mobile telephony. The system encompasses data acquisition through a sensor network, data storage, post-processing, and online data transmission to multiple users. Next,

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(Tanuj Manglani *et al*, 2022) presented a Smart Agriculture Monitoring System that utilizes Internet of Things (IoT) technology to boost agricultural productivity and efficiency. The system integrates sensors to monitor soil moisture, temperature, and humidity in real-time, with data sent to a central server for analysis and visualization, enabling informed decision-making for optimal crop management. (Matti Satish Kumar *et al*, 2020) presents a low-cost soil moisture sensor tested with various soil samples, achieving considerable accuracy. Soil moisture content, expressed as a ratio, indicates the amount of water in soil and is vital for irrigation management. Next, (Reno Muhammad Fadilla *et al*, 2021)proposes an IoT-based fertigation system powered by solar cells to simplify farmers' work. The system is divided into three parts: monitoring, solar power application, and fertigation. Next, (Roshahliza M. Ramli *et al*, 2022) proposed an automated system for mixing nutrient solutions to the required EC levels. This system, which includes a systematic fertilizer mixer, integrates both fertilization and irrigation processes and can be controlled via a smartphone or tablet. Lastly, (Md Zailani et al, 2021)construct the system enables farmers to monitor soil moisture levels that could otherwise result in undesirable consequences. It is possible for this system, which uses the Blynk application installed on smartphones, to check the soil condition at the plantation to determine whether the soil is dry or saturated with water.

The Process of the Project

The project's progression, including design, simulation, prototype development, and system integration, should be organized in a well-thought-out manner. The process of project is divided into four phases: project planning, project design and circuit simulation, development of hardware and documentation. The summary of methodology of project are tabulated in Table 1.

Table 1 : Summary of Methodology of Project

Phase	Activities
Phase 1: Project Planning	• Title selection • Identify problem statement, Objective and scope of the project • Literature review • Search previous article that related
Phase 2: Project Design and Circuit Simulation	• Create a 3D model design using Thinker Cad software • Plan circuit simulation design using Proteus 8 Pro • Write a coding using Arduino. • Test simulation using the embedded code.
Phase 3: Development of hardware	• Design a hardware. • Integrate coding with hardware. • Check if the hardware work as expected.
	• Record result, analysis and documentation

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Phase 4: Result, Analysis and Documentation	

The proses of system is to manage the moisture level for soil, and the FC-28 Soil Moisture Sensor detects the moisture level for soil. When FC-28 Soil Moisture Sensor detects that the moisture has below 70%, it sends a signal to Arduino and turn on the water pump. Finally, the data will be shown by Arduino and displayed on LCD display.

The solar power supply is made up of a 18 Watt polycrystalline photovoltaic (PV) solar panel and a solar charge controller that protects against overvoltage. The 12 V and 1.2 AH battery is rechargeable, sealed, and lead-acid in construction. The relay will be connected to DC water pumps, functioning to control the opening and closing of an electrical circuit's connections. The hardware must be tested to ensure it functions correctly and according to the plan. If any errors are found, they must be identified and corrected. Figure 2 displays the block diagram and components of the solar-powered system for monitoring and controlling plant growth.

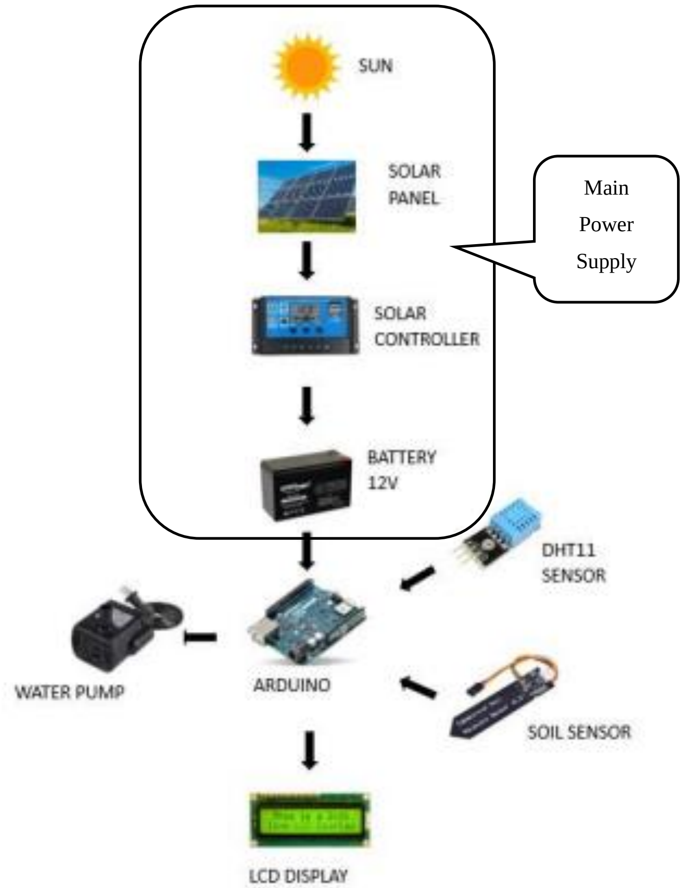

Figure 2 : Block Diagram Of The System

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In Figure 2, the solar panel generates electricity from sunlight, which is then regulated by the solar controller and stored in the 12V battery. The DHT11 sensor collects temperature and humidity data. The soil sensor monitors soil moisture levels. The Arduino processes the data received from the sensors. Based on the soil moisture data, the Arduino decides whether to activate the water pump. If the soil moisture is below a predefined threshold, the Arduino activates the water pump to irrigate the soil. The LCD display shows real-time data and system status for monitoring.

Result and Discussion

This section explains the design and evaluation of a 3D model for solar-powered system for monitoring and controlling plant growth. The 3D model was created using Tinkercad software. For the hardware development phase, the project's circuit connections need to be simulated using Proteus 8 Professional and Arduino IDE software.

3D Design of the System

To ensure the project's hardware design is realistic, it must be displayed in 3D. All major components were developed in 3D for this purpose. Figure 3 and 4shows the 3D model design.

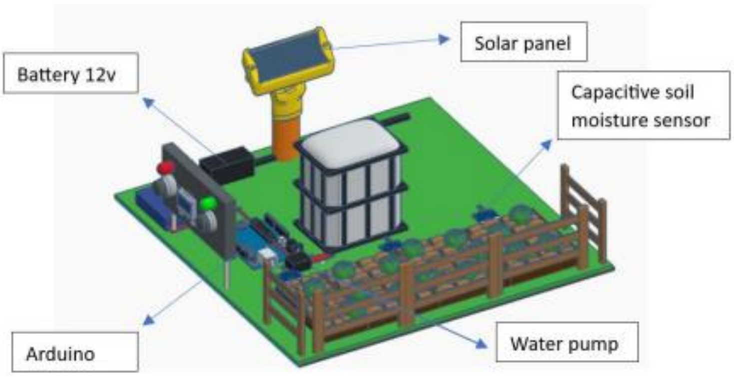

Figure 3 : Top View Of The Project Design

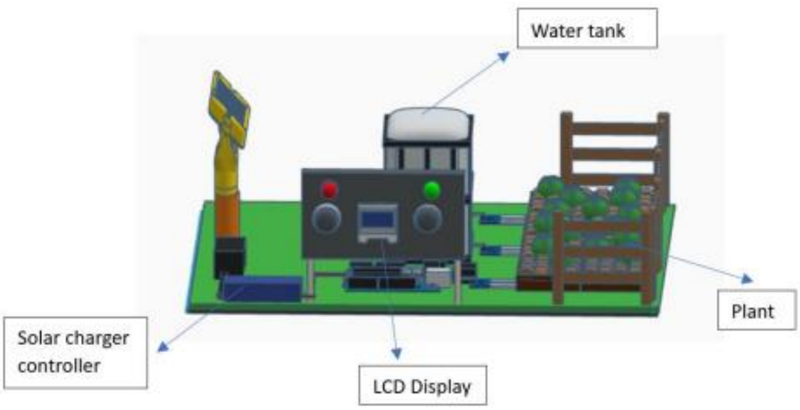

Figure 4 : Side View Of The Project Design

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Circuit Simulation

Figure 5 shows the sensor acts as a control (on and off) of the pump while the Arduino is the one which monitors the entire system. The sensor senses the moisture level of the soil and sends the appropriate signals to the Arduino where the Arduino will then transmit the signal from the sensor to the LCD screen to display the moisture condition of the soil. At the same time, the signal received from the moisture sensor will also trigger the water pump to turn on or off based on the condition of the soil.

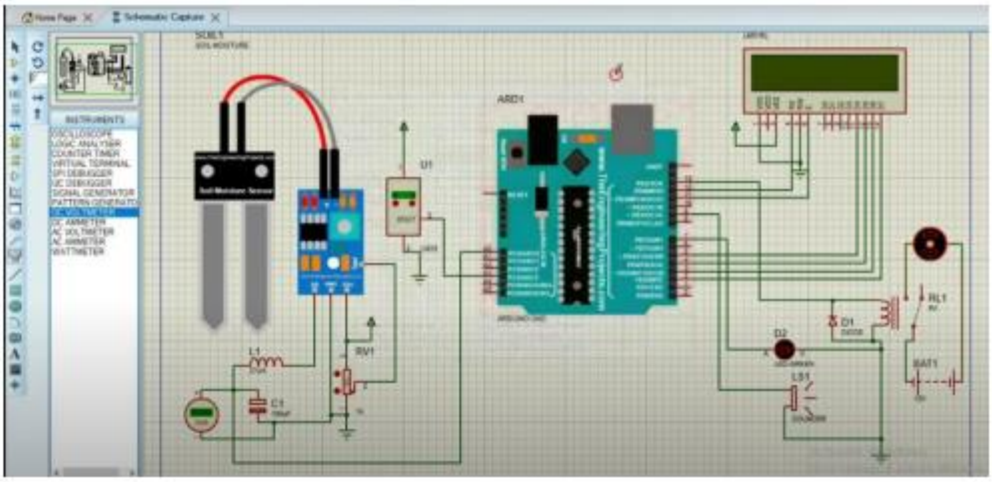

FIGURE. 5: COMPLETE CIRCUIT OF THE PROJECT

Figure 6 shows the simulation of the circuit when the average moisture level is set to 70%. The variable resistor value is decreases and when the value reach below than 70%, the water pump is ON

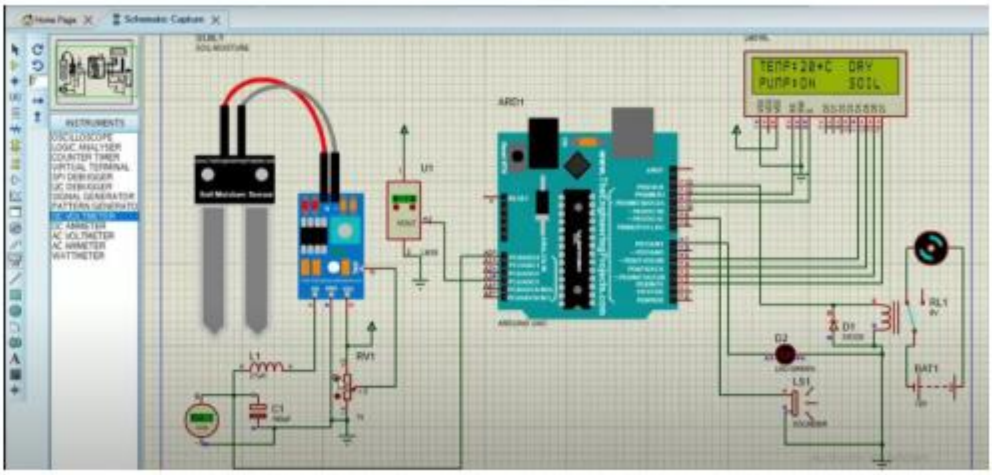

Figure 6: Simulation Of Circuit When Moisture Level Is Low

Figure 7 shows the water pump will ON until the moisture level of the soil reach 70%. After it reach the 70% moisture content, the water pump will automatically turn OFF.

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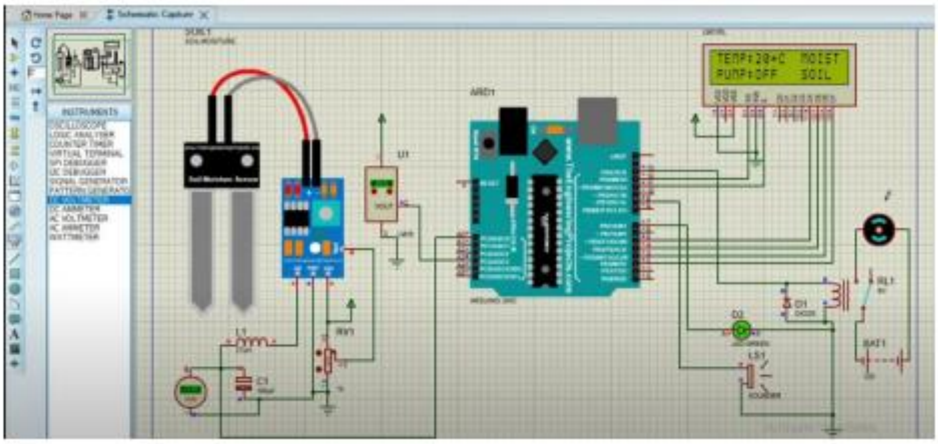

Figure 7: Simulation Of Circuit When Moisture Level Is High

Hardware Development

The hardware development for this project involves several key components. Primarily, the Arduino Mega board and a Liquid Crystal I2C display serve as the core elements of the system. The Arduino Mega is programmed with the necessary code to interface with each sensor used in the project. Secondly, the part of sensors will connect to Analog pin and Digital pin in Arduino Mega board. There are few sensors that are used in this project which are soil moisture sensor and DHT11 sensor.

This project centres around the Arduino Mega board and the Liquid Crystal I2C display. The Arduino Mega board, with its ample I/O pins and processing power, serves as the main controller for the system. It is responsible for reading data from various sensors, including a soil moisture sensor and a DHT11 temperature and humidity sensor, which are connected to its Analog and Digital pins respectively. The coding for these sensors is uploaded to the Arduino Mega, enabling it to process and manage sensor data efficiently.

Once the sensors are connected and the code is uploaded, the system can be operated by powering the Arduino Mega board. The Liquid Crystal I2C display, connected via the I2C protocol, provides a convenient way to visualize the sensor readings in real-time, making it easier to monitor environmental conditions. This setup ensures that the data collected by the sensors is easily accessible and can be used for further analysis or experiment tasks. Figure 8 shows the hardware development for this project.

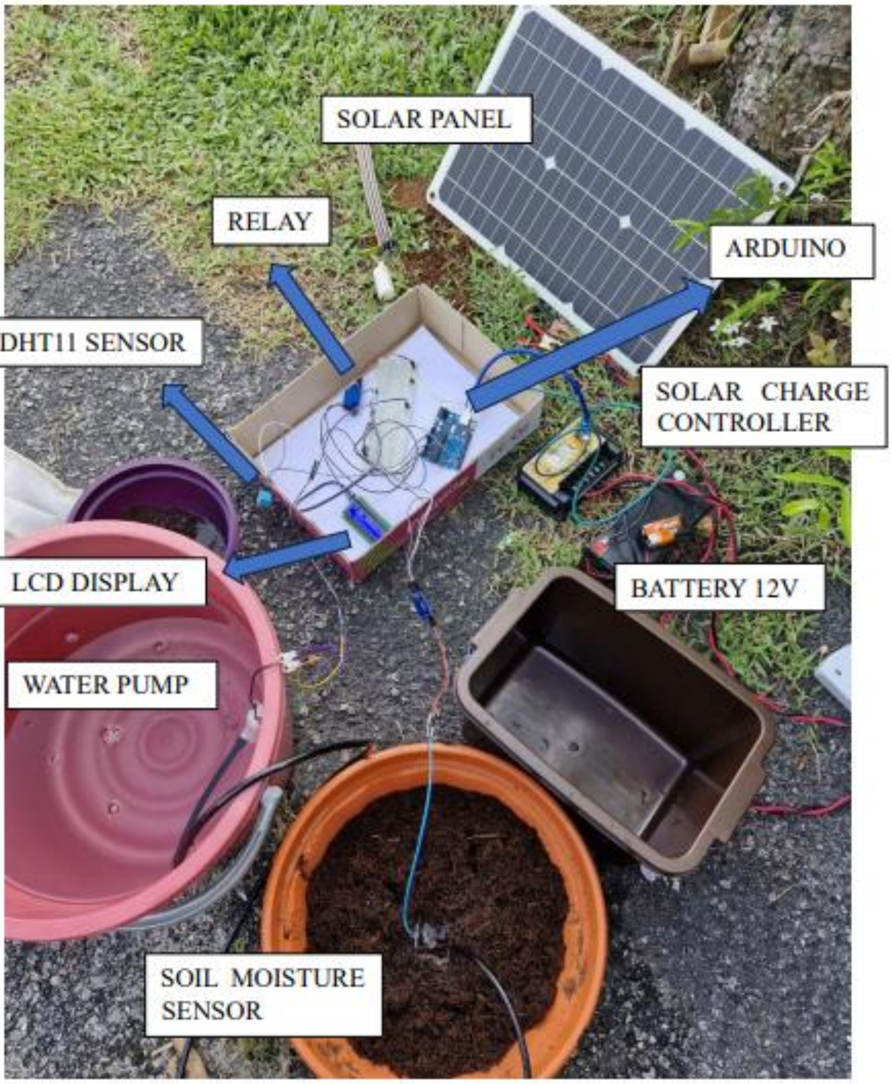

Figure 8: The prototype for PV Powered Monitoring and Controlling System for Soil Moisture Level

For this part, to test the circuit efficiency, the experiment will be done to get the data and study circuit efficiency. All the data that been gathered from the sensors will be recorded and to be tabulated in graph to make it easier. For this test, one type of plant will be used with the device. Data from the sensors will be collected from June 2nd to June 4th, 2024, starting at 8 am and ending at 4 pm in Parit Raja, Johor, Malaysia as the control variable for this test. Additionally, the voltage output data from a solar panel to a 12V battery has been recorded over three consecutive days, June 14th, 15th, and 16th, 2024.

Table 2 tabulate data on temperature (°C), humidity (%) and water volume required (ml),) at different times of the day over 2nd until 4th in June 2024. The data highlights how changes in temperature, humidity affect the water volume needed for maintaining soil moisture. During the testing day, the water pump is on because the moisture soil level below 70%. For instance, higher temperatures and lower humidity levels typically correspond to increased water requirements.

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Table. 2 : Overall Data From The Experimental Results

Date / Time	2/6/2024			3/6/2024			4/6/2024		
	Temp (ºC)	Humidity (%)	Water Volume (ml)	Temp (ºC)	Humidity (%)	Water Volume (ml)	Temp (ºC)	Humidity (%)	Water Volume (ml)
8am	25	92	5	24	93	5.5	25	93	4.3
9am	27	91	3	27	92	3	26	91	3.5
10am	28	89	3	29	90	4	28	88	3.5
11am	29.5	88	4	30	89	4	29	91	4.5
12pm	32	81	4.5	31	83	5	30	82	5
13pm	29	75	5	33	76	5	28	73	5.5
14pm	28	72	4	30	75	5	29	73	5
15pm	29	72	4	32	72	4.5	31	71	4
16pm	31	71	3	29	71	3.5	30	70	4

As temperature rises, water volume requirements increase due to higher evaporation rates, requiring more water to maintain soil moisture. For instance, at 12 pm on June 2, 2024, the temperature peaked at 32°C, and the required water volume was 4.5 ml. Similarly, lower humidity levels accelerate evaporation, increasing water needs. On the same date and time, humidity was at its lowest at 81%, with a water volume requirement of 4.5 ml.

The main supply for the system is using solar energy from PV panel as shown in Figure 2. Based on, the Table 3 tabulate readings of the voltage output from a solar panel to a 12V battery, recorded hourly from 8 am until 4 pm over three consecutive days: 14th, 15th and 16th June 2024. This data helps in understanding the solar panel's performance and its ability to charge the battery throughout the day.

Table. 3 – Reading Of Voltage Output From The Solar Panel 18W to the 12V Battery.

Date / Time	14/6/2024 (V)	15/6/2024 (V)	16/6/2024 (V)
8am	10.5	10.7	10.4
9am	12.0	12.2	12.0
10am	12.8	12.8	12.7
11am	13.5	13.5	13.3
12pm	14.0	14.0	14.0
13pm	14.5	14.4	14.5
14pm	14.8	14.7	14.8
15pm	14.3	14.5	14.0
16pm	13.5	13.7	13.6

Based on the Table 2, this project can conclude that the voltage output data from the solar panel indicates a typical daily pattern of increasing voltage from morning to midday, followed by a gradual decline in the afternoon. These readings are crucial for understanding the charging efficiency of the solar panel and optimizing the use of solar energy to maintain the charge of

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the 12V battery in the fertigation system. The consistent midday peak voltage suggests that the solar panel is performing well under clear weather conditions.

Conclusion

Overall, it can be confidently said that the objectives of this project have been achieved upon its completion. A smart monitoring and controlling system have been successfully developed, allowing users to monitor real-time data including humidity level, temperature value, and soil moisture level of their plants. When the soil moisture value falls outside the desirable range of 70%, the system can automatically turn on the water pump, addressing water deficiencies effectively.

Furthermore, the development of a PV-powered monitoring and controlling system for soil moisture levels involves a systematic approach using advanced design and simulation tools such as Thinker CAD, Proteus 8 Professional, and Arduino IDE. The successful construction of a solar-powered prototype demonstrates the practical application of renewable energy in agriculture. The evaluation process ensures that the system is accurate, responsive, energy efficient, and durable, creating the way for sustainable and efficient agricultural practices. This project highlights the potential of integrating solar energy with smart agricultural technologies to enhance crop management and water conservation.

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