DESIGN AND IMPLEMENTATION OF MICRO-CONTROLLER BASED DUAL SOURCE AUTOMATIC RAIN-SHIELDED SUN DRYING SYSTEM

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Abstract

Sun drying of farm produce, clothing, and other materials often proved difficult during the rainy season. Materials may easily get soaked due to unexpected rainfall and the unavailability of human interventions. The objective of this paper therefore is to design and construct an automatic rain-shielded drying system as a solution to this problem. The system consists of a rain sensor, light-dependent resistor (LDR), digital humidity and temperature sensor (DHT), and Arduino microcontroller as the main components. The rain sensor which senses the rain and dryness sends the appropriate signal to the microcontroller to open or close the system accordingly. Similarly, the LDR takes care of day and night. The actuator for opening and closing of the system is 12 V, 80 rpm, 18 W worm gear DC motor. The system is powered by a solar power supply which makes it function as a stand-alone system as well as from the mains. There is also a provision for charging appliances as a 1000 VA inverter is incorporated into the system as an enhanced feature. The implementation of the system was carried out, tested, and functioned as expected. The system can be useful at home especially for nursing mothers and farmers to dry materials at any time.

Keywords: *Solar power, Rain-shield, Microcontroller*

Introduction

Drying is one of the most often employed techniques for preserving food or agricultural products as it decreases microbial degradation, and spoiling storage potential (Holdsworth, 2015; Jindarat et al. 2011). In Nigeria, most agricultural drying processes still adopt manual control methods as the design of efficient controls for the food drying process system appears complex (Tippayawong et al., 2008). Agriculture-related goods need hot air that is between 45 and 60 degrees, and about the same temperature ranges are needed for drying clothes as well. Materials dried under-regulated environment at a specific humidity level and temperature give a rapid superior quality of the dry product (Bolin et al, 2015). Though the sun has been utilized by humans as a natural means of drying clothing and farm produce for a long; the unpredictability of rainfall usually poses a challenge for sun drying, especially during the rainy season. An automatic cloth retrieval and drying system using a solar energy source, proximity sensor, rain detector, control unit, and DC motor has been reported. (Jian & Chu, 2013; Satish et al., 2017). However, the majority of these currently in-use machines are not only expensive but also consume energy. The objective of this paper is to design and construct a low-cost automatic stand-alone rain-shielded drying system using a sun and electric heater with electronic digital control. A microcontroller connected to a relay, switches, and additional driver circuits acts as a digital controller (Dugan, 2019; Joseph, 2021).

Methodology

Figure 1 shows the block diagram for the system. The heating element in most contemporary electric heaters is chrome wire (Henderson et al, 2015). Humidity sensors, water sensors, photo sensors, and temperature sensors are employed in this type of design. There are several designs of humidity sensors. In capacitive humidity sensors, the dielectric material is hygroscopic. The dielectric constants of a polymer film, which have a range of 2 to 15, are frequently used as a dielectric for capacitive humidity sensors (Anaa, 2021). A resistive humidity sensor also known as a hygristor or an electrical conductivity sensor uses the variation in resistivity measured between two electrodes to calculate the relative humidity. (Anaa, 2021).

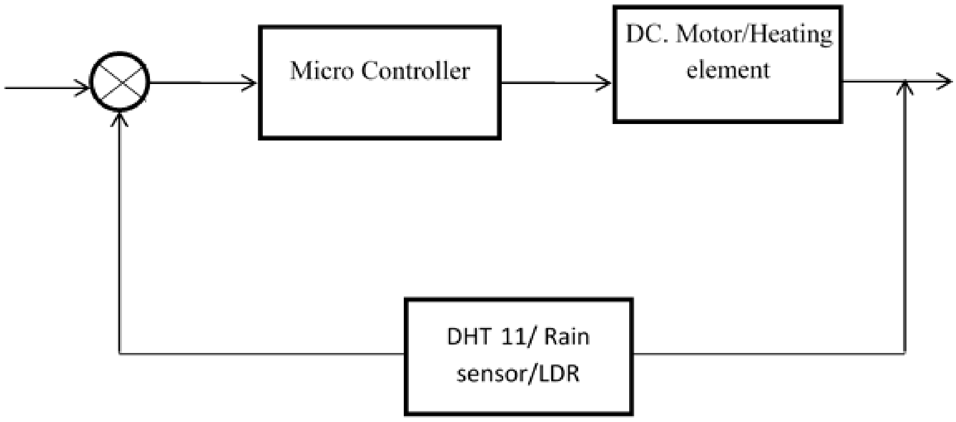

Figure 1: Block Diagram of the automatic rain shield drying system

The water sensor has a sensing pad and a sensor module as components. The sensor's module is both analog and digital. An analog signal between 5 V and 0 V is provided by the analog output and the digital output provides digital output for the built-in comparator circuit which can be connected to an Arduino board or a A5 V relay in other cases (Watelectronics, 2021). The values of the LDR's resistance can vary by order of magnitude, with the resistance value decreasing as the light intensity rises (Setya, 2019). Photoconductivity, which is an optical phenomenon, serves as the basis for how an LDR sensor functions. The material's conductivity increases when light is absorbed by it. (Setya et al., 2019). Relay is used as a mechanical switch with the ability to be controlled electronically via an electromagnet, as opposed to being manually turned on or off (Vamshidar, 2017). A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts (Fred, 2010). Due to their durability, simplicity of installation, and dependability of functioning, limit switches are utilized in a range of applications and settings.

Modelling of DC Motor

Controlling the speed of a DC motor can be done by using either armature current or field current (Ogunyemi, 2022). Figure 2 shows the circuit model for a separately excited DC motor.

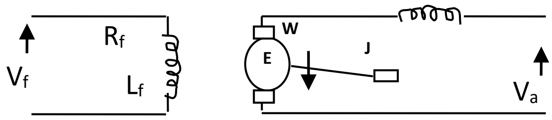

Figure 2: DC motor circuit model

$v_f = R_f i_f + l_f \frac{di_f}{dt}$…………………….. (1)

In Laplace transform we have

$v_f = (R_f + SL_f) I_{f(s)}$

Or

$I_{f(s)} = \frac{v_f}{(R_f + SL_f)}$……………………….. (2)

$w = \frac{d\theta_e}{dt}$ ……………………………… (3)

$w = S\theta_e$……………………………… (4)

The torque produced by the motor is equal to the flux which depends on the field current.

$T_m = K_m i_f t$ ………………………… (5)

Substituting Equation 2 into 5

$T_m = \frac{K_m V_{f(s)}}{SL_f + R_f}$ ………………………… (6)

Assuming there is no mechanical load on the shaft

$T_m = \beta \frac{d\theta_0}{dt} + J \frac{d^2\theta_0}{dt^2}$ ………………………… (7)

Taking the Laplace of this we have

$T_{m(s)} = JS^2\theta_0 + BS\theta_0$ ………………………… (8)

From equations (6) and (8), we have:

$$\frac{K_m V_{f(s)}}{SL_f + R_f} = (JS + B)w_0$$

Thus giving the transfer function as:

$\frac{w_o}{v_{f(s)}} = \frac{k_m}{(SL_f + R_f)(JS + B)}$ ………………………… (9)

Design analysis**:**

The Arduino UNO microcontroller was chosen in this system because it is user-friendly compared to other controllers (Alisher. 2022). Also, it can withstand DC input voltage between 6 V to 20 V compared to the PIC which can only withstand voltage between 5-6 V. The digital read-and-write pin feature of Arduino allows users to read and write the value of an input pin. The I/O mode is set using the pin mode.

Each digital pin of the Arduino microcontroller can be defined to function either as input or output. For instance, all the sensor used were defined to function as input to the microcontroller because they are taking information from the physical environment and then feeding the microcontroller to make decisions on the limit switch port. The motor and relay were defined to serve as output because they are to serve as the final control element. Each digital port of Arduino can supply a maximum of 500 mA, in case one needs to control equipment that is larger than the specified current; it's advisable to use a power transistor.

The Arduino digital port was used to control the two relays which serve as forward and reverse movement of the motor, once the relay receives the signal from the controller it either opens or closes the circuit, and the limit switch was used to stop the movement of the motor in either direction. Figure 3 shows the control circuit diagram for the system

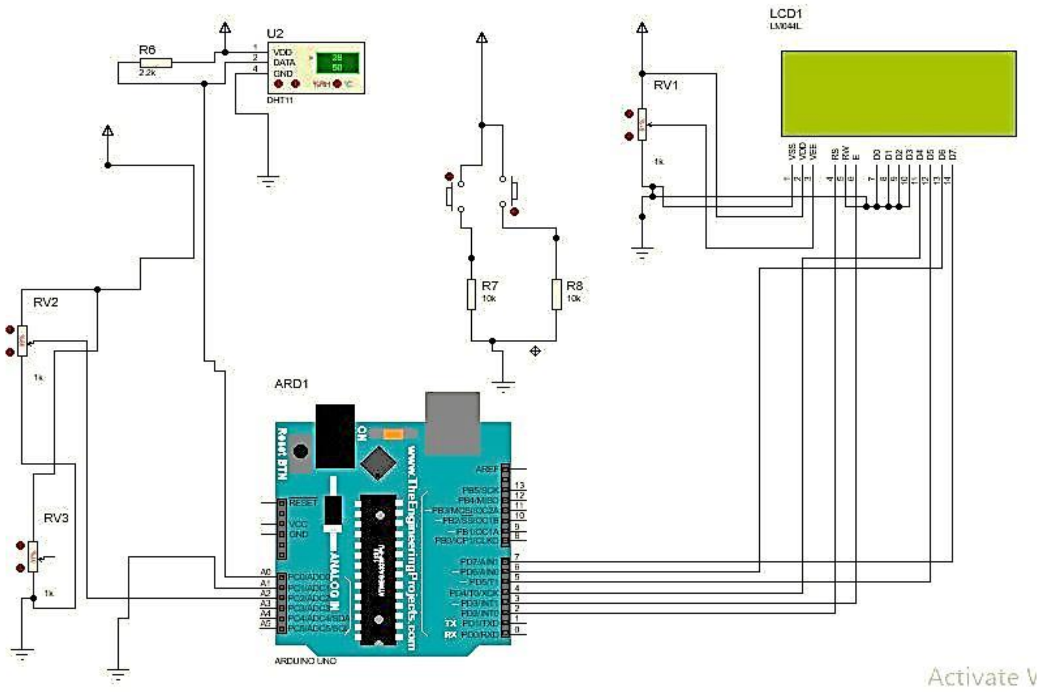

Figure 3: The circuit diagram of the control section of the Automatic rain Shielded drying system

Selection of Materials and Construction Procedure

The Arduino microcontroller used was Atmega 328P with an input voltage of 7-12 V and an operating voltage of 5 V (Anusha, 2017). The rain sensor used has a detection area of 40 mm x 16 mm with an operating voltage of 3-5 VDC. The Digital Humidity and temperature sensor (DHT 11) used has a 3 to 5 V operating voltage as well and the highest current that can be used when measuring is 2.5 mA. VCC, GND, Data Pin, and a Pin that is not connected are the four pins on the DHT11 sensor. The communication between the sensor and microcontroller is enabled via a 10 k Ω resistor. A worm gear DC motor drives the sliding cover linearly, both in reverse and forward movement with an operating voltage of 12 V and speed of 80 rpm. The advantage of this motor is that it is capable of locking itself to a particular position in the absence of a power supply. That is it will remain stationary in that position until power is supplied to it.

The Arduino UNO microcontroller used was programmed with a C programming language using Arduino programming software. Other components such as relay module, sensors, boost and Buck converter, casing, Vero board, connecting wires, jumper wires, and header were also used in the system. After the program had been written and all the conditions were defined, the prototype was first implemented on the breadboard to ensure that the code written was working well. Debugging was done on the software part, to the aspect discovered that it's not functioning well. After successful implementation on the breadboard, the microcontroller was, glued to the casing using hot gum, the sensors were connected to digital pins 2, and 10, as defined in the program, and the Limit switch was connected to pins 3 & and 4, the Liquid crystal display was soldered to their respective port a 5 V was taken from the Arduino Microcontroller and ground as the power supply to the LCD. The buck converter was regulated to 5 V to power the relay modules separately. The worm DC motor has a controller that can control it with the use of two push buttons for the reverse and forward movement (http://www.chegg.com, 2017). The manual operation was achieved by terminating the motor control wires that were connected to the relay and the two wires were connected to the switch to isolate and close the circuit. A separate power switch was given to the motor controller and Arduino microcontroller to override it

Results

Performance test was carried out on the system to ascertain whether the expected results as stated in the objectives were achieved. Motor controller, automatic and manual switches, and reverse and forward function were tested. An open circuit voltage test was carried out on the solar panel and the result was presented. The LDR and the rain sensor were set to a particular value, when it reaches this value, the system is expected to take certain actions either to close or open. A performance test was also carried out to see whether the controller takes action at that particular value. The automatic and manual operation was also tested to see whether it functions or not, as this test was carried out, the time taken for the motor close and open was also taken while the functionality of the limit switch was also tested.

Temperature and humidity as the two most important physical parameters were measured at an interval of five minutes to ascertain the effectiveness of the rain shielded system. The results obtained is presented in Table 1

Table 1: Temperature profile

S/N	Time(mins)	Temperature(°C)	Humidity
1	0	32.90	**66%**
2	5	33.30	**64%**
3	10	33.60	**62%**
4	15	33.90	**60%**
5	20	34.10	**58%**
6	25	34.30	**57%**
7	30	34.50	**57%**
8	35	34.50	**57%**
9	40	34.50	**58%**
10	**45**	**34.40**	**59%**

The value of the LDR ranges between 0-1000Ω, the value decreases when it senses light and increases when it senses darkness (Watelectronics, 2019). The motor was programmed to move forward (close) when it senses darkness i.e. when the value is from 400Ω above the system should close, and when the value is below 400 it should move backward (open). As the values set for the sensor reached the specified values. The action required to be taken by the controller was taken, which implies that the sensitivity of the sensor is very accurate.

The water sensor also reads its value from 0-1000Ω, when it senses rain, the value increases, and when there is no rain the value decreases, it was programmed that when the value reaches 600, i.e. there is rain, the system should close, and once the value decreases to 0% it should open back. And it functions exactly the way it was programmed. The sensitivity of the water sensor is also accurate. The plate below shows the values of both rain and LDR values. The rain is 0% and the sun is 59% which met the condition to be opened. Plates 4 and 5 show the opening of the system when the LDR sensed light and no water was present and closing of the when the rain sensor sensed water.

Plate 1: Opening and closing of the system.

Discussion

When the performance test of the system was carried out, the sensors acquired the required environmental condition and the physical state of the system and triggered the system to close or open the rain shield according to the acquired physical parameters. The limit switch operated to stop the movement of the motor immediately whenever it is touched in either directions. During the performance test, interference was found to exist between the movement of the sliding head and the operation of the LCD display. The display fade once the motor start rotating. This was found to occur as a result of voltage drop. The temperature profile generated in Table 1 shows that the wattage rating of the heater was not sufficient enough to provide the expected temperature that will quickly dry clothes. The time taken for the motor to move from its initial position to its final position is 13 seconds.

Conclusion

An automatic rain-shielded drying system is such an improvement in technology, which helps man to dry grains and other farm produce regardless of the weather conditions. The main objective of this system, which is to close or open whenever it senses rain, light, or darkness with the use of a rain sensor, LDR, and DHT 11, was achieved. The system has also provided the solution to the problem of delay in drying clothes due to cold weather or the absence of sunlight, with the use of a heater incorporated with the system as it is capable of drying clothes at a convenient time the user wants to use it regardless the time or condition of weather. This dual purpose of a stand-alone device will find application in many areas both domestic, commercial, and industrial. However, the system can be improved upon by increasing the heater rating for cold weather applications. Also, lighter materials can be used to reduce the weight. Folding of the extended arm for compatibility is also essential.

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