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Smart Solar Powered Irrigation System

Alao Olujimi[1], Izang Aaron[1*], Oyinloye Adebayo[2], Amusa Afolarin[2], Erihri Jonathan[3]

[1] Department of Information Technology School of Computing and Engineering Science, Babcock University, Ilishan-Remo 121103, Ogun State, Nigeria
[2] Department of Computer Science School of Computing and Engineering Science, Babcock University, Ilishan-Remo 121103, Ogun State, Nigeria
[3] Department of Computer Science, School of ICT, Delta State Polytechnic, Ogwashiuku 320109, Delta State, Nigeria

Corresponding Author Email: izanga@babcock.edu.ng

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ABSTRACT

The desire of man to be in control of everything around him in recent times is born out of the rapid development of smart technologies as everything now depends on the internet. Irrigation system is also becoming smart by using modern technologies, which is more advantageous than traditional irrigation methods. In this work, a smart irrigation system is developed that automates the irrigation process powered by solar energy. This proposed system can optimize the use of water based on different data, such as soil moisture level, weather prediction, and soil temperature. A soil moisture sensor that utilizes IoT technology will be inserted into the farmland to detect the moisture level and then notify the farmer about the current condition of the soil through a developed mobile application. Furthermore, the system can automatically turn ON the motor pump from the mobile app to irrigate the farm when the moisture level and soil temperature are below 50% and will automatically turn OFF the pump after fulfilling the demand of the soil when the moisture level and temperature is above 75%. The whole proposed system is controlled by a microcontroller and a DC power is generated from the solar panel which helps to keep the system working at any time of the day. All these features will make the irrigation system much smarter, more economical, and more eco-friendly. In conclusion, this system is recommended for use by farmers who lives in areas with low access to constant water supply.

1. INTRODUCTION

The most abundant source of energy in use today is solar energy. Solar energy is not only a solution to the current energy crisis and lack of light, but it is also an environmentally benign source of energy.

Solar energy is a renewable energy source that helps and does not have a negative or hazardous effect on the environment, solar energy brings a reduced low operational cost long term as there is no need for a variable cost that will be experienced as a result of using fuels. There is no emission of greenhouse gas released into the atmosphere this makes it one of the best sources of energy in use. Solar energy is limitless, it supplies more energy than we will ever need. Additionally, photovoltaic generating is cited as an effective method for harnessing solar energy [1]. Solar panels, which are made up of a number of photovoltaic cells, are frequently used in communities to drive water heaters, street lights, and other residential appliances [2]. Solar panel prices have steadily declined, which promotes their use in a variety of industries worldwide, including in Nigeria.

Farmlands have recently experienced rapid fertilizer growth and erratic water supply, according to reports from several locations. Due to this, there is significant water and electrical waste during agricultural irrigation processes [3]. Because rain is unpredictable and there is a shortage of water on the ground, irrigation techniques must be done properly [4]. Agriculture is always influenced by soil moisture levels. The quantity and quality of the soil's water content directly influence agricultural production, and this relationship holds regardless of the type of crop being grown [5]. Large amounts of water are wasted when water is used improperly. However, electrical energy is also a significant issue in Africa, particularly in Nigeria [6].

Due to constant water withdrawal from the soil, it has been observed that the moisture level of the soil is decreasing daily. As a result, a proper irrigation system must be carefully planned to avoid this issue. Another issue is the requirement to regularly check the irrigated area to carry out the necessary maintenance and to report fertilization needs [7].

In the past, cost-effective irrigation systems have been created, but they either required large budgets or only utilized conventional, non-renewable sources of electricity. Irrigation systems have always been in place and most have been carried out or supported by non-renewable energy sources that affect the environment. The purpose of agriculture primarily is to provide food to elongate human life, fuels used in irrigation emit gasses harmful to the environment and the agricultural practices themselves. The most logical way is to find means of preserving the environment to better suit agricultural needs. This is where solar energy serves as a better source of power for irrigation agriculture [8]. Large farms must put out enormous effort to maintain all crops by irrigation [9]. As opposed to earlier irrigation systems that did not provide water to all crops, this technique is employed in irrigation systems for farming processes to maintain all crops [10]. Farmers in Nigeria may find a solar-powered irrigation system to be a good alternative at this time due to the country's current energy issue. Once a small investment is made, this green method of energy production offers free energy.

In this study, we suggest a solar-powered automatic irrigation system that uses to transfer water from a bore well to a tank, use water pumps. A microcontroller and a moisture sensor work together to automatically manage the tank's output valve, which controls the amount of water that flows from the tank to the field. Irrigation system that distributes water to all the crops in the best possible way. The other sections of this study comprise of the related works section, the method adopted in this study, the operational block diagram of the smart solar powered irrigation system showing all its components, the circuit diagram that shows the operation of the system and the implications for managers and concluding aspect.

2. LITERATURE REVIEW

This section provides a quick overview of the efficacy of the smart solar power irrigation system. A detailed description of closely related works and the research gaps in each are provided in Section 2.1.

2.1 Related works

Ashwini [11] studies on smart irrigation systems that utilize IoT to monitor crop fields, uncontrolled water use is causing the groundwater level to drop day by day. In addition, a lack of rain and a shortage of land water cause the amount of water on Earth to decrease. Water scarcity is one of the main issues facing the globe today. In every field, water is a must. Water is crucial in daily life as well. One industry where enormous amounts of water are needed in agriculture. Water waste is a significant issue in agriculture. if extra water is applied to the fields. There are numerous ways to prevent or reduce water waste in agriculture. The system's goals are to a) conserve energy and water resources; b) operate both manually and automatically, and c) determine the water level. In comparison to population growth, the agricultural yield has performed badly due to climatic changes and lack of accuracy. Most canal systems used for irrigation include pumping water into fields at regular intervals.

Due to some crops' sensitivity to the amount of water in the soil, this form of irrigation has a negative impact on crop health and results in a low yield. Unlike a conventional irrigation approach, a smart irrigation system controls the water that is supplied. Smart IoT Fuzzy irrigation system was researched by Kokkonis et al. [12]. In order to continuously monitor the environmental conditions of arable areas, this approach uses inexpensive off-the-shelf sensors and actuators. The approach suggests a comprehensive solution to increase both the quantity and quality of agricultural products. Continuous monitoring is done of soil humidity, moisture content, and air temperature. The humidity of the earth is managed using a servo valve. The system's high-level architecture and each of its component elements is shown and studied. It is built using open-source programming languages and environments like Linux, PHP, and MySQL. Additionally, a brand-new fuzzy computational approach for water irrigation is suggested. Multiple ground humidity sensors' measurements of soil moisture, air temperature, and humidity are used as inputs for the algorithm. The fuzzy system includes three levels for each of the inputs. The algorithm's result determines when the irrigation system's central servo valve opens.

Venkatapur and Nikitha [13] suggested an irrigation system that is powered by solar photovoltaic panels rather than an expensive electric power source. An algorithm was designed with a threshold value of temperature and soil moisture programmed into a microcontroller gateway for efficient and optimal water consumption.

Parameswaran and Sivaprasath [10] put forth a solution to assist farmers in irrigating their land effectively using an automated irrigation system depending on soil moisture. A humidity sensor measures the soil's moisture content, and a microcontroller uses this information to control the solenoid valve. A personal computer is used to update the server's or localhost's irrigation status.

Akubattin et al. [14] created a method to track and regulate the temperature and moisture of the soil inside a greenhouse. The Raspberry Pi-controlled system determines whether to water the plant or turn the greenhouse's fans on based on the amount of moisture in the soil.

Zhang et al. [6] created a system that comprises of a microcontroller, a wireless radio frequency (RF) module, and a data transmission unit (DTU). Expandability is improved by using the RF module in the acquisition terminal. Relay stations gather soil moisture data, which the DTU then sends to the monitoring center through the GPRS network.

Kumar et al. [7] presents an innovative method that uses soil moisture sensors to control the water flow in dry areas. The moisture-dependent principle underlies the sensor's operation. The resistance between two sites in the earth is created utilizing inexpensive components and techniques.

Abayomi-Alli et al. [15] Create an automatic irrigation system that uses solar energy. This will offer a financially sensible replacement for the conventional irrigation technique. The goal of this project is to create a system that uses solar energy for intelligent irrigation and enables more effective water conservation on fields. The created system is transportable and made to fit into the current water infrastructure. The system makes use of NRF module-based wireless communication technology. A Bluetooth network-enabled Android app can be used to easily operate the system. In the user interface, users can choose between automatic control utilizing wireless sensors or manual control for planned irrigation.

Gutiérrez et al. [16] created a GPRS, Zigbee, and radio connectivity-based autonomous solar irrigation system. The wireless sensor unit and the wireless information unit are the two main components of the system, and they are connected by radio transceivers. The ZigBee technology is used to configure the wireless sensor, which includes power supplies, sensors, and a microcontroller. To set up a dispersed sensor network for the automated irrigation system, several wireless sensors can be used on-site.

To determine the volumetric water content of the soil, Gokhale et al. [17] introduced a soil moisture sensor. The soil's dielectric constant, also known as soil bulk permittivity, is the foundation of the sensor. In his plan, LM35 wrapped-in was used to measure the soil's temperature. Using an Arduino Uno, the temperature and soil moisture levels are detected, and the analog values are translated properly. The results are then shown on the LCD and relayed wirelessly over Bluetooth to the control room, which is a few miles distant from the farms.

Vishwanathan et al. [18] proposed a novel soil moisture sensor-based method for managing solar irrigation systems in agriculture. The technology automatically determines the appropriate irrigation activity and notifies the user based on the sensed data. The system also emphasizes how the sensors' communication processes consume solar energy. The workings of the system and its component specifics were also covered in the study.

Rehman et al. [19] featured a user-friendly interface, a wireless automatic watering system, and system status information notification. In order to give the user a choice between manual and automatic operation, the system was developed. Additionally, it provides a data history of system operations.

Sharma [20] proposed a wireless sensor technology as a means of automating the Indian agricultural systems. The recommended system was able to control a number of variables, including humidity, soil moisture, and soil pH, by using wireless sensor nodes that serve as inputs to the peripheral interface controller. (PIC). This data is continuously monitored by the controller, and an inbuilt GSM modem sends the farmer SMSes.

In the end, the research's findings from all related literatures reviewed indicate that irrigation techniques and processes in agriculture and other related fields need to be automated and improved especially in developing countries around the world. Additionally, the findings discovered that using solar energy is the most comprehensive and effective way to create an environment free of harmful gases, - which is closely related to agriculture. Using a renewable energy source is one of the best moves that will have a great lasting effect on agriculture yield and transform how the sector is regarded. In recent years, there has been a great movement and shift towards conserving the environment using renewable energy resources which most related works has tried to implement. But most related works did not consider security issues faced by farmers when trying to access their farmland and the mobility of famers and the need to have access to irrigation from anywhere they are. Therefore, because smart solar irrigation is seen as a tool for promoting the growth of planted crops, therefore finding a practical, long-lasting solution was essential. The aforementioned issues were considered in our work which considered and emphasized that building small and compact yet effective smart solar-powered irrigation system is a need that has now been solved.

2.2 Method adopted in research work

The notion of adaptation from manual and conventional irrigation and monitoring was used in the creation of the System. The input and output components, as well as the necessary hardware and software, must first be classified according to functions. Work is facilitated by the networked use of microcontrollers, sensors, and actuators in embedded design. In this project, the motor is managed by a microcontroller. The C programming language and the MicroC IDE are used to create it. In order to determine whether watering is necessary, two moisture sensors assess the amount of moisture in the soil, calculate the average moisture value, and send the appropriate signal to the microcontroller. Up until the necessary moisture level is reached, the plants receive water from the water pump. The battery serves as the necessary power source.

The solar panel is used to recharge the battery which provides the required power. To determine whether the soil is wet or dry, a moisture sensor is utilized. The input signals are then passed to the microcontroller, which manages the entire circuit. When the soil is dry, the microcontroller issues an instruction to the relay, turning on the motor and supplying the field with water. The motor is turned off when the ground becomes damp.

Two functional units make up the suggested system: a solar pumping unit and a smart irrigation device. The solar pumping device uses solar energy to run the pump. Photovoltaic cells positioned next to the pump set use solar energy to generate electricity. For managing the batteries, a controller circuit is created.

A smart irrigation system, on the other hand, has a solenoid valve that is electronically controlled. This valve, which is used to control the flow of voltage, is controlled by a soil moisture monitoring device. This voltage signal is transmitted to the sensing device, where it is compared to the reference voltage that the farmer can adjust in accordance with the needs of the crop.

The required amount of water is directly proportional to the difference between these voltages. The motor, whose rotating angle depends on the voltage differential, is then provided a signal from the sensing unit. Through solenoid valves, the motor regulates the water flow rate. As a result, the moisture difference is proportional to the volume of water flowing through the microcontroller. It is also connected to a mobile application run by the Global System for Mobile Communication (GSMC), which sends SMS to the user so they can monitor the situation in real time from a distance. The system will automatically open the solenoid valves if the moisture value is less than the current value. The pipe's solenoid valves will automatically close after opening for a predetermined period of time. Because the complete system will be activated once every hour, a plant may more easily keep the moisture it needs. The tank's water level sensor will also monitor the water level there, and if it falls below a predetermined threshold, the system will start the motor pumping water from the well. For each occurrence, the client receives an SMS with information about the water level, motor status, and moisture level. Because all nodes are powered by solar energy from solar panels and because the solar pumping unit pumps water through solenoid valves, the system will have less problems with energy supply. As a result, the fluctuation in moisture differential is inversely related to the field's water flow. The Global System for Mobile Communication (GSMC), which is utilized by farmers for real-time monitoring from a distance, is further connected to the microcontroller.

3. THE SMART SOLAR POWERED IRRIGATION SYSTEM

Photovoltaic cells in the proposed system use sunshine to power it. To determine whether the soil is dry or wet, this method uses soil moisture sensors that are buried beneath the surface. The soil's moisture is tested to know whether there is water in the soil, this is used to determine when the soil lacks water and will be good for irrigation and when to stop pumping water in order not to have excess water in the soil and destroy the crops. The brain of the device that regulates the entire system is a microcontroller. When the moisture level in the soil decreases, the soil moisture sensor sends a signal to the relay unit, which is connected to the motor. When the soil is dry, the engine will automatically turn on, and when the soil is moist, it will automatically turn off. The sensor placed beneath the soil measures the soil's moisture content and provides a signal to the electronic decision-making unit's microcontroller informing it whether the field needs water or not.

The instructions from the program stored in the microcontroller come before the signal from the sensor, which is received through the comparator's output. The motor automatically turns ON when the soil is dry, and when moisture reaches its present level in a wet state, the motor shuts OFF. On an LCD, the motor's ON and OFF states are shown. A solar photovoltaic cell, a renewable energy source, powers the entire system. These cells transform solar energy into electricity that may either be utilized immediately or stored in a battery. Electric devices are powered by electricity.

A solar panel, charge controller, battery, Ethernet shield, relay, soil moisture sensor, humidity sensor, and DC pump are all components of the Smart Irrigation System. Solar energy serves as a source and produces electricity. A charge controller uses these charges to store them in the battery. The Arduino, humidity sensor, soil moisture sensor, and DC pump all require power from the battery, which is provided by a charge controller. With the aid of a relay and an Arduino, the DC pump can be turned ON and OFF based on readings from soil moisture sensors and humidity sensors. Using an Arduino and Ethernet shield, these data are supplied to the mobile app, which then uses the internet to transmit notifications. The suggested system's operational blocking diagram is shown in Figure 1.

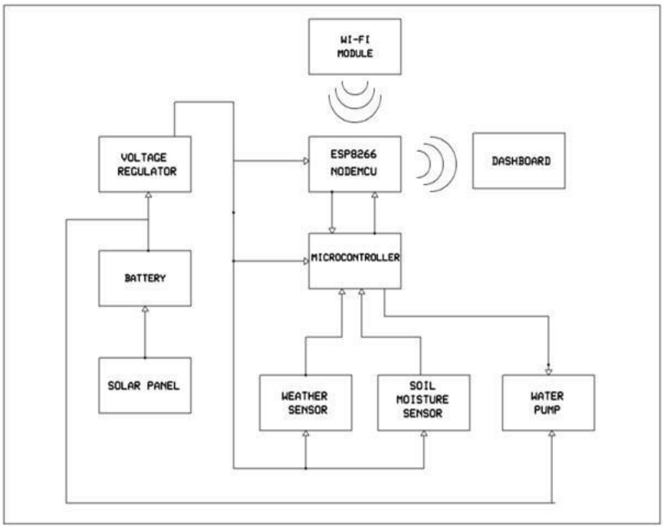

Figure 1. The smart solar powered irrigation system operational block diagram

3.1 The operational block diagram components

The components used to design the smart solar-powered irrigation system are explained in this section.

The soil moisture sensor determines if there is enough water in the soil, if there is, no action is performed, but if there isn't the soil moisture sensor sends a signal to the microcontroller powered by the battery recharged by the energy trapped from the sunlight through the solar panels. the microcontroller then sends a signal to the water pump that an action is needed, the water pump then pumps water from the reservoir, to the soil and if the soil moisture sensor detects that there is enough water in the soil, the pumping stops. the WIFI allows for a display to be connected to the system to get readings and see the analytics of the performance and also for manual control of the system.

3.1.1 ARM microcontroller

In the realm of digital embedded systems, the ARM-Cortex microcontroller is the most widely used, and most industries only use ARM microcontrollers since they offer a wealth of features that can be used to develop products with cutting-edge looks. The ARM microcontrollers are high-performance, cost-conscious components utilized in a variety of applications, including automobile body systems, wireless sensors and networking, and industrial instrument control systems.

The 32-bit RISC microcontroller known as the ARM, or Advanced RISC Machine, is a type of RISC computer. The Acorn computers company first made it available in 1987. The ARM is a group of microcontrollers created by many producers, including STMicroelectronics, Motorola, and others. Several variants of the ARM microcontroller architecture are available, including ARMv1, ARMv2, etc. and each one has its advantages and disadvantages.

Because the ARM processors have a smaller instruction set than other processors, which enables a smaller size for the IC, they contain fewer transistors. being also space-efficient as a result. These CPUs are found in the majority of electronic gadgets, including tablets, smartphones, and other mobile devices.

3.1.2 Soil moisture sensor

Soil moisture sensors calculate the volumetric water content of the soil. Because the direct gravimetric measurement of free-soil moisture necessitates the removal, drying, and weighing of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil as a proxy for the moisture content, such as electrical resistance, dielectric constant, or interaction with neutrons. Since the relationship between the measured property and soil moisture can vary depending on the environment, including the kind of soil, temperature, and electric conductivity, calibration of the relationship is required. Reflected microwave radiation is used in agriculture and hydrology for distant sensing and is influenced by soil moisture. Portable probing instruments can be used by both farmers and gardeners. Soil moisture sensors are generally used to describe sensors that measure the volumetric water content. Another class of sensors that gauge the water potential quality of soil moisture includes tensiometers and gypsum blocks. The term "soil water potential sensors" is another name for these devices.

3.1.3 WIFI (IoT module)

An Internet of Things (IoT) module is a tiny electronic component installed in physical items that connect to wireless networks and transmit and receives data. The IoT module, also known as a "radio chip" or "IoT chip," incorporates the same data circuits and technologies as mobile phones but lacks features like a display and keyboard. The fact that IoT modules offer always-on connectivity is another important point of differentiation. This feature results from the fact that IoT apps must automatically transfer data in real time without a send button being pressed.

They must function consistently for ten years or more in order to support the business case and expense of the technology. They are designed for exceptional durability and longevity.

3.1.4 Water sprinkler

An irrigation sprinkler is a tool used to irrigate lawns, gardens, golf courses, and other locations. It is also known as a water sprinkler or just a sprinkler. They are also utilized for cooling and dust management in the air. Sprinkler irrigation is a technique for putting water under control in a way that mimics rainfall. Pumps, valves, pipes, and sprinklers are only a few of the possible components of the network used to distribute the water.

Sprinklers for irrigation can be utilized in residential, commercial, and agricultural settings. It can be useful for uneven terrain with poor water supplies and sandy soil alike. At regular intervals, the rotating nozzle-topped perpendicular pipes are joined to the primary pipeline. Water escapes from the revolving nozzles when air is inflated through the main pipe. The crop receives a spray of it. Water is piped to a more central place inside the field for overhead high-pressure sprinklers or guns to disperse during sprinkler or overhead irrigation.

3.1.5 Water pump

Water pumps are devices for moving water, and because they transport water from its source to the fields and crops, they are essential to agriculture. A hose, sprinklers, or other types of irrigation can all be utilized with water pumps.

Water pumps come in a broad variety, ranging from basic manual pumps to ones propelled by electricity or fossil fuels.

3.1.6 Lead acid battery

Lead-acid batteries were the first rechargeable batteries used in commercial applications, developed in 1859 by the French physician Gaston Planté. We still don't have any affordable alternatives to cars, wheelchairs, scooters, golf carts, or UPS systems 150 years later. In situations where newer battery chemistries would either be prohibitively expensive, the lead-acid battery has maintained its market share.

Fast charging is not possible with lead-acid batteries. 8 to 16 hours is the usual charge time. To avoid sulfation, a periodic completely saturated charge is necessary, and the battery must always be stored charged. Battery sulfation results from being left in a depleted state, making a recharge possibly impossible.

3.1.7 Osyphotrone photovoltaic solar panel

Using semiconducting materials that show the photovoltaic effect, a phenomena researched in physics and photochemistry, photovoltaics (PV) converts light into electricity. However, employing solar energy as a primary source necessitates the installation of energy storage systems or high-voltage direct-current power lines that add to the expense. The best-known application of photovoltaics is as a way to produce electricity by employing solar cells to convert solar energy into an electron flow through the photovoltaic effect. Solar cells use sunshine to generate direct current electricity that can be used to power devices or recharge batteries.

3.1.8 Solar charge regulator

A solar charge controller regulates the flow of power from the solar array into the battery bank. The deep cycle batteries are not overcharged during the day because of this, and it also stops the batteries from being drained at night by power running backwards to the solar panels. Although some charge controllers have other features like lighting and load management, regulating electricity is their main responsibility.

4. CIRCUIT DIAGRAM

The Figure 2 below shows the circuit diagram of the smart solar powered irrigation system. This diagram was designed in line with the operational block diagram.

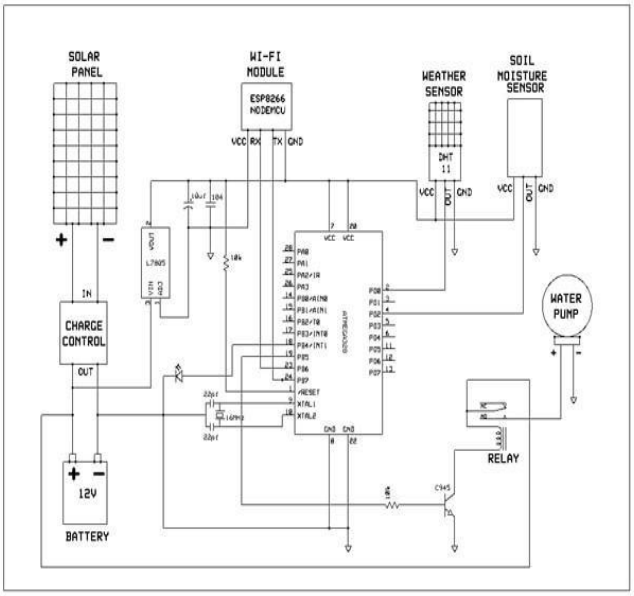

Figure 2. The circuit diagram of the smart solar powered irrigation system

4.1 System operation

When the soil is dry or when the user so chooses, the Smart Solar-powered irrigation system can pump water to irrigate the soil. The system was tested using the temperature sensor and the soil moisture sensors, which are tools used to detect the soil's temperature as well as the amount of water present in the soil, after the components had been connected and the codes had been written. The ARM Microcontroller receives data from the soil moisture sensor via the programs that have been developed to assign different signals to each component, and the battery that powers the circuit board to which all components are linked is charged by the solar panel.

If the soil moisture sensor requires a response, the microcontroller then sends the information to the pump, which subsequently pumps the water to the soil based on the data the soil moisture sensor is sending it. which means that if the soil is adequately moist, the soil pump does not turn on to irrigate the soil if the water level is below the expected level.

5. CONCLUSION AND RECOMMENDATION

In this research, a smart irrigation system, powered by solar energy was achieved. The system design uses an IoT technology able to monitor and track its operations. By actualizing the proposed framework there are different benefits for the government and the agriculturists/farmers. By using the programmed irrigation system, it optimizes the utilization of water by diminishing wastage and diminishes human intercession for farmers. The overabundance of vitality created utilizing solar panels can be given to the framework with little alterations within the framework circuit.

This research work is very important to people with unreliable access to energy, as it contribute to rural electrification and reduce energy costs for irrigation and also it provides job opportunities, basically to businesses within your locality that deal exclusively in solar panels.

Maintaining the water content or soil moisture is crucial in the world of agriculture. Water usage issues could hinder plant growth and cause farmers to stop farming. This is the primary issue that led to the creation of this project. This technology records data on the amount of moisture in the soil and maintains moisture levels within acceptable ranges. A sensor, specifically a moisture sensor, can be used to measure the amount of moisture. The water pump turns ON or OFF in accordance with the amount of moisture that has been measured. For farmers who do not have unlimited time to water their crops or plants, gardeners and farmers are the main beneficiaries of this research. Additionally, it protects farmers who squander food. water during irrigation. The system can be extended to nurseries where manual administration is distant and few in between.

The managerial implications of the smart solar powered irrigation system is that the system conserves electricity by reducing the usage of grid power which will cost more. It will also offer rural famer a lower cost of running irrigation systems that require the use of fuel to run the traditional method with generator to power the system. Lastly the system also conserves water by reducing water losses due the manual irrigation method.

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