Solar Powered Smart Irrigation System

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Abstract: **Integrating solar energy with irrigation systems has resulted in smart, energy-efficient, cost-effective, and environmentally sustainable irrigation systems. This research paper provides an overview of solar power smart irrigation systems, highlighting their components, working principles, and performance. The various types of smart irrigation systems based on different control strategies and sensors are discussed, along with their advantages and limitations. The potential of solar power smart irrigation systems in increasing water-use efficiency, reducing water waste, and improving crop yields is also discussed. Additionally, the current state-of-the-art and future trends in solar power smart irrigation systems are presented. Overall, this research provides a comprehensive understanding of solar power smart irrigation systems and highlights their potential in addressing the global water crisis and promote sustainable agriculture.**

Keywords: **Raspberry Pi 3B+, Solar panel, Lead acid battery, Digital solar charge controller, DC-to-DC buck converter, Sugar cube relay, DC water pump, PC817 Optocoupler, BC547 transistor, 1N4007 diode, IN4148 diode, LED, Capacitor, Resistor, Small copper clad PCB.**

1. Introduction

The solar-powered smart water irrigation system is an electronic-based embedded system designed for smart agriculture purposes. With the help of such a system, farmers can save lots of water as it is promising automatic control of water pumps. By using various soil moisture sensors this system can control water pumps automatically based on soil moisture level. Apart from water pump control, the system is also integrated with a webpage GUI which continuously shows system information such as soil moisture level from all sensors, water pump status, and other system-related information. With the help of local n/w and client-server (HTTP over tcp-ip) web interface, one can access the webpage with the help of local IP (or URL). All input and output devices are interfaced and controlled through a Raspberry Pi 3b+ SBC (Single Board Computer), which is a computer system in a single-board package. As it is a computer system that can be booted with a dedicated kernel and OS (Operating System) by flashing an OS image into a micro-SD card which acts as a hard-disk storage drive to store system binaries as well as user non-volatile data (text, applications, media, etc.,). For I/O devices interfacing this SBC consists of various multifunctional GPIOs (General Purpose Inputs & Outputs) to which multiple sensors and other output devices are connected. The system is booted with Linux Debian distro-based OS (Raspbian) which also has Desktop GUI and terminal/CLI interface to run IDE for programming purposes. For I/O control and web-socket programming, various libraries and packages are used. The complete application for smart agriculture systems is implemented in embedded Python programming.

2. Hardware and Software Design

1) Raspberry Pi 3 Model B+

The Raspberry Pi 3 Model B+ is a single-board computer that offers improved performance and features compared to its predecessors. It is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad-core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT The dual-band wireless LAN comes with modular compliance certification, allowing the board to be designed into end products with significantly reduced wireless LAN compliance testing, improving both cost and time to market. The Raspberry Pi 3 Model B+ maintains the same mechanical footprint as both the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B.
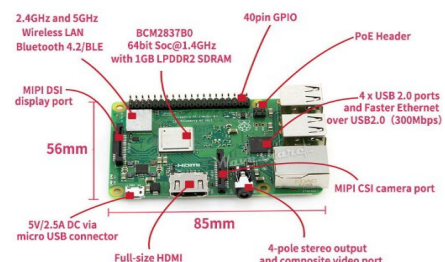

Fig. 1. Raspberry Pi 3 Model B+

2) Solar Panel

These panels are designed with solar cells composed of semiconductor materials. The main function of Solar panels is to convert solar energy into DC electrical energy generally of 12V, which is further used for the rest of the circuit. The number of cells required and their size depends on the rating of the load. The collection of solar cells can produce maximum electricity. But, the solar panel must place exactly at right angles to the sun's rays.

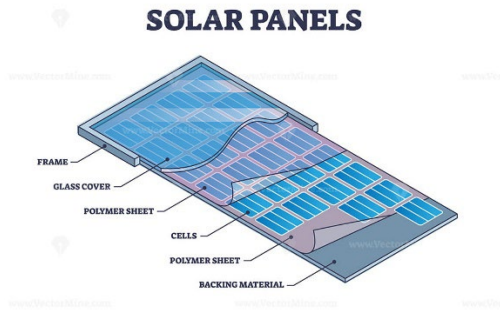*Corresponding author: meghadharmik19@gmail.com

Fig. 2. Solar panel

3) Water pump

A submersible pump (or sub-pump, electric submersible pump) is a device that has a hermetically sealed motor close-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation, a problem associated with a high elevation difference between the pump and the fluid surface. Small DC Submersible water pumps push fluid to the surface as opposed to jet pumps having to pull fluids. Submersibles are more efficient than jet pumps. It is usually operated between 3v to 12v.
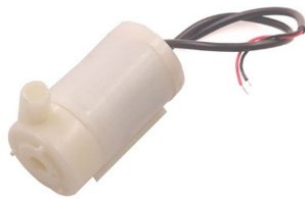

Fig. 3. Water pump

4) Transistor (BC-547)

A BC547 transistor is a negative-positive-negative (NPN) transistor that is used for many purposes. Together with other electronic components, such as resistors, coils, and capacitors, it can be used as the active component for switches and amplifiers. Transistors have an emitter terminal, a base or control terminal, and a collector terminal. In a typical configuration, the current flowing from the base to the emitter controls the collector current. A short vertical line, which is the base, can indicate the transistor schematic for an NPN transistor, and the emitter, which is a diagonal line connecting to the base, is an arrowhead pointing away from the base.
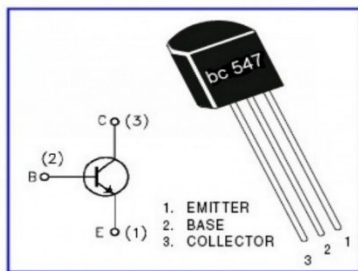

Fig. 4. Transistor BC547

5) PC817 Optocoupler

An optocoupler also called an optoisolator, photo-coupler & optical isolator is one kind of semiconductor device that allows the electrical signal to transmit between two isolated circuits through light. This component includes two parts an LED and a photosensitive device. Different kinds of optoisolator ICs are available like PC817 IC, MOC3021 IC, MOC363 IC, MCT2E IC & PC817 optocoupler. PC817 IC is an optocoupler that includes a phototransistor and an IR diode. In various circuits, filters play a key role to remove the noise. When the circuit including the resistor and capacitor always eliminates the noise from the incoming signal however the resistor & value capacitor frequently depends on the inward signal.
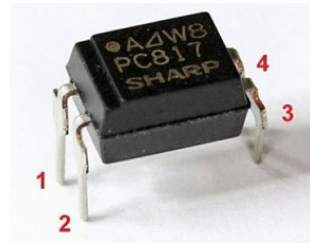

Fig. 5. PC817 optocoupler

6) Diode (IN4007)

In electronics, a diode is a two-terminal electronic component that conducts primarily in one direction (asymmetric conductance), it has low (ideally zero) resistance to the flow of current in one direction, and high (ideally infinite) resistance in the other. A semiconductor diode is a crystalline piece of semiconductor material with a p–n junction connected to two electrical terminals.
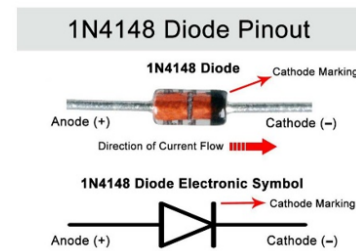

Fig. 6. IN4007 diode

7) IN4148 diode

Fig. 7. IN4148 diode

A diode is a device that allows current flow through only one direction. That is the current should always flow from the Anode to the cathode. The cathode terminal can be identified

by using a grey bar as shown in the picture below. For IN4148 Diode, the maximum current carrying capacity is 300mA, it can withstand peaks up to 2A. The specialty of this diode is its fast recovery time of 8ns at a forward current of 10mA, hence this diode is used in places where fast switching is involved.

8) Sugar cube relay

A sugar cube relay is an electromagnetic component that is used to isolate circuits electrically and join them magnetically. They are very beneficial gadgets and permit one circuit to exchange to any other one even as they may be separate. They are frequently used to interface a digital circuit (operating at a low voltage) to an electrical circuit that works at a very excessive voltage.

Fig. 8. Sugar cube relay

9) Resistors

Carbon composition resistors (CCR) are fixed values. They are made out of fine carbon particles mixed with a binder (for example clay). After baking, it has a solid form. Although carbon composition resistors are widely applied in circuits, the majority of resistors today are made by the deposition of a metal or carbon film over a ceramic carrier.
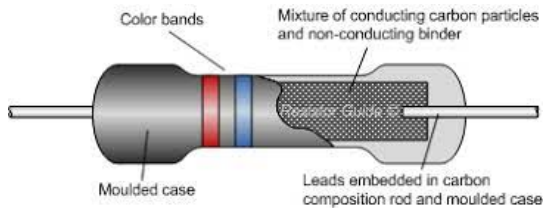
Fig. 9. Resistor
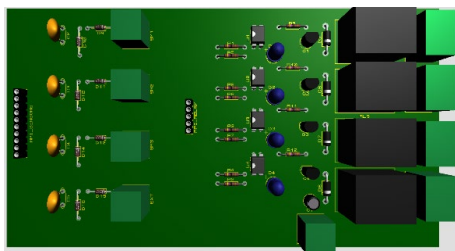
10) Small copper clad PCB

Fig. 10. Small copper clad PCB

A printed circuit board, or PCB, is used to mechanically support and electrically connect electronic components using conductive pathways, tracks, or signal traces etched from copper sheets laminated onto a non-conductive substrate. Copper Clad Laminate, abbreviated to CCL, is a type of base material for PCBs. With glass fiber or wood pulp paper as reinforcing material, a copper-clad board is a type of product through lamination with copper clad on either one side or both sides of the reinforcing material after being soaked in resin.

11) Lead acid battery

A lead acid battery is a rechargeable battery that uses lead and sulphuric acid to function. The lead is submerged in the sulphuric acid to allow a controlled chemical reaction. This chemical reaction is what causes the battery to produce electricity. Then, this reaction is reversed to recharge the battery.

Fig. 11. Lead acid battery

12) 16GB MicroSD card

MicroSD cards are more commonly used to expand the storage system of smartphones, drones, gaming devices, and cameras. Hardware devices are also backward compatible with microSD cards, just like full-sized SD cards. The same rules apply to microSD cards as they do to SD cards.

Fig. 12. 16GB micro-SD card

13) Capacitor

Fig. 13. Capacitor

An electrolytic capacitor is a type of capacitor typically with a larger capacitance per unit volume than other types, making them valuable in relatively high-current and low-frequency electrical circuits. This is especially the case in power-supply filters, where they store the charge needed to moderate output voltage and current fluctuations, in rectifier output, and especially in the absence of rechargeable batteries that can provide similar low-frequency current capacity. They are also widely used as coupling capacitors in circuits where AC Should be conducted but DC should not; the large value of the capacitance allows them to pass very low frequencies. capacitors.

14) LEDs

LEDs are a particular type of diode that convert electrical energy into light. LED stands for "Light Emitting Diode." And this is reflected in the similarity between the diode and LED schematic symbols:

Fig. 14. LED symbol
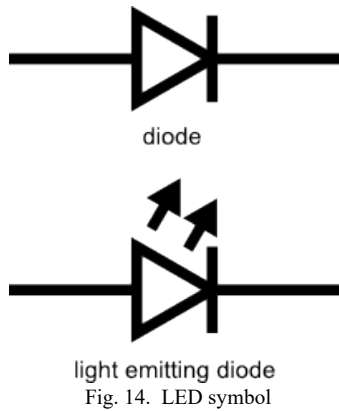
In short, LEDs are like tiny lightbulbs. However, LEDs require a lot less power to light up by comparison. They're also more energy efficient, so they don't tend to get hot like conventional lightbulbs do (unless you're pumping power into them). This makes them ideal for mobile devices and other low-power applications. Don't count them out of the high-power game, though. High-intensity LEDs have found their way into accent lighting, spotlights, and even automotive headlights.

Fig. 15. LEDs

15) DC-to-DC Buck Converter

Switching power supplies offer higher efficiency than traditional linear power supplies. They can step-up, step-down, and invert. Some designs can isolate output voltage from the input. This article outlines the different types of switching regulators used in DC-DC conversion. It also reviews and compares the various control techniques for these converters.

Fig. 16. DC-to-DC Buck Converter

16) Buzzer

An audio signaling device like a beeper or buzzer may be electromechanical or piezoelectric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarms, music, bell & siren.

Fig. 17. Buzzer

17) Digital solar charge controller

A solar charge controller is used to charge the battery by regulating and controlling the output from the solar PV array; it also protects the battery from being overcharged or over-discharged. Overcharging of the battery creates a release of hydrogen and oxygen gases from the electrolyte, which could cause explosion and failure. If the battery is allowed an excessive discharge of current,

the battery charge will be drained. So, the life of the battery will be reduced and cause premature failure of the battery. Solar charge controllers redirect or switch off all or part of the array to reduce the current flow to the battery when it is becoming full. If the battery is discharged below a specified voltage, which is a low voltage preset point, the disconnection of some or all the loads takes place.

Fig. 18. Digital solar charger controller

B. Software Used

1) Raspbian OS

Raspbian is a free operating system based on Debian optimized for Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make your Raspberry Pi run. However, Raspbian provides more than a pure OS: it comes with over 35,000 packages, pre-compiled software bundled in a nice format for easy installation on your Raspberry Pi.

2) Thonny Python IDE

An integrated development environment (IDE) facilitates computer programmers by integrating fundamental tools (e.g., code editor, compiler, and debugger) into a single software package. Users do not need to install the language's compiler/interpreter on their machines; an IDE provides the

environment itself. Thonny is a free, dedicated IDE for Python designed for beginners.

3) Proteus ISIS & ARES

Proteus is a software suite containing schematic, simulation as well as PCB designing. ISIS is the software used to draw schematics and simulate the circuits in real-time. The simulation allows human access during run time, thus providing real-time simulation. ARES is used for PCB designing. It has the feature of viewing the output in 3D view of the designed PCB along with components. The designer can also develop 2D drawings for the product.
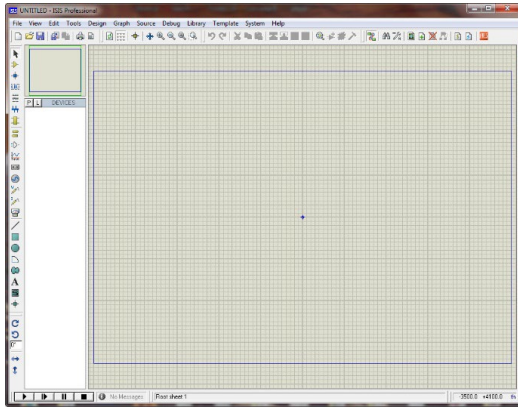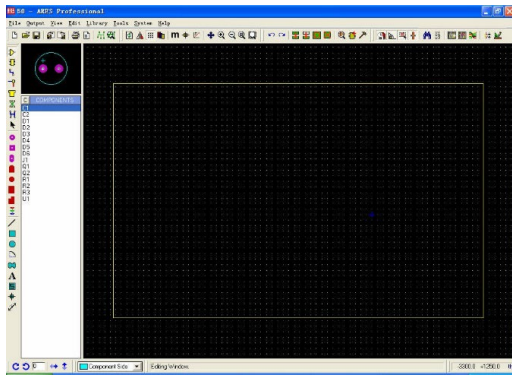

Fig. 19. ISIS software

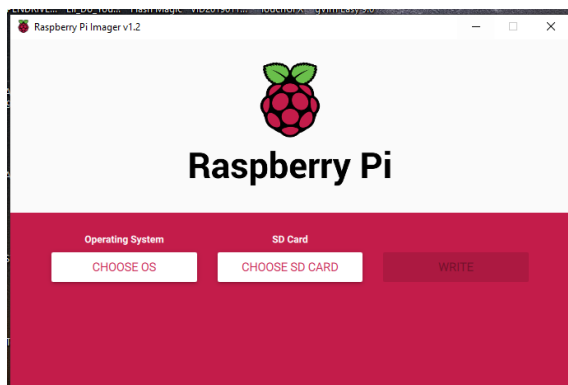Fig. 20. ARES software

4) Raspberry Pi Imager

Fig. 21. Raspberry Pi Imager

Raspberry Pi Imager is an application that helps users to install different operating systems into an SD card. Once the

operating system is installed onto the SD card, we can put the SD card into our raspberry pi to boot it and work on it.

5) Python3 Interpreter

Python 3 interpreter program that interprets other programs is known as an interpreter. When we build Python applications, it translates the developer's source code into an intermediate language. Python 3 interpreter is very useful and important to run and execute Python code.
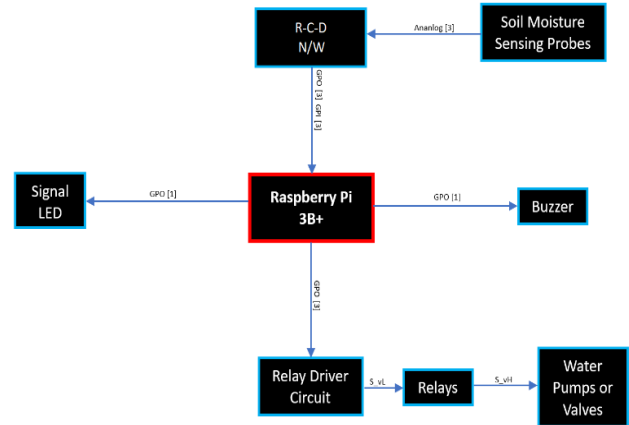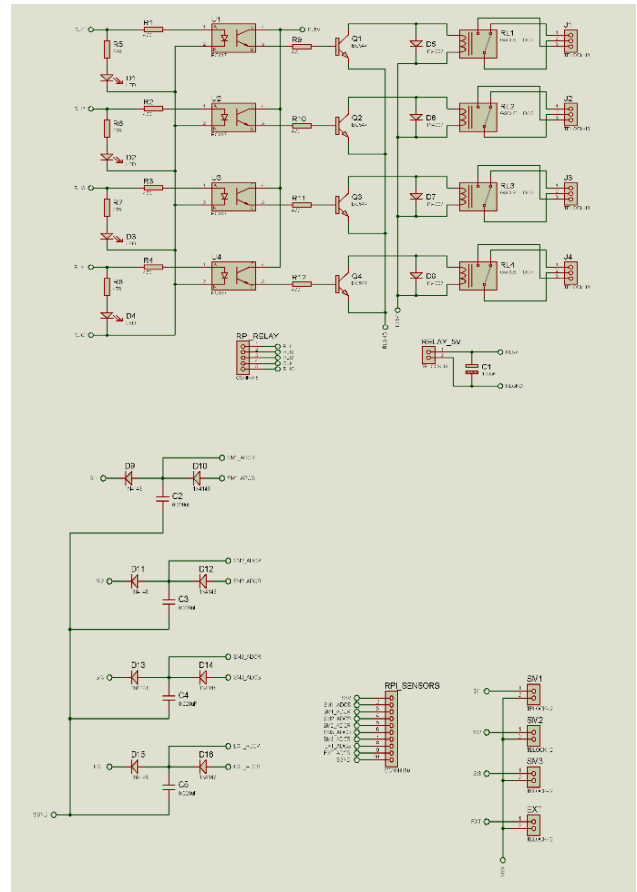

Fig. 22. Block diagram

Fig. 23. Circuit diagram

3. Working

1) The solar panel converts sunlight into electrical energy. This energy is used to charge the lead-acid battery through the

digital solar charge controller. The charge controller ensures that the battery is charged optimally and prevents overcharging or deep discharging.

2) The DC-to-DC buck converter regulates the voltage from the battery to a level suitable for powering the Raspberry Pi and other components. It steps down the higher battery voltage to the desired lower voltage required by the system.

3) The Raspberry Pi 3B+ acts as the central control unit of the system. It runs the necessary software and algorithms to monitor the agricultural environmental conditions and control the irrigation process.

4) Soil moisture sensor is connected to the Raspberry Pi. These sensors collect real-time data about agricultural conditions. the soil moisture sensors measure the moisture content in the soil.

5) After that Raspberry Pi processes the sensor data using the software and algorithms programmed on it. It analyzes the collected data, compares it to predefined thresholds or patterns, and determines whether the plants require watering based on the programmed criteria.

6) Then Raspberry Pi decides that irrigation is necessary based on the sensor data analysis, it activates the irrigation system. It triggers the PC817 optocoupler, which activates the BC547 transistor. The transistor, in turn, energizes the sugar cube relay, allowing current to flow through it. This activates the DC water pump and starts the irrigation process.

7) The diodes, such as the 1N4007 and IN4148, provide electrical protection. The 1N4007 diode is connected across the pump to protect against voltage spikes when the pump is turned off. The IN4148 diode can be used to protect against reverse polarity or voltage spikes in other parts of the circuit.

8) The LEDs, such as the green and blue LEDs, are connected to the Raspberry Pi to provide visual indications. For example, the green LED can indicate that the system is operational, and the blue LED can indicate when the pump is activated or the irrigation process is in progress.
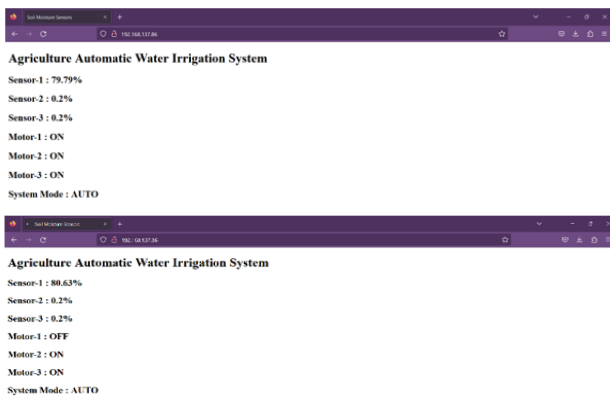

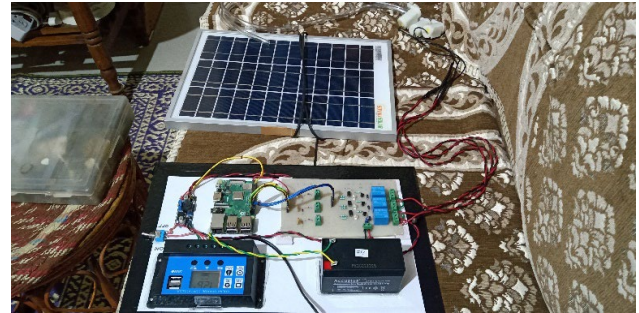Fig. 24. Agriculture automatic water irrigation system

Fig. 25. Experimental hardware setup

A. *Advantages*
1. Solar power is pollution free and causes no greenhouse gases to be emitted after installation.
2. Renewable clean power that is available every day of the year, even on cloudy days produces some power.
3. Return on investment unlike paying utility bills.
4. You can also adjust the water usage by adjusting the control valve.
5. This system is simple and low-tech, so there are fewer things to go wrong.

B. *Disadvantages*
1. Installation cost is high
2. Weather dependant

4. Conclusion and Future Scope

The proposed system is beneficial to the farmers when this system is implemented. And also useful to the government with solar panel energy, a solution for the energy crisis is a problem. When the soil needs water as indicated by the sensor this automatic irrigation system is implemented. Then the various crops are also irrigated with this system by turning on the button.

According to the button pressed, the irrigation system detects the crop's moisture level. For example, in Wheat, Paddy, and Sugarcane crops moisture content of the soil is detected and irrigated automatically. The automatic irrigation system is used to optimize the usage of water by reducing wastage and reducing human work. The energy needed for the water pump and controlling system is given by solar panels. Solar panels are small grids that can produce excess energy. Using solar energy reduces the energy crisis problem.

The system requires minimal maintenance and attention because they are self-starting. To further enhance the daily pumping rates tracking arrays can be implemented. This system demonstrates the feasibility and application of using solar PV to provide energy for the pumping requirements for sprinkler irrigation. Even though this system requires more investment but it solves more irrigation problems after a long run of this

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