iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: V Month of publication: May 2023

DOI: https://doi.org/10.22214/ijraset.2023.52429

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

Smart Sprinkler System

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Abstract: The research paper provides a comprehensive overview of the system's design, which includes selecting appropriate solar panels and DC motors. The paper describes the mounting structure's design and construction, which was designed to ensure the system's stability and durability. The paper also discusses the integration of the soil moisture sensors, which are essential for the system's optimal performance. The sensors were calibrated to ensure accurate measurements of the soil's moisture content. The system uses solar panels to generate electricity, with a DC motor rotating the sprinkler according to the sun's direction, ensuring optimal energy efficiency. The system's control unit integrates soil moisture sensors, which measure the moisture content of the soil and activate or deactivate the sprinkler accordingly. The research paper includes the results of the system's performance evaluation under various environmental conditions. The system's energy efficiency was found to be optimal, with the solar panels generating sufficient power to operate the sprinkler and the DC motor rotating the sprinkler efficiently. The soil moisture sensors were also found to be highly accurate, ensuring that the sprinkler was activated or deactivated based on the soil's moisture content. The system's performance evaluation also demonstrated that it can reduce water usage by up to 70%, making it an effective solution for water conservation in agriculture.
Keywords: Solar energy, Sprinkler, Motor, Electricity, Water, Moisture sensor

I. INTRODUCTION

Agriculture is a critical sector that sustains human life by providing food, fiber, and other essential commodities. However, agriculture is also a resource-intensive activity that consumes a significant amount of water, energy, and other natural resources. With the global population projected to reach 9.7 billion by 2050, the demand for food is expected to increase by 70%, putting more pressure on farmers to produce more food with limited resources. In this context, smart agriculture is emerging as a viable solution to meet this challenge by utilizing advanced technologies to enhance the efficiency, productivity, and sustainability of farming practices.

One of the key technologies driving smart agriculture is smart sprinkler systems. These systems use various sensors, data analytics, and machine learning algorithms to optimize water usage and improve crop yield and quality. Smart sprinkler systems have several advantages over traditional irrigation systems, including precision watering, real-time monitoring, and automated controls. In this research paper, we will explore the potential of smart sprinkler systems in agriculture and discuss their benefits and challenges. We will also review the current state of the art in this field and propose a framework for designing and implementing smart sprinkler systems in agriculture.

Smart Sprinkler Systems in Agriculture: Smart sprinkler systems are irrigation systems that use sensors to collect data on soil moisture, temperature, humidity, and other environmental factors. This data is then analyzed by machine learning algorithms to optimize watering schedules and amounts based on the needs of the crops. Smart sprinkler systems can also be equipped with other features such as real-time monitoring, remote controls, and weather forecasts to further improve their efficiency and accuracy. The benefits of smart sprinkler systems in agriculture are manifold. First and foremost, they help to conserve water by using it more efficiently. According to some estimates, up to 50% of the water used in traditional irrigation systems is wasted due to overwatering, evaporation, or runoff. Smart sprinkler systems can reduce water consumption by up to 30% by precisely targeting the water to the crops that need it. This not only conserves water but also reduces the energy needed to pump and distribute it.

Second, smart sprinkler systems can improve crop yields and quality by ensuring that the plants receive the right amount of water at the right time. Overwatering or underwatering can have adverse effects on crop growth and yield. By providing the crops with the optimal amount of water, smart sprinkler systems can help to maximize their growth potential and produce higher yields.

Third, smart sprinkler systems can reduce the environmental impact of farming by minimizing the use of fertilizers and pesticides. Overwatering can lead to the leaching of fertilizers and other chemicals into groundwater or nearby water bodies, causing pollution and environmental damage. Smart sprinkler systems can reduce the need for these chemicals by optimizing the watering schedule and reducing runoff.

II. LITERATURE REVIEW

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Solar power surpasses the energy consumption of all commercial sources on Earth, making it a reliable option for addressing disease alleviation and clean water provision. Previous studies have explored various concepts in photovoltaic (PV) powered water purification. Forstmeier, Feichter, and Mayer (2007) discussed the challenges and opportunities in developing such a system, highlighting the fluctuation of PV energy as the main obstacle. Nevertheless, their findings demonstrated the potential of sustainable water purification through PV. Saraceno (2005) developed a solar-powered portable water purifier that utilized solar cells to operate a pump for water supply to the purification radiation source. Wright (2011) proposed a water purification apparatus incorporating a purification filter and solar power system. Elasaad, Bilton, Kelley, Duayhe, and Dubowsky (2015) designed and tested a photovoltaic powered reverse osmosis system (PVRO) in a rural Mexican community, providing insights into system design and deployment. Joseph, Newton, Wandrie, and Carter (2012) developed a solar-powered water purification system using distillation to produce potable water. Jaskolski, Schmitz, Otter, and Pellegrino (2019) evaluated the performance of 16 solar PV-powered drinking water systems, revealing successful removal of ions while noting location-dependent chlorine levels. These studies collectively demonstrate the feasibility of different solar-powered water purification systems.

In Pakistan, the rising cost of diesel has prompted the opportunity for farmers to convert their tube wells to solar-powered pumps. With 1.1 million tube wells in the country, only 30% currently have access to electricity, while the rest rely on oil, a significant source of greenhouse gas emissions. These tube wells require 2.3 billion liters of diesel annually, and due to inadequate electricity supply from the national grid, farmers face difficulties in irrigating their crops. Therefore, flexible techniques, such as adopting solar-powered irrigation systems with solar pumps, are recommended to address this issue. Water scarcity from rivers and lakes further exacerbates the challenge, as groundwater extraction using oil-run tube wells becomes necessary. Research is underway to explore power plants that utilize water for extracting hydrocarbons, as well as other energy-related activities. However, little attention has been given globally to ensure water availability for rice crop production while reducing energy consumption. Irrigation accounts for 70% of fresh water usage in agriculture, and the cultivation of rice requires substantial water resources. Farmers are increasingly shifting away from river and lake water, which no longer meets their irrigation needs. This emphasizes the intersection of irrigation and energy crises.

In India, a survey conducted by the Bureau of Electrical Energy in 2011 revealed the presence of approximately 18 million agricultural pump sets, with around 0.5 million new connections added each year, averaging a capacity of 5HP. The agriculture sector's total annual consumption amounts to 131.96 billion KWh, comprising 19% of the overall electricity consumption. Solar-powered smart irrigation techniques have been identified as a potential solution for farmers and the energy crisis. The proposed solar-powered system incorporates techniques analyzed and modified from previous studies. The system utilizes pulse width modulation (PWM) technique for inverter operation, minimizing harmonics and increasing efficiency, as outlined in a referenced paper. The system's rating was calculated based on pump specifications mentioned in another cited paper.

III. METHODOLOGY

The smart sprinkler system project requires various parts and supplies, including a soil sensor, water pump, relay module, Arduino Uno, sprinkler, pipe, servo motor, and solar panel. The system is controlled using the Arduino Integrated Development Environment (IDE), where code is written to program the soil moisture sensor and servo motor. The Arduino Uno is responsible for monitoring and controlling the system, using the input from the soil moisture sensor to determine the appropriate output for the relay module. By regulating the water pump and sprinkler, the system ensures that crops receive the optimal amount of water without wasting resources. Finally, the solar panel provides the necessary electricity to power the servo motor and Arduino, allowing the system to operate autonomously during daylight hours.

An efficient method of improving irrigation systems is to employ sensors to monitor soil moisture levels. In this project, a soil moisture sensor is used to measure the soil's moisture content and transmit the result to an Arduino board. The code determines whether an output signal is "HIGH" or "LOW" by comparing the input value to a previously defined threshold. If the amount of soil moisture is adequate, the output signal is "LOW," and the pump stops running to avoid over-irrigation. If the soil dries out, the Arduino sends a "HIGH" signal, and the sprinkler keeps sprinkling water. The system needs a constant power source. The Arduino Uno and servo motor are powered by electricity produced by solar panels. In order to maximize the efficiency of the panels, they are connected to a servo motor, which alters the angle of incidence for the panels. From 6:00 am to 6:00 pm, the panels turn once 180 degrees to face the sun. The 9-volt pump cannot be powered by the system's panels because they are insufficiently strong. The solar panels are simply utilized as a demonstration because an external power source is used to operate the pump instead.

The project's flowchart involves several steps in sequence. First, the soil moisture sensor detects the moisture level of the soil and sends the value to the Arduino, which compares it to a previously coded threshold. If the soil moisture level is lower than the threshold, the Arduino gives an output signal as ‘LOW,’ indicating that the soil is adequately watered, and the pump terminates its supply, preventing over-irrigation. If the soil moisture level is higher than the threshold, the Arduino gives an output signal as ‘HIGH,’ indicating that the soil needs to be watered, and the sprinkler continues to sprinkle water. The solar panels generate electricity to power the servo motor and Arduino Uno, which continuously monitor the soil moisture level and adjust the sprinkler's watering duration and frequency as needed. The servo motor rotates the solar panels according to the sun's direction, ensuring maximum energy output. The system operates during daylight hours, with the pump supplying water for 15 minutes every two hours. Overall, this system ensures optimal soil moisture levels and crop growth while minimizing water waste.

IV. CALCULATIONS

The effectiveness of the irrigation system is a crucial factor that must be taken into account to guarantee the best possible use of water resources. An arrangement of sprinklers that can cover each other's weak points is required to distribute water effectively across a bigger region. Water can be evenly distributed by employing several sprinklers, ensuring that crops receive an appropriate supply while reducing water waste. The experimental setup includes several components, such as sprinklers, soil moisture sensors, solar panels, servo motor, and Arduino Uno. The field has a radius of 1.5 meters, which makes the total area of the field approximately 7.07 square meters (πr^2 = π * 1.5^2 = 7.07 m^2). The field is divided into four quadrants, and each quadrant has an area of approximately 1.77 square meters (7.07/4 = 1.77 m^2). In each quadrant, a sprinkler is placed at the center to ensure uniform water distribution. The sprinklers used in the setup have a coverage area with a radius of 50 cm, which means that each sprinkler can cover an area of approximately 0.785 square meters (πr^2 = π * 0.5^2 = 0.785 m^2). Therefore, each quadrant requires approximately two sprinklers to ensure complete coverage (1.77/0.785 ≈ 2). The soil moisture sensors are placed at a depth of 10 centimeters below the surface in each quadrant. The sensors detect the moisture content of the soil and send the data to the Arduino Uno. The Arduino Uno compares the data to a pre-programmed threshold and sends signals to the water pump and sprinklers to turn them on or off accordingly. The solar panels used in the setup are placed on a support structure above the field and connected to a servo motor that rotates them according to the sun's direction. The size of the solar panels is not specified in the research paper, but it is mentioned that the panels used in the system are not powerful enough to run the 9-volt pump. Therefore, an external power source is used to power the pump, and the solar panels are for demonstration purposes only. The system is programmed to water the field for 15 minutes every two hours during daylight hours. Based on this schedule, the system waters the field for a total of 1.5 hours (15 minutes x 6 cycles) each day. The total amount of water used by the system can be calculated by multiplying the water flow rate of the pump by the total watering time.

For calculating the energy consumed by the water pump, we need to first calculate the amount of water required to irrigate 1 acre of land using sprinklers with a coverage area of 20 square meters.1 acre of land is equal to 4046.86 square meters. If the sprinklers have a coverage area of 20 square meters, we will need a total of 4046.86/20 = 202.34 sprinklers to irrigate the entire acre of land. Since it is not possible to use a fraction of a sprinkler, we will round up to 203 sprinklers.

The next step is to calculate the water flow rate required by the water pump to supply water to all 203 sprinklers. Assuming a standard water application rate of 2.5 cm per hour, we will need to apply 2.5 cm of water to the entire acre of land in 1 hour.

Volume of water = area of land * water application rate Volume of water = 4046.86 m^2 * 0.025 m Volume of water = 101.17 m^3

Since we need to supply water to all 203 sprinklers, the water flow rate required will be:

Water flow rate = Volume of water / number of sprinklers / time Water flow rate = 101.17 m^3 / 203 sprinklers / 1 hour Water flow rate = 0.249 m^3/hour/sprinkler

Now that we know the water flow rate required, we can calculate the power required by the water pump.

Power = Water flow rate * Density of water * Gravity * Head / Pump efficiency Power = 0.249 m^3/hour/sprinkler * 1000 kg/m^3 * 9.81 m/s^2 * 30 m / 0.7 Power = 2,425.05 W

Therefore, the water pump needs to produce 2,425.05 watts of power to supply water to all 203 sprinklers.

To power the water pump using solar panels, we need to calculate the energy required by the solar panels. Assuming a solar panel efficiency of 15%, we can calculate the energy required as follows:

Energy required = Power / Solar panel efficiency Energy required = 2,425.05 W / 0.15 Energy required = 16,166.66 W

Therefore, the solar panels need to produce 16,166.66 watts of energy to power the water pump.

To irrigate a 1-acre field using sprinklers with a coverage area of 20 square meters, a water pump with a power rating of 2 HP is required. To power the water pump using solar panels with an efficiency of 15%, solar panels with a total power output of 16,166.66 watts are needed.

Number of solar panels = Total power output required / Power output of each panel

Number of solar panels = 16,166.66 watts / 330 watts
Number of solar panels = 49.01
Therefore, we would need approximately 50 solar panels, each with a power output of 330 watts, to power the 2HP water pump using solar energy with 15% efficiency to irrigate a 1-acre field using sprinklers with a coverage area of 20 square meters.

V. FUTURE SCOPE

As technology progresses, there are opportunities to enhance the user-friendliness of solar-powered systems. One such advancement is the ability to remotely control the motor pump using a mobile phone. This enables users to conveniently operate the system from a distance. Additionally, mobile phone applications can provide real-time water level indications for both the reservoir and overhead storage tank, allowing users to monitor the water levels conveniently. Although these technologies are currently not widely known or popular, they are already available in the market.

To further improve the efficiency of solar panels, the integration of light detecting sensors can be implemented. These sensors would adjust the angle of the solar panel to maximize its alignment with the sun. By continuously optimizing the panel's position, this technology can enhance the energy capture capability of the solar panels. While these advancements are already existent, they have yet to gain significant popularity.

VI. CONCLUSION

A design of a solar powered smart sprinkling system was successfully developed. The implementation of soil moisture sensor proved to be helpful in automating the sprinkling process. Calculations were performed to determine the positions of sprinklers, moisture sensors and solar panels for maximum efficiency and performance. The minimum capacity of the water tank was also determined. All these calculations were done for a specific size of area and some baseline values were taken from the references.

VII. ACKNOWLEDGEMENT

We are truly appreciative to our college, Vishwakarma Institute of Technology, for giving the support and resources we needed to finish our thesis. We would like to take this opportunity to convey our appreciation and sincere thanks to our project guide Professor Srinivas Chippa Sir for all of their aid and advice during the course of our thesis.

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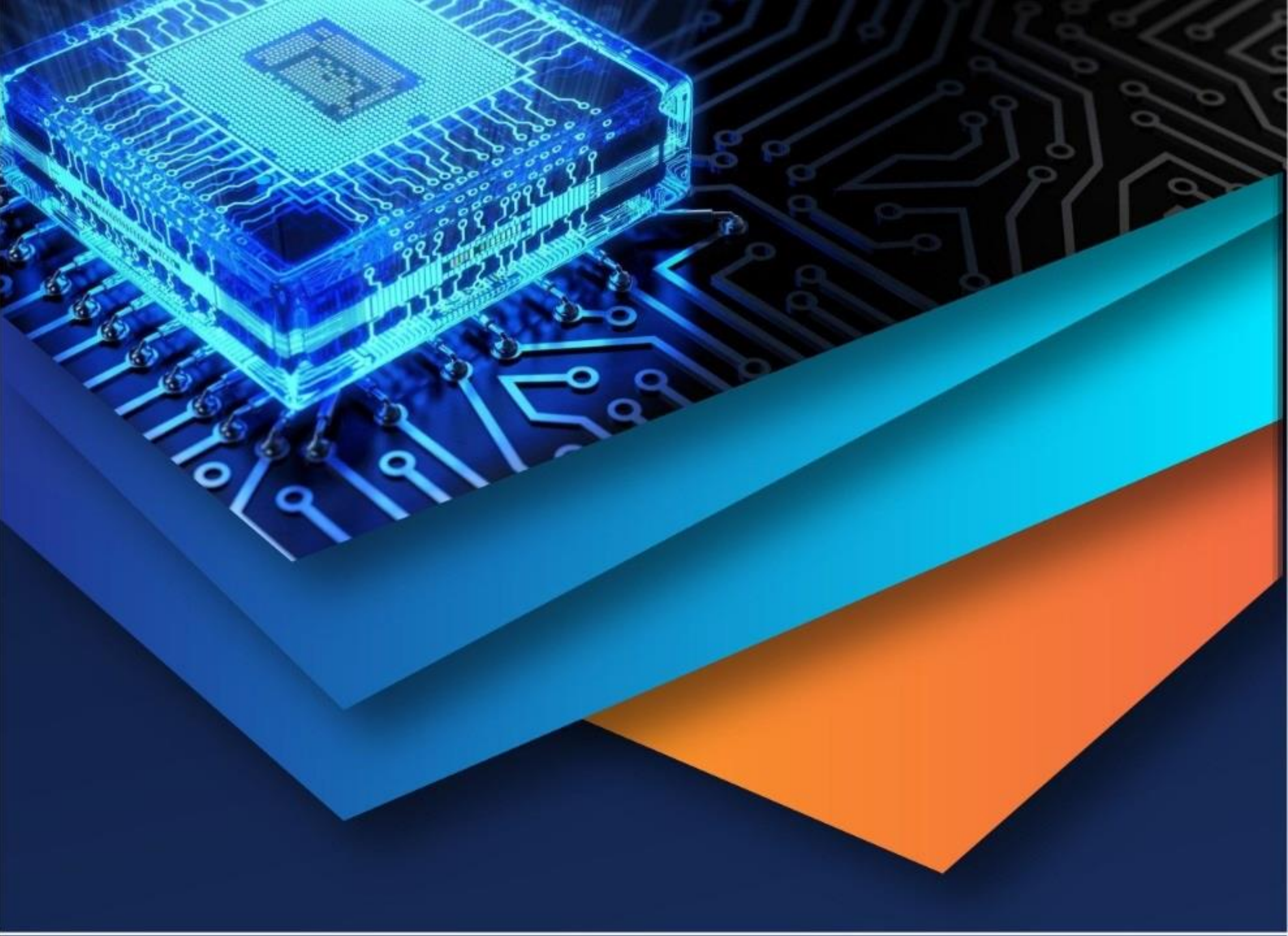

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