A Smart Garden System with a Dual-Axis Solar Tracker

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Abstract

This paper designs a smart garden system to overcome the hassles associated with manual watering, to reduce the maintenance required for the garden system, and to automate this watering process. The Arduino, relays, sensors, valves, pumps used in this standalone garden system are all powered by a dual-axis solar tracker system. Fritzing software is used to develop a printed circuit board for the smart garden system to improve the aesthetics and to reduce the number of connections from the Arduino. A prototype of this garden system is developed with the main advantages of easy installation, reduced maintenance, water conservation, and need-based garden watering.

Keywords: Arduino, Garden System, Moisture Sensor, Smart Garden, Solar Tracker, Water Conservation.

1. Introduction

Garden systems are developed and maintained in offices, malls, schools, educational institutions, governments, and houses to keep us fresh, energetic, and to improve the aesthetics of the place. These gardens also help us to reduce the pollution level and to increase the oxygen level in the surroundings. To optimize the electricity and water consumption of the garden system has led to the development of autonomous systems. These automation systems are used in many places to reduce the amount of work done during maintenance, save water, and to simplify the mundane jobs. A creative solution to overcome the maintenance problem of the garden system is developed in this paper to monitor and water the garden effectively. This smart garden system by using the Arduino program controls the relays and pumps which are used to water the garden based on the inputs received from the sensors.

An *iRain* system has been developed in [1] for irrigating urban gardens. This scheme is developed using *ZigBee* and implements the rational use of water. In [2], authors have established a *Raspberry-Pi* based irrigation monitoring and management system. This system is an IOT based mobile integrated garden system. In [3], a *Raspberry-Pi* incorporated garden system is developed, and the effect of light intensity on the growth of plants has been investigated. An adaptive home irrigation system based on wireless sensor network has been implemented in [4]. In [5], an application has been developed, which can be used with the mobile to monitor the maintenance process of the garden. A prototype of a smart irrigation system is discussed in [6-7]. The main disadvantage of the system proposed in [7] is the complexity of using both *Raspberry*-Pi and *Arduino*. The problem is user must be aware of the programming and implementation of both the controllers when implementation with one is convenient and possible.

The literature survey of the existing solutions in this area indicates there are scopes for improvement in terms of design, development, innovation, and implementation. In the works available in literature, a separate supply is used for powering the components used in the garden system but in this work solar panel powers all the components. The efficiency of the solar system is improved by using dual-axis solar tracker. Another advantage of the proposed system compared with the existing design is its easy installation and portable design. An innovative need-based watering of plants compared to direct watering to preserve water used for the garden system is proposed. The prototype of the proposed system is

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developed and used in the hallway of the electrical department at Jubail Industrial College, Saudi Arabia.

The seasonal variation and its impact on smart watering have been studied in [8]. Testing and implementation of a fuzzy logic incorporated irrigation system using *ZigBee* are carried out in [9]. An efficient smart irrigation system with a low budget has been incorporated in [10]. The design of the in-house garden using solar tracker has been discussed in [11]. The literature surveys on solar trackers are available in [12-15].

The paper is organized as follows: the next section describes the design of the smart garden system followed by future work and conclusion.

2. Design of Smart Garden System

This section discuss the design of the solar tracking system using sensors and its connection to *Arduino*. The prototype uses two *Arduino's*. One of them is *ArduinoMega* which is the brain of this watering system. An *Arduinonano* is used to control the solar tracker. Even though one Arduino could control the entire system, the prototype uses two *Arduino's* to improve the aesthetics and to simplify the connections. The battery charged through the solar tracker via a charge controller powers the *Arduino*. This section discuss the design of the solar tracking system using sensors and its connection to *Arduino*. The prototype uses two *Arduino's*. One of them is *ArduinoMega* which is the brain of this watering system. An *Arduinonano* is used to control the solar tracker. The battery charged through the solar tracker via a charge controller powers the *Arduino*. This section also discuss the system design using *Fritzing* software.

A.Dual-Axis Solar Tracker System

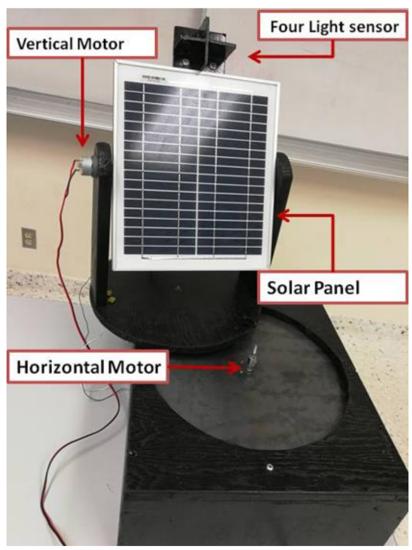

Fig. 1.Prototype of Dual Axis solar tracker system

Even though authors of this paper have developed efficient solar tracking system using Homer software [16-17], to reduce the cost of the prototype the authors have used just four sensors for tracking as shown in Fig. 1. Fig.2 shows the block diagram of the dual-axis solar tracker. The purpose of dual-axis solar tracker in this design is as follows:

- To make the garden system standalone where the tracker is sufficient to power all the sensors, pumps, and *Arduino* used in the design. This design does not use any external source of power.
- To align the solar panel with the sun thorough out the day.
- To maximize the energy captured from the sun.
- During the night if there is a light source, then the tracker can align itself towards the source.

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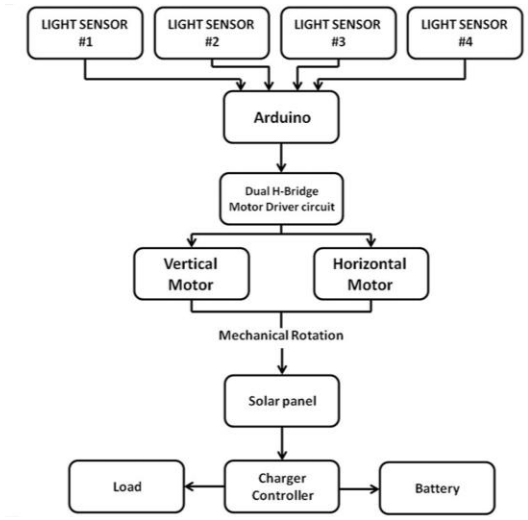

Block Diagram of Dual Axis solar tracker system

The vertical and horizontal electric motors of the solar tracker are *RioRand* DC motors with the following specification: 12 V, 0.07 A, 3.5 RPM, high torque, 37 mm gearbox. These motors are capable of rotating a 10 W, 1.08 kg, 21.6 V, poly-si, solar panel which has a dimension of 340*290*17 mm. The open-circuit voltage of the solar panel is 21.6 V, and short circuit current is 0.61 A. The solar tracker is controlled using a dual H bridge controller (L298N) connected to an Arduino. Fig.1 shows the prototypes of the solar tracker with the sensors. The readings obtained from the four Light Dependent Resistors (LDR's) are compared with the readings of the variable resistor connected to the Arduino. The resistance of the LDR will change from 70MΩ in the dark to 200Ω in the daylight. The set point of the variable resistors is used to vary the sensitivity of the system. The Arduino is programmed to decide which motor to rotate and sends a pulse to a dual H-bridge motor driver to move the corresponding motor. The programming logic to control the dual-axis tracker is as follows:

- The light sensors are named as Top Right (TR), Bottom Right (BR), Top Left (TL), and Bottom Left (BL). The readings obtained from the light sensors are stored in the Arduino.
- The average value of the top (AVT) sensors is calculated as (TR+TL)/2 and stored in AVT. In the same way the average value of the bottom (AVB), the average value of the right (AVR) and the average value of the left (AVL) sensors are calculated and stored in the Arduino.
- The average difference of the top and bottom light sensors is calculated using the formula (AVT-AVB)/2 and stored in DV. In the same way, the average difference of the right and left light sensors are calculated and stored in DH.

TABLE I. CONTROL OF DUAL-AXIS TRACKER

DV>Set point & DH>Set point	**AVT>AVD**	**AVT<AVD**
AVL>AVR	VM-CW HM-CW	VM-CCW HM-CW
AVL<AVR	VM-CW HM-CCW	VM-CCW HM-CCW

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- The rotations of the motors are calculated based on the rules summarized in Table I. CW and CCW in Table I represent clockwise and counter-clockwise direction of the solar panel.

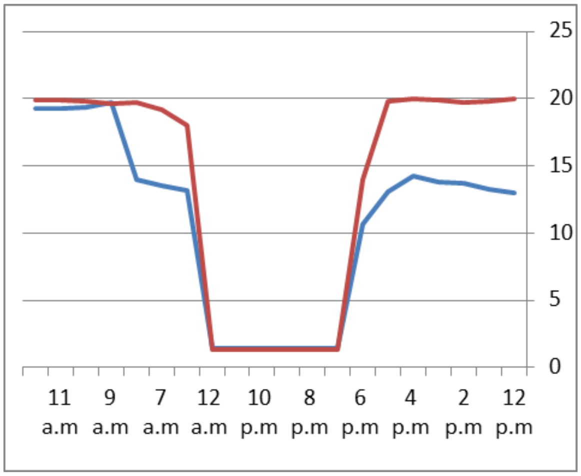

Fig 3. The output voltage comparison of the proposed dual axis solar tracker (red color) with static solar panel (blue color). The Y-axis represents the output voltage of the solar panel and X-axis represents the time.

The dual-axis solar tracker is connected to a charge controller circuit to control the charging process of the battery. The designed dual-axis solar system was tested every hour for one day by measuring its no-load voltage and comparing it with the static tracker. Fig.3 shows the plot of no-load voltage versus time. As seen from the plot shown in Fig.3 it is evident that dual-axis solar tracker can produce more voltage than a static tracker at any point of time, especially on the part of the day where there is sunlight.

A. Plant Watering System

The design of the proposed plant watering and water level indication system is shown in Fig. 4. In the prototype, there are two-soil moisture sensors (FC-28) connected to the two layers of plants in the design and they are watered through a pump connected to the water tank. The operating voltage of the moisture sensor is 3.3V to 5V. The sensor contains two probes and is also connected to a comparator LM393 chip. The sensor can be calibrated based on the plant to be watered. The sensor will measure the wetness of the soil and compare it with the set point and then will provide the Arduino with a high or low signal. The low signal indicates the soil is wet and high signal indicates soil is dry and plants need to be watered. The moisture sensor can be calibrated by adjusting a potentiometer which is located on the comparator chip. In this prototype, flowering plants will be used and hence the sensor is calibrated according to the water needs of the flowering plants. The flowering plants are potted in a *GARDENFLOR* potting soil. The Fig. 5 shows the connection diagram of the proposed smart garden system.

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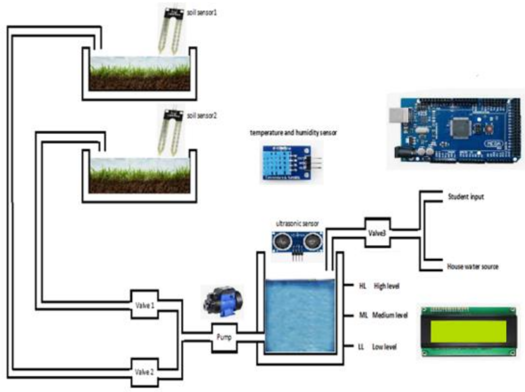

Fig. 4 Design of plant Watering System.

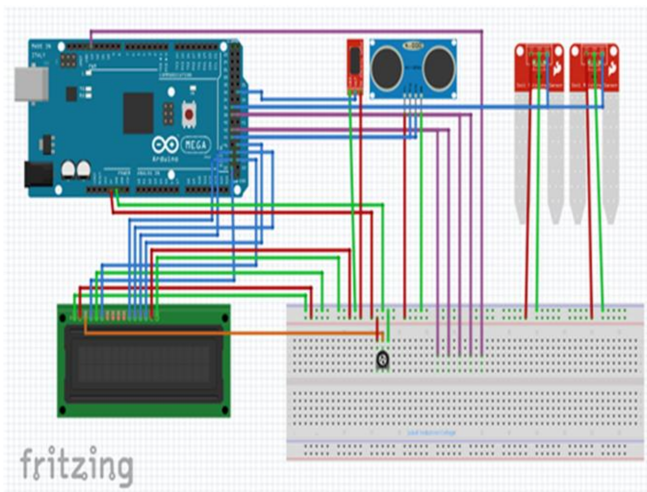

Fig 5. Connection diagram of smart garden system.

Based on the output of the soil sensor 1 which indicates the wetness of the soil and the ambient temperature measured by the temperature sensor (LM35) the valve 1 connected to the pump is opened to water the plants automatically. In the same way, the plant in layer 2 is watered automatically by opening valve 2. A low-pressure *JOVTOP* JT-800 solar DC water pump is used in this prototype. This model can work with a DC 6V-24V and has a power rating of 2W. The *K-Rui* valves used in this design can work with 12V DC voltage and has a power rating of 4.8W. Out of the three valves used in this prototype, only one valve operates at any point of time due to the rating of the solar panel, and this is achieved by efficient Arduino programming.

One of the main advantages of the system is the ability to reprogram the Arduino and customize the watering of the plants based on the need for each plant. This reprogramming of Arduino is more advantages when compared to the traditional method of watering the plants for the regular time duration in a day. This need-based watering of plants saves water and makes the proposed system efficient when compared to traditional methods.

A 9.5-litre water tank is connected on top with an ultrasonic sensor (HC –SR04) to measure the level of the water in the tank. One significant advantage of this sensor is the non-contact nature of this sensor concerning the water. The sensor requires a 3.3V-5V supply. The sensor calculates the time taken for the transmitted signal to be received by it. Based on the time, the distance of the water in the tank is calculated. This ultrasonic sensor has to be calibrated based on the water tank.

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An LCD indicates the level of water in the tank in percentage. In the prototype, if the distance of water from the sensor is 3cm, the tank is 100% full. If the distance measured is between 12 cm to 14 cm, the tank is 50% full. If the distance is more than 24 cm, then the tank is empty. The water in the tank is sufficient to water the plant for a month. A red LED, or a buzzer can also be used to indicate the low level of water but has been avoided in this prototype since an LCD is used.

To conserve water, an innovative idea is used in this project. This water tank has two inputs, as shown in Fig. 4. One of the inputs is from any water source available in the house/college, and another input is from a small green container where students can fill them with water manually, as shown in Fig. 6. It is prevalent in colleges students buy water bottles and sometimes could not complete the water. This water which is usually wasted by the students can be poured manually in the small green container attached to the prototype.

B. System Design using Fritzing

Prototype of smart garden system

The design of the prototype is carried out using *Fritzing* software [18]. The prototype of the proposed smart garden system is shown in Fig. 6. It has two levels for planting small plants. The water tank, the PCB, the battery, and all the connection is in the bottom of the prototype closed using the door and not visible. The prototype has wheels and is easily portable. Fig. 7 shows the PCB design and fabrication of the smart garden system. Fig. 8 shows the PCB design and fabrication of dual axis solar tracker.

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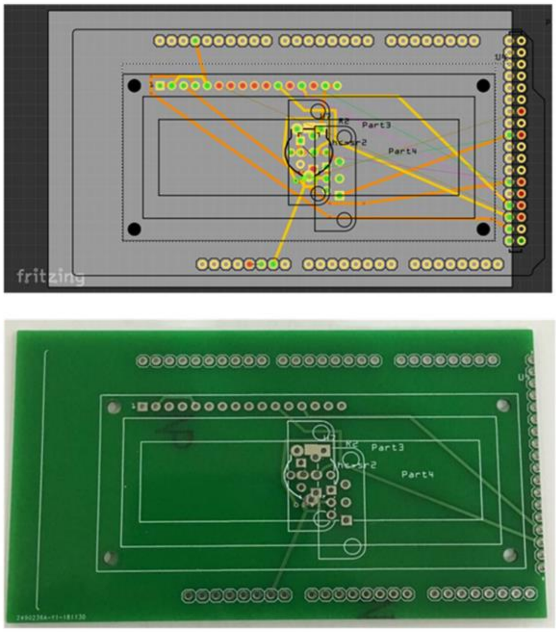

Fig. 7. PCB design and fabrication of smart garden system

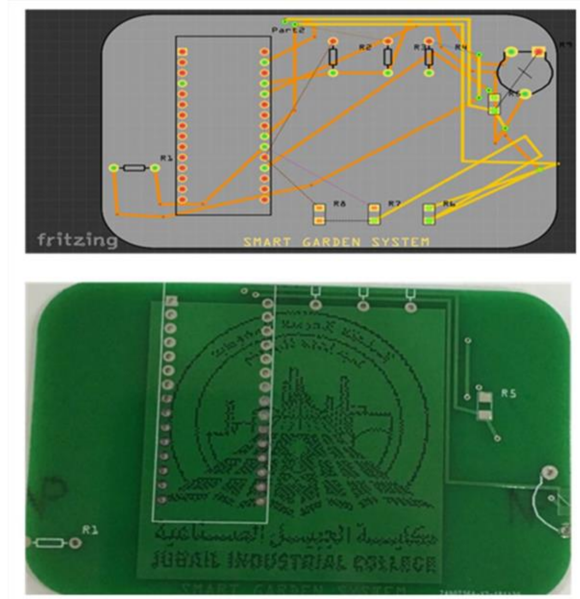

Fig. 8. PCB design and fabrication of dual axis solar tracker

3. Future Work

The design of the smart garden system is discussed in this paper. In future, a mobile app is planned to be developed using *Blynk* or *Cayenne,* which are IoT platforms with a drag and drop mobile application builder. Using this mobile application, the plant can be effectively monitored even when the institution or house is closed for a long vacation. A data logger is to be designed, and using a data logger the effectiveness of the solar panel, the growth of the plant and monitoring of the garden can be improved.

4. Conclusion

This paper describes the design of a smart garden system using *Arduino*. The design of the system, the connection diagram, the PCB layout is all developed using *Fritzing* Software. The main advantage of the proposed system is the need-based watering of the garden and very less maintenance. Moreover, it conserves water and the efficient dual-axis tracker system powers the system components without an external source of power which makes the prototype standalone. It also ensures the improvement of the aesthetics of the place. A dual-axis solar tracker system is designed to power the *Arduino* and the components which ensure no external source of power is needed for the system.

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