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Development of a solar-powered system for soil monitoring with an automated irrigation feature

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Abstract

This study focuses on the development of a solar-powered system with an automated irrigation feature for soil monitoring. The project aims to design and develop a solar-powered system with at least 2 days of autonomy that integrates soil monitoring, irrigation, and solar management functions using a microcontroller-based platform. The system comprises essential components such as a humidity sensor for measuring atmospheric water content and a soil moisture sensor for evaluating soil moisture levels. These sensors are meticulously calibrated to ensure accurate assessment of soil conditions. To maintain uninterrupted timekeeping, a real-time clock is implemented, even during power outages. The system utilizes an Arduino microcontroller as the central hub for implementing a programmed algorithm. During specific time intervals (6:00 am - 6:30 am, 12:00 pm - 12:30 pm, and 6:00 pm - 6:30 pm), the system actively monitors soil moisture and humidity levels. When either of these levels drops below a predefined threshold, the algorithm triggers a relay module to establish a connection between the microcontroller and water pumps. Controlled by the microcontroller, the water pumps deliver water to the plants until the desired moisture level is reached, after which they automatically turn off. By combining solar power, soil monitoring, and automated irrigation, this technology represents a significant advancement in promoting efficient and eco-friendly farming practices. Its primary objectives include optimizing crop yield, conserving water resources, addressing challenges associated with conventional methods, and contributing to a more sustainable future.

Keywords: Photovoltaic; Microcontroller; Soil Moisture Sensor; Temperature; Real-Time Clock

1. Introduction

Solar energy is increasingly employed across various applications. Among the most suitable and straightforward uses of photovoltaic electricity is the utilization of solar panels or PV systems for water pumping and irrigation purposes. Photovoltaic technology utilizes solar cells to convert sunlight into direct current (D.C.) electricity. Currently, solar-powered water pumping systems are widely adopted for crop irrigation in agricultural settings. This system offers significant advantages by enhancing simplicity and reducing overall costs. It is a reliable and cost-effective solution that can increase agricultural productivity. Additionally, PV systems prove to be highly economical for supplying electricity in locations such as agricultural fields. Furthermore, traditional irrigation systems consume a substantial amount of water and energy[1].

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To overcome these challenges, there is a growing need for new farming technologies that can save resources, cut costs, and increase crop production. Solar-powered systems have emerged as a practical and sustainable solution for various agricultural tasks, like monitoring soil conditions and providing water for plants. This project will focus on the development of a solar-powered system designed for monitoring soil and automatically watering plants. By using solar energy to power the monitoring and irrigation devices, the system becomes cost-effective and environmentally friendly[2].

The project will provide an overview of the system's design, explaining its different parts and how they work together. It will also discuss the potential benefits of the system, such as less water consumption, and lower operational expenses. Finally, the report will present the results of testing and evaluation, demonstrating how the system effectively improves agricultural productivity and sustainability.

1.1. Problem statement

Farmers who do not adopt solar systems and automatic irrigation face multiple challenges in their agricultural practices. These include high energy costs, limited access to electricity in remote areas, environmental impact from non-renewable energy sources, water inefficiency, labor intensiveness, dependence on weather patterns for irrigation scheduling, and limited control and precision in delivering water to crops. These challenges result in increased operational expenses, environmental harm, inefficient water usage, labor limitations, and reduced control over irrigation processes. To this end, the present project seeks to develop a solar system and automated irrigation system that can mitigate these challenges, offering cost savings, environmental sustainability, efficient water usage, labor optimization, and improved crop productivity.

1.2. Aim and objectives of the research

The aim of this research is to develop a solar-powered system for soil monitoring with automated irrigation feature, which can be used in agriculture to optimize crop yield, conserve water, and reduce energy costs.

The study aims to achieve the following objectives:

- To design and develop a solar-powered system with at least 3 days of autonomy.
- To develop a microcontroller-based system that integrates soil monitoring, irrigation, and solar management functions.
- To design and develop a solar-powered system for soil monitoring with an automated irrigation feature that is suitable for use in small to medium-sized farms.
- To incorporate real-time sensor technology to enable the system to monitor soil moisture levels, temperature, and humidity accurately.
- To implement a soil moisture monitoring mechanism that triggers automated irrigation when required, optimizing water usage and crop yields.

2. Review of related literature

This project focuses on an automatic irrigation system. As stated in the introduction, Agriculture plays a crucial role in sustaining the world's population, but it also faces significant challenges such as the over-reliance on chemical fertilizers and pesticides that harm the environment, unpredictable weather patterns that reduce crop yields, and the high cost of energy for irrigation. These challenges require innovative solutions that are sustainable and cost-effective. A solar-powered system for soil monitoring with an automated irrigation feature could provide such a solution. This literature review aims to explore the current state of research on solar-powered soil monitoring and automated irrigation systems, highlighting their potential benefits and limitations.

2.1. Solar-Powered Systems for Soil Monitoring

Solar-powered systems have been developed to monitor soil moisture, temperature, and humidity. These systems typically use sensors to measure the moisture content of the soil and transmit the data wirelessly to a central location for analysis. Solar panels provide the energy required to power the sensors and transmit data, making these systems energy-efficient and sustainable.

Several studies have demonstrated the effectiveness of solar-powered soil monitoring systems and its benefits to the climate, economy, and human’s everyday life at large. A study [3] Solar Powered Irrigation System (SPIS) shows that, there are multiple opportunities for PV technology due to the need for energy, the availability of renewable resources, and falling costs of renewable energy technologies worldwide. While the employment of photovoltaic solutions for on-grid and off-grid electrification is quite common, the exploitation of PV-based water abstraction and conveyance technology options in the irrigation sector is still relatively rare.

Fossil energy sources that power most water pumps used for irrigation purposes are limited in availability and have severe impacts on the global climate. Therefore, there is a significant potential to introduce PV technology in irrigated agriculture to a much larger extent, especially in developing countries like Nigeria where electricity supply tends to be insufficient and unreliable, if not unavailable in rural areas. To make photovoltaic water pumping in irrigation an attractive alternative for farmers, it is promoted by subsidizing the technology. One major limitation is the narrow daily operational window of solar-powered pumps, which is up to 60% narrower than pumps driven by conventional energy sources. This limitation can be countered by introducing modern, water-saving micro-irrigation approaches[2].

2.2. Automated Irrigation Systems

Automated irrigation systems use sensors to monitor soil moisture levels and trigger irrigation when necessary. These systems can be programmed to water crops at specific times, reducing water wastage and optimizing crop yields. Automated irrigation systems have been found to be more efficient than manual irrigation methods and can save farmers valuable time and resources.

For example, research by Chigozie O. et al[4]. developed an automated irrigation system that used real-time soil moisture data to control irrigation. The system achieved a high irrigation efficiency of 80%, reducing water usage by 40% compared to manual irrigation. Several studies other have demonstrated the effectiveness of automated irrigation systems.

2.3. Solar-Powered Automated Irrigation Systems

Solar-powered automated irrigation systems combine solar-powered soil monitoring and automated irrigation features. These systems use solar panels to power the sensors and irrigation systems, making them energy-efficient and sustainable[5].

Automated irrigation systems use sensors to monitor soil moisture levels and adjust irrigation schedules accordingly. The use of automated irrigation systems can reduce water usage and optimize crop yields. According to a[6], automated irrigation systems can increase crop yields by up to 25% compared to traditional irrigation methods. However, the high cost of these systems can be a barrier to their adoption by small farmers.

In conclusion, the literature review indicates that solar-powered systems for soil monitoring and automated irrigation can provide a sustainable and cost-effective solution for the challenges facing the agricultural sector. These systems have been demonstrated to be effective in optimizing crop yields, reducing water usage, and promoting sustainability. The development of a solar-powered system for soil monitoring with an automated irrigation feature can make a significant contribution to sustainable agriculture and promote food security for future generations. The integration of soil moisture sensors and automated irrigation systems can further improve the sustainability and cost-effectiveness of these systems. Future research should focus on the development of more advanced solar-powered systems that can be implemented on a larger scale.

3. Review of system hardware and software

The design procedure involves determining the appropriate materials and components to be used in the circuit as well as their properties, which includes components values, voltage ratings and maximum current ratings. These could be actualized easily by consulting the data sheet provided by component's manufacturer. The analysis of each unit will be conducted in detail, for example, the value of capacitor in the power supply can only be determined by mathematical analysis where a formula is used and some important parameters such as total load current and frequency of mains voltage are used to calculate for the capacitance.

3.1. Block Diagram of the System

The block diagram shows the hardware used in the project which includes the Arduino Uno, Humidity sensor, real-time clock module, soil moisture sensor, DC pump, Solar Charge Controller (SCC), Solar Photovoltaic (PV) Panel and battery bank. as shown in figure 1 below.

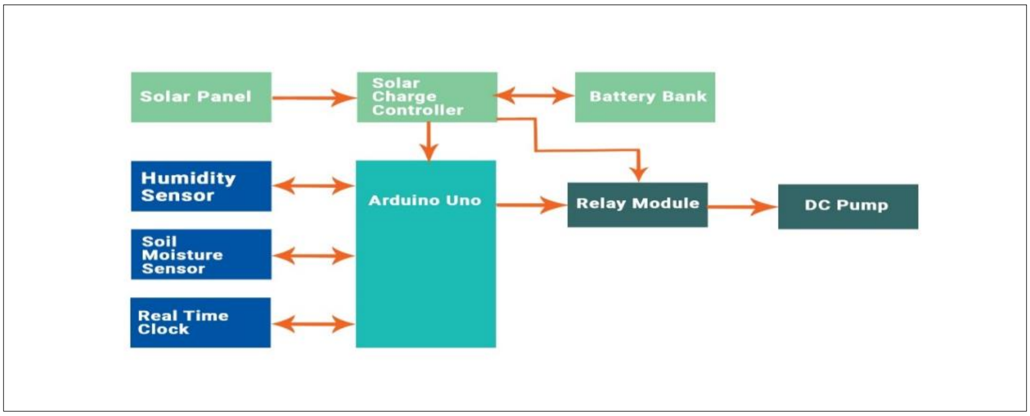

Figure 1 Block Diagram of the System

3.1.1. Block Diagram Description

Figure 1 illustrates the primary components employed in this project. The humidity sensor is utilized to quantify the atmospheric water content, while the soil moisture sensor is employed to assess the moisture levels in the soil. The Real Time Clock ensures uninterrupted timekeeping, even during power outages. These sensors are carefully calibrated to function harmoniously, delivering an optimized evaluation of the soil conditions. The system operates based on a meticulously programmed algorithm, which will be elucidated subsequently through the aid of a flow chart. The algorithm is implemented within the Arduino microcontroller, which serves as the central hub connecting all sensors.

Although the Arduino UNO microcontroller controls the water pumps in this project, it cannot directly activate the pumps. To bridge this gap, a relay module is utilized to establish a connection between the microcontroller and the water pumps. The moisture sensor gauges the soil's moisture level, while the humidity sensor measures the water content in the air, promptly signalling the microcontroller when watering is necessary. The water pump dispenses water to the plants until the desired moisture level is attained. The entire system is designed to operate on solar power, enabling its usage in remote regions lacking access to electricity. This environmentally friendly approach indirectly contributes to mitigating global warming, making the system an ideal "fit and forget" solution.

3.2. Arduino Uno Microcontroller

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.[7].

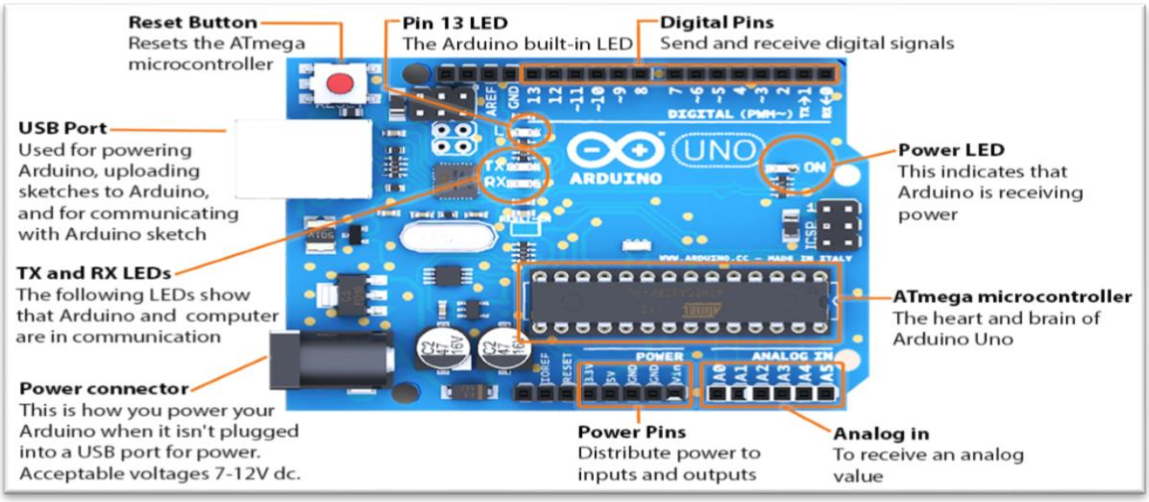

Figure 2 Arduino hardware

The Arduino hardware and software was designed for artists, designers, hobbyists, hackers, newbies, and anyone interested in creating interactive objects or environments. Arduino can interact with buttons, LEDs, motors, speakers, GPS units, cameras, the internet, and even your smart-phone or your TV! This flexibility combined with the fact that the Arduino software is free, the hardware boards are pretty cheap, and both the software and hardware are easy to learn has led to a large community of users who have contributed code and released instructions for a huge variety of Arduino-based projects[8], [9].

3.3. Soil Moisture Sensor

This module serves the purpose of detecting soil moisture. It determines the amount of water present in the soil by measuring the volumetric content of water. The output provided by this module indicates the level of moisture. The moisture sensor is comprised of two probes which are responsible for detecting soil moisture. These probes are coated with immersion gold to protect Nickel from oxidation. The probes enable the flow of current through the soil to the LM393 comparator IC. The sensor then reads the resistance to obtain the moisture values. The Moisture sensor module includes a Moisture sensor, Resistors, Capacitor, Potentiometer, Comparator (LM393 IC), Power, and Status LED. Refer to figure 2 below for an illustration of the integrated circuit setup.

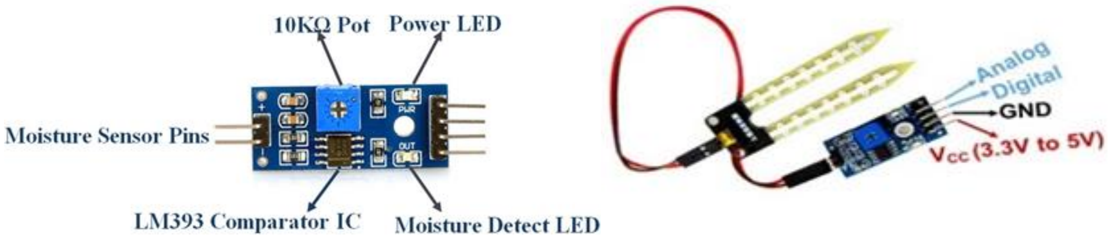

Figure 3 Soil Moisture Sensor

The configuration of these pins can be observed in table 1 below, which also displays the voltage levels and specifications of the soil moisture sensor pins. It is worth noting that the soil moisture sensor possesses additional advantageous features, including affordability, compatibility with microcontrollers, portability, and widespread availability [14].

Table 1 Soil Moisture Sensor Pin Configuration

Pin Name	Description
VCC	The VCC pin powers the module, typically ranges from 3.3V to 5V with operating current of 15Ma
GND	Power Supply Ground
DO	Digital Out Pin for Digital Output. 0V to 5V, adjustable Trigger level from pre-set
AO	Analog Out Pin for Analog Output

3.4. Real-Time Clock (DS3231)

The DS3231 is an affordable real-time clock (RTC) that operates over the I2C protocol and offers exceptional accuracy. It incorporates a temperature-compensated crystal oscillator (TCXO) and crystal, ensuring precise timekeeping. The device includes a battery input, allowing it to maintain accurate time even during interruptions in the main power supply. By integrating the crystal resonator, the DS3231 enhances long-term accuracy and simplifies the manufacturing process by reducing the number of individual components required.

The RTC provides comprehensive timekeeping information, including seconds, minutes, hours, day, date, month, and year. It automatically adjusts the date for months with fewer than 31 days and accounts for leap years. The clock can be configured to operate in either 24-hour or 12-hour format, complete with an AM/PM indicator. It also offers two programmable time-of-day alarms and a programmable square-wave output. Communication with the device occurs through a bidirectional I2C bus, where address and data are transferred serially.To enhance functionality, the DS3231 incorporates a precision temperature-compensated voltage reference and comparator circuit. This circuit monitors the

VCC status to detect power failures, provide a reset output, and automatically switch to the backup power supply when necessary. Additionally, the RST pin can be used as a pushbutton input for external reset generation. For a visual representation of the RTC module (DS3231), please refer to figure 4 below.

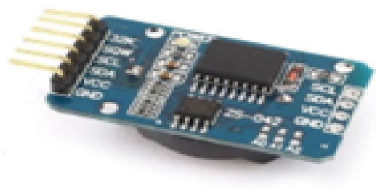

Figure 4 RTC Module

3.5. RTC Technical Specification

The following are some of the specifications and features of RCT module:

VCC = 2.3V to 5.5V

Voltage Range on Any Pin Relative to Ground -0.3V to +6.0V

Operating Temperature Range DS3231S 0°C to +70°C

3.6. Humidity Sensor (DHT22)

The humidity sensor is a device that detects and measures the moisture content in air or gas mixtures. It is used in various applications such as monitoring industrial and agricultural products, as well as in equipment like incubators, sterilizers, and pharmaceutical processing equipment[10].

There are different types of humidity sensors available, including capacitive, resistive, semiconductor, optical, and surface acoustic wave sensors. Capacitive sensors have advantages such as low power consumption, good linearity, and wide range of humidity detection, but they require a complicated fabrication process. On the other hand, resistive sensors are easier to fabricate and offer high sensitivity, low cost, and low power consumption. Materials commonly used for humidity sensor fabrication include metal oxides, polymers, and carbon-based materials. However, metal oxide sensors degrade in humid environments, and polymers have poor stability in highly humid conditions. Slow response and recovery times, as well as high operating temperatures, are ongoing design challenges for these sensors[11], [12].

3.7. Software Design

The software design phase of the project encompasses flowchart creation, programming, and coding. Rather than simply typing instructions, a professional programmer follows a program development cycle [2], which involves several key steps:

- Understanding the problem.
- Planning the logic.
- Coding the program.
- Utilizing software (compiler or interpreter) to translate the program into machine language.
- Testing the program.
- Implementing the program.
- Maintaining the program.

For this project, the problem has been properly understood, which involves designing a soil monitoring system that involves a soil moisture sensor, real time clock, and humidity sensor. Additionally, the system should be capable of being triggered at designated times. The next step in the project is to plan the logic that the program will follow. This will be elaborated in the upcoming section using a flowchart as a visual aid

4. Model experimental setup

To create a solar system for powering the irrigation system, it is essential to conduct a thorough evaluation of the system's power requirements. This entails analyzing the load and determining the appropriate size for the solar system. To be able to design an optimal soil monitoring system we needed to understand the best weather conditions to water the plant putting into account the temperature of the surrounding, the humidity and time of the day. The optimal temperature for plants varies depending on the specific plant species. Different plants have different temperature preferences for optimal growth and development. However, a general range for optimal plant growth is typically between 20 to 30 degrees Celsius (68 to 86 degrees Fahrenheit). Research studies have explored the effects of temperature on plant growth and development. For example, a study published in the journal "Foods" by Chowdhury, Milon Kiragain, et al in 2021, titled "Effects of temperature, relative humidity, and carbon dioxide concentration on growth and glucosinolate content of kale grown in a plant factory" examines the effects of temperature, relative humidity, and the carbon dioxide (CO2) concentration on kale growth and glucosinolate content in different growth stages of cultivation in a plant factory, the investigation reveals that the optimal temperature, relative humidity, and CO2 range for growth (20–23C, 85%, and 700–1000 ppm) and total glucosinolate content (14–17C, 55–75%, and 1300–1600 ppm) were different that. Furthermore, it is important to note the best time to water the plant[13]. The best time to water a plant is typically in the early morning or late afternoon. Watering during these times helps minimize water loss through evaporation and allows the plant to make the most efficient use of the water provided. However, it's important to consider the specific needs of the plant species and the environmental conditions in your region, as they can influence the optimal watering time. Additionally, factors such as soil type, plant size, and stage of growth also play a role in determining the watering schedule.

In this context, our system is designed to keep the temperature below 35 degrees Celsius and humidity below 85%. Should these thresholds be exceeded, the sprinkler pump will be automatically activated. As for the watering schedule, it will involve three intervals throughout the day.

4.1. Flow Chart of the System

Flowchart is a pictorial representation of the logic flow of the program, it helps to visualize more easily how the program statement will connect. The flow chat will show how the algorithm of the soil monitoring system works.

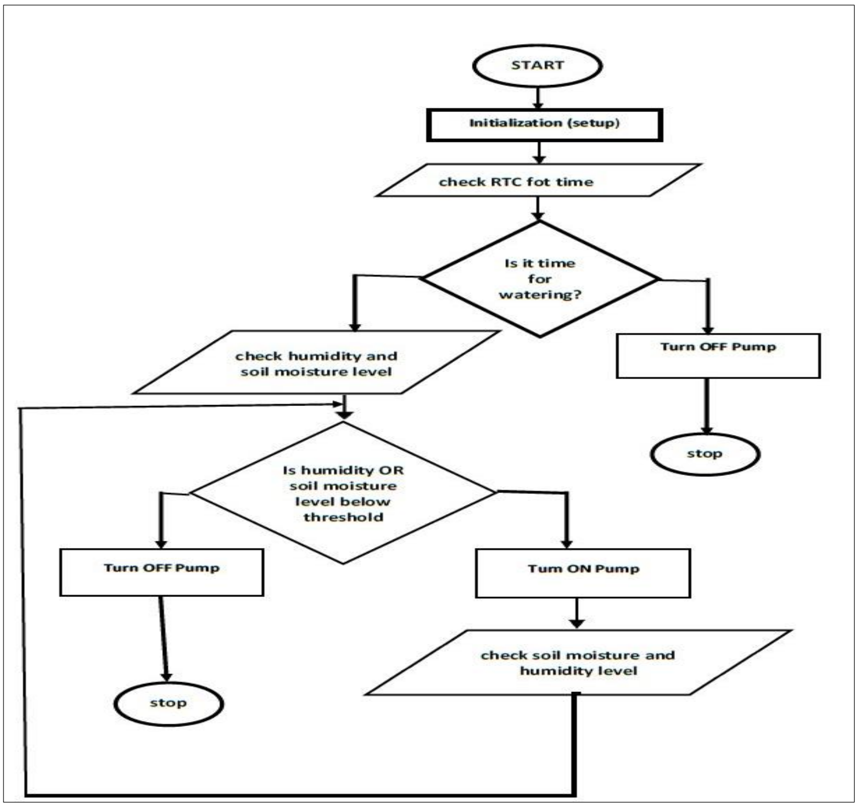

Figure 5 Flow chart of the system

To facilitate this process, Arduino provides an integrated development environment (IDE) based on the Processing language. For this project, the Arduino Integrated Development Environment (IDE) was utilized, as it encompasses a text editor, C compiler, debugger, built-in libraries, and programmer. The Arduino IDE was employed to perform steps three and four of the program development cycle, which involve coding the program and translating (compiling or interpreting) it into machine language.

The IDE consists of two main sections: void setup and void loop. The setup section executes once when the circuit is powered on, allowing the programmer to declare variables and set the pin mode as input or output. The loop section is where the main code and instructions are written, as it continuously repeats. Remarkably, the Arduino can translate and execute approximately 300,000 lines of C source code per second.

4.2. Hardware Design of the System

In this project, the circuit diagram utilized is depicted in Figure 9 below. The hardware design process entails designing the circuitry for each functional block within the system.

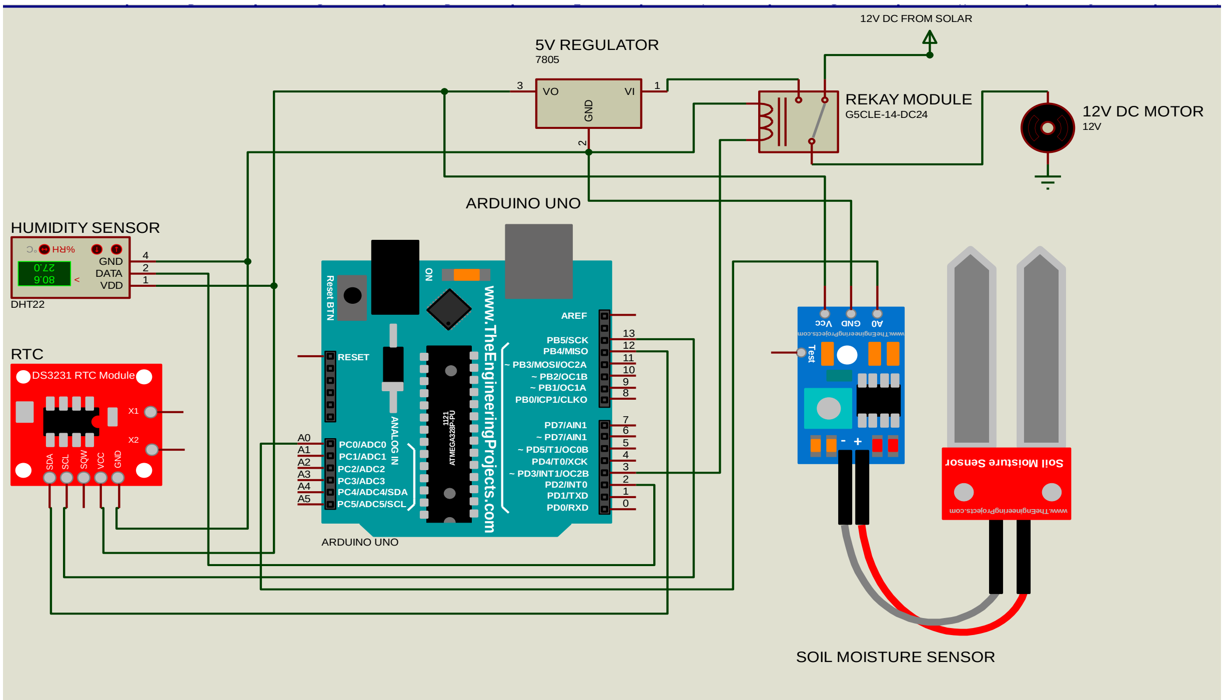

Figure 6 Circuit Diagram

4.2.1. Solar System Design

The process of determining the appropriate size for a photovoltaic power system is relatively straightforward. This section presents a six-step method for accurately sizing the system according to the user's projected requirements, objectives, and financial resources. The sizing process includes the following steps:

- Estimating the electricity demand
- Determining the suitable battery size and specifications
- Identifying the appropriate array size and specifications
- Specifying the controller for the system
- Determining the right size and specifications for the inverter
- Sizing the wiring required for the system.

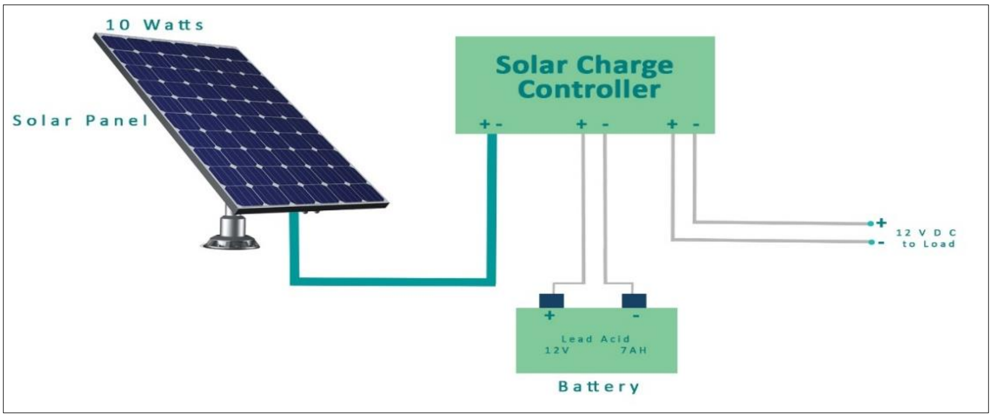

Figure 7 Solar system circuit diagram

It's important to note that this method is not specific to a particular product, but rather provides general specifications for the system. The 6 steps will subsequently be explained in the following paragraph.

4.3. Estimating the load demand

The various load voltage and current of the sensors and modules used for this project are calculated as shown in table 2 below:

Table 2 Cumulative load current and voltage

Loads	**Max current (*mA*)**	**Rated voltage**	**Hours of use per day**	**Power (W)**	**Days of autonomy**	**Energy (Wh)**
Arduino UNO microcontroller	200	5v	24	1	2	48
RTC (DS32131)	0.5	3V	24	0.0015	2	0.072
Soil Moisture Sensor	15	5V	3	0.075	2	0.45
Humidity sensor	2.5	5V	3	0.0125	2	0.075
Relay	70	5V	3	0.35	2	2.1
DC pump	350	12V	3	4.2	2	25.5
LED	50	5V	3	0.25	2	1.5
TOTAL				6Watts		77.697Wh

Table 2 presented above displays the aggregate load currents, voltage, power, and energy values for all components involved in this project. The total power consumed by the load is documented as 6 Watts. The system possesses a 2-day autonomy, implying its capability to operate for a continuous period of 2 days even in the absence of sunlight for recharging. Referring to the aforementioned Table 2, it is evident that the system's energy consumption over the span of 2 days amounts to 77.7 Watt-hours (Wh).

4.4. Battery sizing and specification

The process of battery sizing entails selecting the battery type (such as lithium-ion or lead-acid) and specifying its voltage rating, amper-hour capacity, depth of discharge, and efficiency. By employing these parameters and conducting mathematical analysis, it becomes possible to determine the energy output of the battery within a given day. In our case, the required ampere-hour (Ah) value for our system can be calculated by dividing the watt-hour (Wh) by the battery voltage.

Eb = 77.7Wh / 12V = 6.475Ah.

For this particular system, a 12V lead-acid battery with a capacity of 7.2 Ah will be utilized. Therefore,

Eb = Vb * Ah * DoD * Eff,

where: Eb represents the battery energy in watt-hours (Wh),

Ah denotes the ampere-hour rating of the battery (Ah),

DoD signifies the depth of discharge, and

Eff refers to the efficiency.

Based on industry standards, a lead-acid battery typically has a depth of discharge of 50% and an efficiency of 80%. Substituting these values into the equation, we have:

Eb = 12V * 7.2Ah * 0.5 * 0.8 = 34Wh

4.5. Solar system sizing

To initiate the sizing of the solar array, it is necessary to adjust the average daily load (in amp-hours) to accommodate the inefficiencies of the selected batteries and controller. This is done by dividing the average amp-hour per day load by the estimated battery energy efficiency, commonly taken as 0.8.

Battery Efficiency = 0.80

Average Load per day = 3.2 amp-hours

Average Peak Amperes = 3.2 / 0.8 = 4.05 amp-hours

Next, divide this value by the peak sun hours per day available. The resulting figure represents the array's peak amperage.

Peak Sun Hours per Day = 6 hours

Average Peak Amperes of Array = 4.05 / 6 = 0.67 amp-hours per day

At this stage, a specific PV module must be chosen to meet the system's requirements. A 10W solar panel with a rated voltage of 18V is selected.

4.6. Specifying the controller

The selection of the charge controller is based on the battery load and the short circuit current of the solar panel. The charge controller's rating should be equal to or greater than both the battery current and the panel's short circuit current.

To calculate the battery current, divide the battery bank's watt-hour capacity by the battery voltage:

Eb = 34Wh / 12V = 2.8A

Therefore, the charge controller should have a current rating above 3 amperes to adequately handle the system's requirements.

5. Result and discussion

The system is designed such that between 6:00 am – 6:30am, 12:00pm-12:30pm and 6:00pm-6:30pm the soil moisture sensor is activated to monitor the soil moisture level also, the humidity sensor is also monitoring the moisture level in the air. If the soil moisture level OR humidity level is below the set threshold value, the pump is activated by sending a signal to the relay.

5.1. Enclosure

The electrical enclosure was made from rigid plastics. The pictorial views of the enclosure used in this project is shown from various angle in the figure below.

Figure 8 The prototype of the project

5.2. Testing

Various tests were carries out after the construction of the project. The main objective of this testing was to determine the optimal voltage rating at the output of the charge controller and to identify the maximum current needed to power the entire system. The output power supply units of +5V and +12V underwent testing to measure their respective output voltages under both no-load and full-load conditions. During the no-load test, the voltage of the +5V supply section was measured at 4.95V, while the +12V supply section registered a voltage of 11.94V. Subsequently, under full-load conditions, the corresponding voltages were measured as 4.85V for the +5V supply and 11.83V for the +12V supply.

Software testing is a crucial process that aims to assess the performance of a software application or program. Its primary objective is to determine if the developed software adheres to the specified requirements and to uncover any defects, thereby ensuring a defect-free and high-quality product. Software testing is essential for identifying software bugs and verifying if the software aligns with its intended requirements. In this particular project, the software employed is the Arduino IDE, which is coded in the C# programming language. The system underwent testing utilizing an Arduino UNO development board, alongside other interconnected modules.

5.3. Summary

The solar-powered system for soil monitoring with an automated irrigation feature was successfully designed and developed as part of this project. Its primary objective was to optimize crop yield, conserve water, and reduce energy consumption in agriculture. The system incorporated solar panels to harness renewable energy, a microcontroller for data processing and control, and real-time sensors to monitor soil moisture levels and humidity.

During specific time intervals throughout the day, the system activated the soil moisture sensor and the humidity sensor to monitor the respective levels in the soil and air. If either the soil moisture level or humidity level fell below the predefined threshold value, the system triggered the water pump by sending a signal to the relay. This automated irrigation mechanism ensured that crops received adequate moisture when needed, optimizing water usage and promoting crop growth.

The solar-powered system provided a sustainable and cost-effective solution for farmers, reducing their reliance on conventional irrigation systems and fossil fuels. By utilizing solar energy and integrating real-time sensor technology, the system facilitated informed decision-making regarding irrigation schedules based on accurate data. It contributed to efficient water management, increased crop productivity, and decreased operational costs. The project's success demonstrated the potential of the developed system to enhance agricultural practices by promoting sustainability, conserving resources, and mitigating the environmental impact of conventional farming methods. The fit-and-forget nature of the system, coupled with its minimal maintenance requirements, offered farmers a user-friendly solution that saved valuable time and resources for other farming activities. Overall, the solar-powered system for soil monitoring with automated irrigation showcased its significance in advancing agricultural efficiency and ensuring food security for future generations.

6. Conclusion

In conclusion, the development of a solar-powered system for soil monitoring with automated irrigation been designed successfully and tested to function automatically. Since this system have been proven to work satisfactory, the aims and objective of this project have been achieved. This project presents a significant solution for the challenges faced by the agricultural industry. By integrating real-time sensors, the system enables precise monitoring of soil moisture and humidity levels, allowing farmers to make informed irrigation decisions. Furthermore, this project can be used to improved standard of living, give our crops healthier live, make our environment greener and also serve as a means of income if the project designer decides to commercialize it.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Reference

[1] E. Said Mohamed, A. A. Belal, S. Kotb Abd-Elmabod, M. A. El-Shirbeny, A. Gad, and M. B. Zahran, "Smart farming for improving agricultural management," *Egypt. J. Remote Sens. Sp. Sci.*, vol. 24, no. 3, pp. 971–981, 2021, doi: 10.1016/j.ejrs.2021.08.007.

[2] A. Waleed, M. T. Riaz, M. F. Muneer, M. A. Ahmad, and A. Mughal, "Solar (PV) Water Irrigation System with Wireless Control," no. November, 2019, doi: 10.1109/RAEE.2019.8886970.

[3] E. A. B. Pandya, "Solar Powered Irrigation Systems (SPIS)," *Irrig. Drain.*, vol. 68, no. 2, pp. 379–380, 2019, doi: 10.1002/ird.2348.

[4] C. Onyema, S. Wasinya Pallam, and A. Abioye, "The Design and Construction of a Water Fountain with Water Level Monitoring and Automatic Sprinkler System with Ground Moisture Sensor and Real-Time Clock," vol. 1, no. 1, pp. 1–15, 2022.

[5] A. I. Abdelkerim, M. M. R. S. Eusuf, M. J. E. Salami, A. Aibinu, and M. A. Eusuf, "Development of solar powered irrigation system," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 53, no. 1, 2013, doi: 10.1088/1757-899X/53/1/012005.

[6] M. A. Afolayan, O. Ibrahim, and A. T. Ibukunoluwa, "Design and construction of a solar-powered automatic irrigation system with IoT support," *J. Sci. Tech. Educ.*, vol. 8, no. 1, pp. 259–268, 2020.

[7] "What is Arduino? | Arduino Documentation." https://docs.arduino.cc/learn/starting-guide/whats-arduino (accessed May 29, 2023).

[8] "What is an Arduino? - SparkFun Learn." https://learn.sparkfun.com/tutorials/what-is-an-arduino/all (accessed May 29, 2023).

[9] "Arduino Integrated Development Environment (IDE) v1 | Arduino Documentation." https://docs.arduino.cc/software/ide-v1/tutorials/arduino-ide-v1-basics (accessed May 29, 2023).

[10] "Humidity Sensor Basics | Types, Parameters, Applications, Projects." https://www.electronicsforu.com/tech-zone/electronics-components/humidity-sensor-basic-usage-parameter (accessed Jun. 02, 2023).

[11] P. V. Shinde, M. Saxena, and M. K. Singh, "Recent developments in graphene-based two-dimensional heterostructures for sensing applications," *Fundam. Sens. Appl. 2D Mater.*, pp. 407–436, Jan. 2019, doi: 10.1016/B978-0-08-102577-2.00011-7.

[12] "Humidity Sensor - an overview | ScienceDirect Topics." https://www.sciencedirect.com/topics/materials-science/humidity-sensor (accessed Jun. 02, 2023).

[13] M. Chowdhury *et al.*, "Effects of temperature, relative humidity, and carbon dioxide concentration on growth and glucosinolate content of kale grown in a plant factory," *Foods*, vol. 10, no. 7, 2021, doi: 10.3390/foods10071524.