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Design and Implementation of a Sustainable Microcontroller-based Solar Power Automatic Water Irrigation Control and Monitoring System

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Abstract:

The major cause of the shortage of land reserve water is the lack of rainfall, which makes the proper operation of irrigation systems extremely important. A major concern for farmers these days is water scarcity. Pakistan is an important agricultural nation, and a major part of the economy depends on agriculture. This study analyses soil moisture monitoring and automatic plant watering systems since they are really helpful in all kinds of weather. In this study, a prototype is designed and implemented using Arduino-based automation sensors employed for the control and observation of a solar-powered smart irrigation system. Implementation of an Arduino solar-built automatic irrigation system for the agricultural farm, which robotically switches the motor when water is essential, delivers for irrigation when the moisture of the earth drives under the threshold value rate, which turns on the pump on autopilot. An estimation was carried out for solar power energy potential agriculture system conditions using soil and humidity sensors. The measurements and mathematical formulation were observed to monitor the effectiveness of solar-based power generation. This study can implement an automatic programming-based controller system to switch irrigating water constructed utilizing soil moisture to sense soil wetness. This scheme senses the dryness of the irrigation area. This system improves the conventional system alternated with an automatic system. This analysis is conducted for a 20-watt power panel integrated with a 5-watt electrical drive with a battery capacity of 1200 m-Ah. A modified energy model was used to determine the agricultural load for a 5-watt DC motor. To develop a facility analysis a simulation-based solar-powered irrigation model is designed using Dip Trace Software. The results showed a cumulative analysis to implement this system inspired by smart, sustainable, clean, renewable energy technologies, which meet the farmer's demands, significantly increase the productivity of farming, and reduce wastage of water and energy. As compared to previous studies, this system detects the soil humidity and temperature range to cross the set point, so the pump will be on for 10 seconds, and this system will be able to operate without any human interaction. This system is inspired by renewable energy technologies and can operate without conventional power systems.

Keywords: *smart irrigation, sustainable, irrigation scheduling, Solar, power generation, Karachi, Pakistan, microcontroller, proptype, monitoring, and controlling.*

I. INTRODUCTION

The unsustainable agricultural system is the major cause of ecological problems. Global energy management utilizes fossil fuels to produce power with large carbon emissions. There is a need to implementation and awareness of renewable energy technologies for low carbon potential systems. [1]. Pakistan is currently in an energy shortage and crisis. The implementation of off-grid photovoltaic agricultural practices is required to save water and energy. This study examines the impact of solar energy implementation in irrigation systems. The factors including financial parameters, labor cost, further extensions, risk analysis, and tube availability parameters were analyzed. The finding discloses the positive association with solar and irrigation integration. The awareness of this digital technology is required in developing countries like Pakistan for green energy solutions. [2] Pakistan is a developing nation with the effects of climate change, decreasing in floods. This variation in climate has a negative effect on agricultural resources, soil, and moisture content. Pakistani farmers implementing techniques to resolve this matter [3]. The aim of this study is to design an efficient system to save water during irrigation. Sensors including moisture sensors, humidity sensors, temperature sensors, and smoke sensors integrate with the microcontroller. A web page is developed to observe and control irrigation manually and automatic controlling utilizing wireless sensors [4]. The major objective of this study is to provide an automatic and sustainable gardening system that is inspired by eco-friendly systems for plantations. This system includes an Arduino Nano microcontroller, moisture sensor, relay module, and water pump. All components are synchronized for the optimal soil level sensing for efficient water management. It minimizes the huge wastage of water and energy and provides sustainable plantation practices. Further enhancement with artificial intelligence and machine learning improves the practices [5]. This study focuses on the development of smart water systems for domestic and irrigation applications. The components utilized are a 555 timer Integrated circuit, M08A (IPC-7351) PCB Footprint, and moisture sensor. Using timer IC for timing interval in water management on a set threshold value. The operation of this system is a stable mode that controls the water for a sustainable solution. Employment of sensor probes and circuits that identify the water fluctuations. The implementation of this system automates the water pumping and efficient water management without utilizing any controller. [6] Water wastage and oversaturation due to conventional systems are major causes for irrigation systems in Nigeria. A smart irrigation system is designed to resolve this problem using Arduino technology. The objective is to design this system for optimum water usage. The components utilized are an Arduino module, Data logger, LCD display, pump, Tank, moisture sensor, and battery. Arduino programming C++ was written to sense the moisture in the soil for automatic switching of the water pump. This system is 97% more effective than conventional system practices normally. There is an implementation of a large scale for this system for the purpose of food and water security [7]. An agricultural system with smart system integration increases production. Develop a system that reduces the wastage of water based on a computer vision system. This system utilizes a Raspberry Pi camera imaging system to monitor the soil color by capturing pictures without any labor involvement. A relay, pump, and batteries are integrated with the system to achieve power stability and power disruption. The installed Pi4 Raspberry model is instructions for hardware monitoring and the algorithm written in Python programming observes and analyses the soil color [8]. This study focuses on the smart sensor cloud-based system to monitor and switch a small-scale irrigation system. To observe soil moisture sensors are integrated with the Node MCU microcontroller which processes and switches the data remotely by adjusting parameters using applications. The microcontroller data is transferred to a cloud server for recording. Solenoid valves are utilized to begin the irrigation system. This system is give optimal solution for water security. This cloud server-based optimal solution improves water management for sustainable irrigation practices. Components utilized for monitoring and switching are Node MCU, DHT11 sensor, and soil sensor [9]. This study proposed to develop a soil moisture sensor constructed with copper to enhance efficiency. An automated irrigation prototype was effectively developed and tested. This system is designed and implemented for water security. The components including the power supply, motor pump, moisture sensor, and microcontrollers are utilized for experimental setup to improve agricultural productivity. The Arduino IDE software enabled the programming of the system. On the pre-set value the soil moisture sensor senses and activates and deactivates the motor pump [10]. Mini agricultural economic schemes are needed to be implemented. This is a low-cost agricultural sustainable approach to enhance agricultural production. In this prototype Internet of Things-based automation system integrated with solar is designed and implemented using Arduino Uno. In this system 5V relay, solar panel, moisture sensor, ACS712 5A current sensor, 25V voltage sensor, YF-S201 flow sensor, and humidity sensor and DHT11 temperature sensor, charge controller, and water pump are utilized. The microcontroller is programmed to automatically control and monitor the system [11]. In Bangladesh, there is a huge wastage of water during irrigation and there is a lack of smart irrigation schemes. This study aims to project and develop an Internet of Things-based irrigation system. The solar panel utilized for this system is using a solar tracking system to increase the solar power. This prototype uses a 12V battery, 150-watt solar, 12V pump. The microcontroller is used for monitoring and processing the data. The sensor outputs are analogue the controller's Analog to digital terminal receives analogue output and transforms into a digital configuration. The controller receives input and output parameters are displayed on the LCD panel. [12]. This study focuses on an emerging intelligent system for agricultural purposes with optimum energy management. This system is combined with soil moisture and weather forecasting systems via using cloud-based networks. The photovoltaic-based system is also integrated with irrigation systems for a sustainable approach. The suggested system was tested via simulations and dSpace experiments. The estimation analysis was conducted for the proposed solar, battery, and pump. This system can achieve 9.24% water and energy savings [13]. In Singapore, spaces are utilized in cities for sustainable farming. Internet-of-Things and solar both are integrated and implemented. For the techno-economic study on Solar cells to decrease power depletion by controlling agricultural schemes. In the testing, a water irrigation arrangement was considered for parameter collection. This was detected that a 45 W solar PV was capable of harvesting up to 460 watt-hours. Based on the developed prototype, the addition of solar is reasonable utilizing power generated from the sun [14]. In India, agriculturalists use solar power-driven smart irrigation schemes to improve food and water security. This scheme includes a separate water movement controller arrangement that utilizes a moisture sensor combined with a solar-powered pump. The implementation of this system is to improve farmer's facilities with saving energy and water. The microcontroller automatically switches the pump when water in essential. The sensor communicates the experimental parameters to the controller if the humidity of the soil becomes low. The objective of this research is to meet farmers' demand using renewable sources [15]. Emerging a water energy-saving irrigation system incorporates actual soil moisture parameters including the amount of water necessary for vegetable harvests. Use solar energy arrangement for battery connected scheme to function the valves and pump. This scheme is proved via simulation and dSpace-based research studies. This proposed energy system proves a development in the optimum solar energy production and storing size to energize the pump with 9.24 % energy savings [16]. This study provides a water-solar power irrigation system to save energy and water facilities to save for the upcoming generations. This system totally depends on solar renewable energy technologies. The required electricity is generated by the solar and provides power to operate the sensors and motor. Due to programming using Arduino IDE software, the sensor can perform the operating time of the motor. The water tank provides water needed for the irrigation area. The sensor detects the necessity of water and the controller sends information to switch the motor. The Arduino UNO is utilized with the setup of sensors to detect the moisture level [17]. Solar is one of the main renewable energy sources on the earth. The sun tracking system is important to raise the amount of energy produced from the solar due increase in radiation and intensity of sun rays. Solar panel rotates using motor and light-dependent resistors This tracking system is synchronized with an automated Solar motorized irrigation system to increase the productivity of system. The power produced from a solar store in the battery and water pump starts when the soil becomes dry automatically using a soil moisture sensor. Microcontrollers and sensors are integrated to control this process. [18]. The Pakistan area covers 796,096 km2 with 95% of high sunny coverage, with sunshine 8 to 8.5 hours per day. There is a need to implement an efficient irrigation system inspired by sustainable energy to improve the productivity and economy of Pakistan [19].

The prototype-based study is designed to automate irrigation practices. The soil and moisture sensors are utilizing to switch the motor pump. This system is the optimum solution with low energy consumption with economical for small and large-scale irrigation applications. This reduces water depletion with sustainable practices. This system uses an Arduino microcontroller with a 12V DC power supply to ensure low power consumption. This integrated system controls the motor using moisture sensors. It reduces labor costs with fewer human efforts for both small and huge irrigation systems. [20]. In 2022, the Pakistan Government approved the Quaid-e-Azam Solar Park rated 1000 MW. A feasibility analysis was carried out using RETScreen software to reduce energy shortage. The energy shortfall of Pakistan reached up to 6000 MW [21]. Indonesia's economy major part depends on agricultural activities. For irrigation Indonesia uses fossil fuels that produce huge emissions the implementation of a sustainable solar-powered irrigation system solves this problem. In this study, automatic solar power is integrated with the sun-tracking system. The implementation of this study necessitates the suitability of soil moisture, level, this system is equipped with an Internet of things-based application to monitor. [22]. The energy production of different solar contains PV cells Mono and polycrystalline silicon-based technologies generation built on nano-crystalline films. Photovoltaic Cells are the equipment that transforms solar into energy. These cells are produced by semiconductor material like silicon, which property is to hit electrons loose once they absorb solar energy. [23]. The power generation of Pakistan is liable to fossil fuels by importing at high rates. Renewable energy is a sustainable approach that produces energy without emissions. Figure 1 shows the comparative analysis of the power generation share of Pakistan. [24]

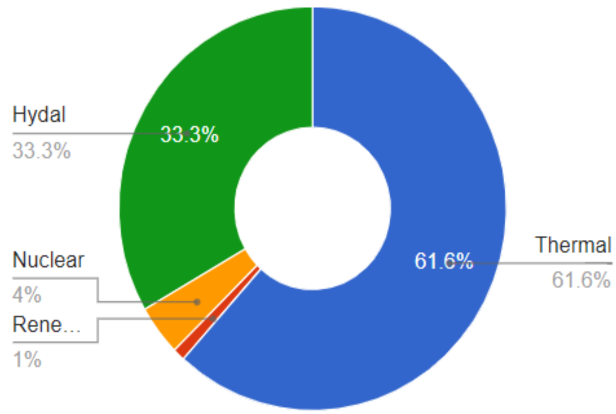

Figure 1: Pakistan Power Generation Scenario. [24]

Renewable energy systems are increasing around the globe. There is a lack of awareness related to renewable energy technologies in Pakistan. The implementation of these systems meets the energy gap in Pakistan [25].

II. MATERIAL AND METHODS

A. Study Area

For this solar power irrigation system implementation, Pakistan was selected to represent the significant impact of this technology. A prototype is designed and implemented to study experimental study. Pakistan's total area is 881,913 km^2 with higher solar radiations. Figure 2 shows the sunshine statics for Pakistan.

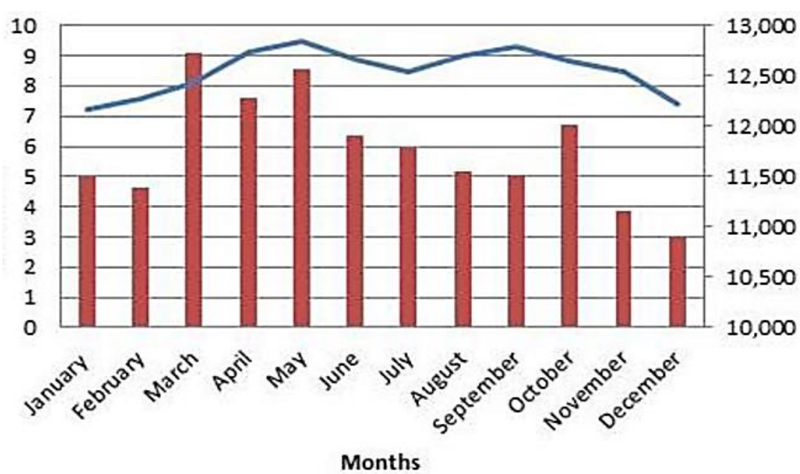

Figure 2: Average sunshine statistics of Pakistan. [3]

B. Components

The components used in the prototype are as follows:

Microcontroller: In this study, a microcontroller (ESP 32D) was used to synchronize all the actions of the irrigation arrangement. This microcontroller panel includes a combination of analog and numeric Input Output ports. The microcontroller collects all raw data from the integrated sensors. The moisture sensor transmits data to the controller and the controller is integrated with the motor for the switching purpose. Solar cells are connected to the motor for clean energy production and the battery is used for the backup purpose.

Humidity Sensor: In this study, the humidity sensor DHT-11 is utilized for temperature and moisture sensing. This sensor voltage range is 3.5 to 5.5 volts and a standby current is 0.3 mA to 60 uA as mentioned in Table 1. The measured temperature range is 0 to 500, while the measured humidity range is 20% to 90%. Both humidity and temperature are 16-bit data.

Table 1: Humidity Sensor Specifications

Pin name	Description
Common Collector Voltage	Supply 3.5V to 5.5V
Communication	Serial data communication temperature and humidity levels.
Ground	Ground connected to the main circuit

Centrifugal pump: The centrifugal pump TL-C01 is driven by a DC brushless motor, as shown in Figure 5. This pump is approachable with the pump's materials that are of parallel viscosity to water. The controller is integrated with the irrigation system to switch irrigated areas. Table 2 shows the specification of the Centrifugal pump

Table 2: Centrifugal Pump Specifications

Parameters	Description
Supply	12VDC, Battery, Solar Powered
Current	2A
Protection	Over-voltage and current protection.
Life	22000 hours

Solar Panel: The solar panel YD-W20 is used to power via a combination of an 18V solar panel module with a maximum 20-watt power output, as shown in Table 3. The solar panel will charge and supply during daytime, and battery backup will be utilized.

Table 3: Solar Panel Technical Specification Midity Sensors Specifications

Parameters	Description
Pmax	20 watt
Current at Pmax	1.06A
Voltage at Pmax	18.9 V
Short circuit current	1.28 A
Open circuit voltage	22.52 A
Operating temperature	42 Co

Flow sensor: The water flow sensor YF- S-201A and it is a PVC regulator body made up of a water flow sensor. The rotor reels as water passes through it. The hall-effect sensor produces steady pulse indications when its speed varies with a change in flow. The specifications are shown in Table 4.

Table 4: Flow Sensors Technical Specification

Parameters	Description
Supply	4.5-24 VDC
Working current	10mA
Flow rate	1-30 L/min

Soil moisture sensor: The soil moisture sensors LM393 module has two output manners: digital & analog. The digital output manner delivers a high or short indication, dependent on the humidity content of the earth. The analog productivity manner delivers a voltage indication that is proportional to the humidity content of the earth. The specification is shown in Table 5.

Table 5: Soil Moisture Sensors Technical Specification

Parameters	Description
Operating voltage	3.3 to 5 VDC
Output	Digital & Analog
Sensitivity	Adjustable
Temperature range	0^0 to 60^0
Probe length	100 mm

C. Methodology

This study's main component, the ESP32D controller, has fifteen digital and analog Input and Output pins. It can be written in C language using the Arduino IDE software over a B-type USB interface. The program design is philological. All hardware components of this prototype are connected to this microcontroller. This controller receives the humidity sensor signals, and in case there is a need for water in which field, it generates the signal to allow the pump operation after reaching the humidity level stable, so it generates the pump operation off signal during this process. also, estimate the water flow amount with the help of a flow sensor. A humidity sensor is connected to this controller to maintain the environment's humidity level. LCD connected to this controller to show the operation of this circuit with the help of codding, as illustrated in Figure 3 demonstrates the study process of demonstrates the study process of the control strategy for a solar power automatic irrigation system, which combines the humidity and the water flow control. The solar panel is integrated next to the motor to power the motor utilized in this irrigation system. This system operation comprises automated watering by using a microcontroller integrated with moisture sensors for healthy growth. The sensors communicate with the controller to compare the moisture parameters. This integration of the system operates the watering of the irrigation area. The dip trace simulation software is utilized to model the facility schematic flow of the project.

Hardware Implementation: This study's main component, the ESP32D controller, has fifteen digital and analog Input and Output pins. All hardware components of this prototype are connected to this microcontroller. This controller receives the humidity sensor signals and, in case of need of water in which field, generates the signal to allow the pump operation after reaching the humidity level stable, so the pump operation off signal is generated during this process. The flow sensor is used to measure the flow of the water. The humidity sensor is linked to the controller to maintain the environmental humidity level. LCD connected to this controller to show the operation of this circuit with the help of codding. Solar power DC pumps are used for water circulation in three different fields. All pumps are connected to the DC power relays. DC power relays connected to the photo coupler circuit. Flow sensors are used in this study to

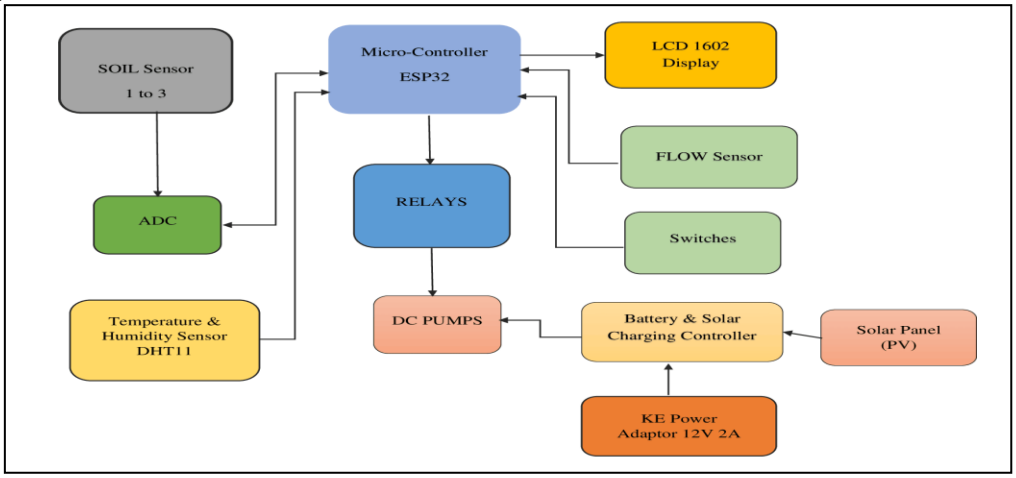

Figure 3: Flow Chart of the Solar Powered Automated Irrigation System

control the water management. Circulations of water in all fields are possible via these sensors. Flow sensors are connected to the controller with a photocoupler circuit for over-current protection. If the moisture level is below the defined value so, generate the signal to the controller of this field water requirement. The ESP32 offers a combination of wireless connectivity, low power consumption, affordability, ease of programming, and community support, making it a suitable choice for building smart irrigation systems. Pairing it with a 20-watt solar panel ensures that the system can operate efficiently while being powered by renewable energy. The brain box system control strategy of hardware implementation is shown in Figure 4.

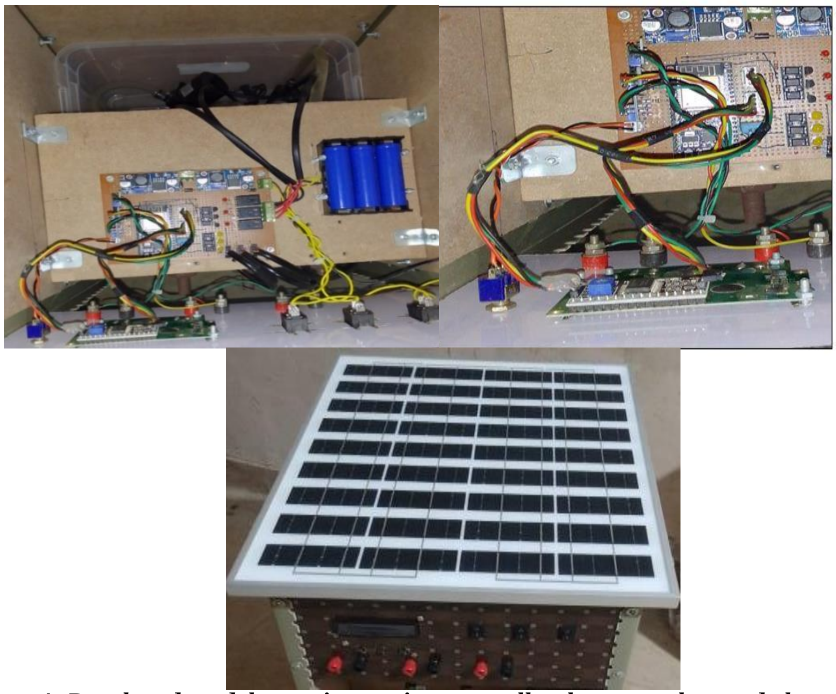

Figure 4: Developed model contains a microcontroller, battery, relay, and charge controller

***Software Implementation*:** Figure 5 shows the Arduino IDE programming and these are used in this study to interface all equipment parameters. All values are inserted into this database software, and the values burn all codding and then get the defined results. Moisture sensors sense the moisture quantity in the field. If the moisture quantity reduces to a low level, the sensor sends a signal to the controller. The controller automatically triggered the relay to start the pump in the needy field for ten seconds. After ten seconds, the pump was off due to power and water savings. Solar panels and batteries are directly connected to the DC power supply.

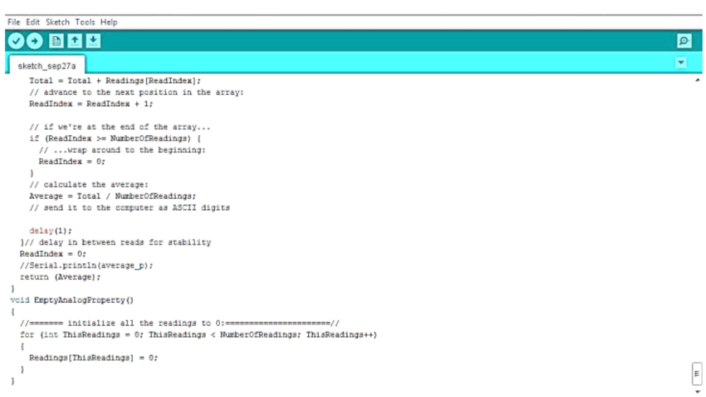

Figure 5: Arduino IDE Programming

***Mathematic Modelling*:** This system is based on three moisture level sensors, and three water DC pumps to monitor three different field moisture conditions. If the field moisture is down to a certain value so only operate the field DC pump. Water requirement at a time in two fields so only the DC pump is operating after completing the operation of pump number, then automatically operate the other pump due to power saving protocols. Three flow sensors are installed in this study to calculate the overall water-consuming quantity. Every pump has a flow sensor to calculate the water amount. A 16x2 digital LCD display is used to show the overall activity of the circuit. The display shows the following parameters: moisture, temperature, water flow amount in a liter, pump switching status, moisture, and humidity adjustment option. A toggle switch is installed to control the circuit, and three switches are installed for solar energy, charging circuit, and pump.

Current calculation of Solar panel at the maximum power point

$$P = V \times I \text{ -------- (i)}$$

Where P is the solar panel output in watts, V is the voltage across the panel, I is current through the solar panel,

$$\text{Maximum Power of panel } (P_{max}) = 20 \text{ watt}$$

$$\text{Voltage at maximum power } (V_{mp}) = 18.9 \text{ V -------- (ii)}$$

$$\text{Short-circuit current } (I_{sc}) = 1.58 \text{ A}$$

Now we calculate maximum power point current (I_{mp}) using this formula Equation (ii) value put in the Equation (i)

$$P_{max} = V_{mp} \times I_{mp}$$

$$20 \text{ watt} = 18.9 \text{ V} \times I_{mp}$$

$$\text{Now, solve for } I_{mp} \text{-------- (iii)}$$

$$I_{mp} = \frac{20\ W}{18.9}$$

Now calculate the equation (iii) value and get the answer

$$I_{mp} = 1.058 \text{ A} \quad \text{-------- (iv)}$$

This value directly impacts the solar panel efficiency and performance this value identifies the solar panel rating as correct which we have used in this study because the total current of the circuit is less than 1 ampere. So the solar panel is working properly in the same way our study efficiency increases.

DC pumps current equation

$$I = \frac{P}{V} \text{ -------- (v)}$$

Where I is the current in amperes P is the power in watts, V is the voltage in volts, Power of the pump is 5 watts

Supply voltage of the pump,

$$V = 12V \text{ -------- (vi)}$$

The operating time is 10 seconds, the Flow rate is 10 L/min, Flow height is 5 meters

Now we find out the current consuming value of the pump if 10-second running helps this equation:
Equation (vi) value is put in the Equation (v) and got pump current value.

$$I = \frac{6}{12}$$

$$I = 0.5\ A \text{ -------- (vii)}$$

Only one pump current consumes 0.5 ampere for 10 seconds of operation. Three DC pumps are installed in this prototype but at a time only one pump operates due to power saving protocol. In other way at the same time requires water in more than one field but pumps operate one by one due to power saving and growing efficiency.

Battery charging circuit calculation:

The battery voltage per cell is 3.7 DC volts, number of cells whole battery bank is three, so the total voltage of the battery is 11.1 DC volts.

Battery capacity 1200 mAh which is equal to 1.2 ampere-hours (Ah). Battery charging time is 0.5 hours in case of battery total discharged so only 30 minutes are required to charge the whole battery.

Solar panel maximum current (I_{mp}) is 1.058 A.

Calculate the required voltage for charging the battery.

$$I = \frac{\text{Battery capacity (Ampere hours)}}{\text{Charging time (hours)}}$$

This system charges battery in the 30 minutes.

$$I = \frac{1.2}{0.5} \text{ -------- (viii)}$$

$$I = 2.40\ A$$

The battery charging parameters are the following:

$$V = \frac{\text{Power (watt)}}{\text{Charging current (Ampere)}} \text{ -------- (ix)}$$

Now put the value of equation (ix)

The charging current is 2.40 A and solar power is 20 watts input equation (viii)

$$\text{Voltage (V)} = \frac{\text{Power (watt)}}{\text{Charging current (Ampere)}}$$

$$\text{Voltage (V)} = A\ \frac{20}{2.4} \text{ -------- (x)}$$

$$\text{Voltage (V)} = 8.333\ V$$

The battery charging current is 2.40, and the battery charging voltage is 8.330 V
The above-mentioned parameters are used to detect the solar charger control specification. The effective utilization of this system with solar charge controller to provide power to the battery and the charging current is 2.40 A and the charging voltage is 8.330 V.

III. RESULTS AND DISCUSSION

In the outcome phase, the microcontroller and soil sensor were working experientially. The system works efficiently and controls the watering flow. The main sensor utilized is a soil sensor that detects the humidity of the system. The purpose of implementing this project is to lessen the water shortage and healthy growth. Furthermore, the system is eco-friendly, energy- and water-saving for the implementation of a smart agricultural system.

For the case study of Pakistan, an agricultural cooling system is considered a case study utilizing plant operation on solar power.

A. Location Analysis

For this study, Pakistan is selected as the study location. Figure 6 demonstrates the solar radiation statistics for the case study Pakistan,

B. Facility Analysis

To develop a facility analysis a simulation-based solar-powered irrigation model is designed on Dip Trace Software. The coordination control strategy that combines soil moisture and humidity sensors of solar power automatic irrigation systems is implemented. Figure 7 is the schematic design of this system using Dip Trace Software. The modeling parameters are shown in Table 6.

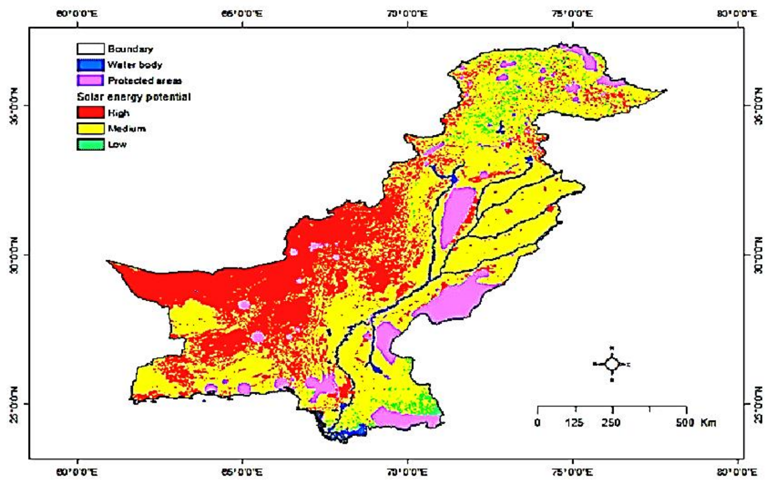

Figure 6: Pakistan Solar Radiation

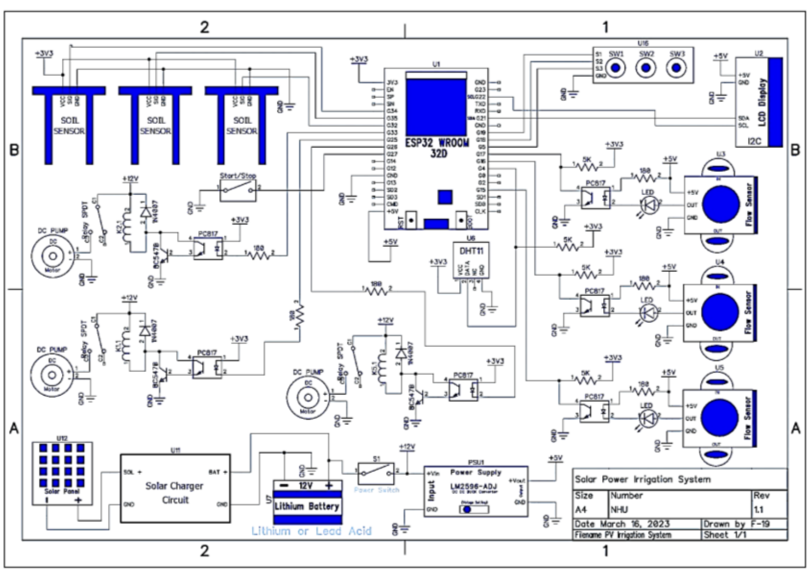

Figure 7: Schematic of the Solar Power Automatic Irrigation System

IV. Conclusion

The cumulative increase in power shortage, the solar-based automated irrigation system is implemented for the case study Pakistan has been conducted. Pakistan has an excessive potential for power generation using photovoltaic technology. The implementation of a 20-watt solar power automatic plant in Pakistan is a model for local empowerment of the agricultural sector for sustainable development and reduction of emissions. Step-by-step techniques were sensibly observed when assembling all the parts fixed in the control of the whole system to confirm operative functioning condition. The system works automatically via a triggered response by the soil humidity instruments that sense the humidity level of the soil as it affects altered plant development. The humidity sensor transmits the signal to actuate the DC pump, which uses pipes to carry water from the source to the plant if the humidity level is discovered to be below a certain threshold. When the set value humidity level is reached, the system cuts the water flow on its own, and the Water Pump is switched OFF. Therefore, there is also the trend to decrease water usage in a condition of water shortage resulting from uncomplimentary climatic and weather situations. Also, there is availability of a continuous power source to the whole system, using solar energy which is frequently used to charge the battery that delivers electrical energy to power the water pump. Thus, the main goal is to implement a smart efficient, economical, and

Table 6: Modelling Parameters for the Equipment

Parameters	Description
System voltage	**12 VDC**
Controller supply	**3 VDC**
Humidity sensor Vcc	**3.5 VDC**
DC pump Vcc	**12 VDC**
Pump current	**2 A**
Solar Pmax	**20 W**
Solar current at Pmax	**1.06 A**
Voltage at Pmax	**18.9 V**
Solar Short circuit current	**1.28 A**
Solar Open circuit voltage	**22.52 A**
Battery voltage	**12 VDC**
Battery capacity	**1200 mAh**
LCD module voltage	**5VDC**
Overcharge voltage	**3.9~4.35V ± 0.05V**
Flow sensor supply	**3.5 VDC**
Flow sensor current	**10 A**

useful irrigation system for farmers based on large and small-scale systems. The result showed a cumulative analysis of the application of an automatic solar power irrigation system. A modified model was used to determine the control strategy of this solar power irrigation system. The utilization of this scheme lessens the manual human interface for irrigation systems. The development of this automated system is a sustainable approach to healthy growth. Implementing this study can significantly enhance the production and monitoring of conventional agricultural systems.

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