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Original Research Article

Solar Powered Automatic Poultry Egg Incubator

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ABSTRACT

This work describes the design and construction of an automatic egg incubator system which replicates the conditions of natural incubation for hatching of poultry eggs. It can be powered from solar energy especially when power outages occur from the national grid. The incubator operates with the use of a PIC18F2620 microcontroller for controlling its operation while temperature and humidity sensor (DHT11) was used for data acquisition which is then sent to the microcontroller for processing. It also incorporates automatic turning of eggs thereby averting heat loss which is a major shortcoming in the manually operated incubators. Performance evaluation of the system from test results showed that its portability, sensitivity, reliability and operational simplicity proved the system to be a viable tool which can be deployed by farmers for incubation and hatching of poultry eggs.

1. INTRODUCTION

There is a growing consumer demand for chickens and their eggs due to the increase in human population (Solomon and William, 2003). With poultry food demand increasing, the unreliability associated with the production of chicks using the natural method of the broody hen has necessitated the need for artificial incubation of eggs (Nithin *et al*., 2014). In order to boost production and increase income, poultry farmers in local communities have evolved ways of artificially incubating eggs through the provision of heat, relative humidity, good ventilation, and regular turning of the eggs (Abiola, 2014). Many have attempted the use of bush lamps and kerosene stoves to achieve the heating requirements of their small hatcheries which resulted in the production of toxic gases which are harmful to the eggs and poultry attendants (Okonkwo, 1989; Nithin *et al.*, 2014; David, 2018). A much better way is the use of electricity-based egg incubators. However, this also is laden with issues especially the incessant power outages associated with the national electric grid and its attendant consequences (Aliyu *et al.,* 2013). Using electric generators to ensure constant supply of power usually increases the running cost of such farms.

Several methods and works have been done on artificial incubation of eggs but these systems have their own demerits. Manually operated incubators such as those reported in Samuel and Gideon (2011), Nithin *et al.* (2014) and Umar *et al.* (2016) etc. had shortcomings which included high cost, risk of inflammation, inefficient manual turning of eggs, power outages during cloudy weather and air pollution from fossil fuel. These effects negatively impacted on the egg hatching process. Also, a lot of challenges are associated with automatically operated incubators such as those reported in Pallavi *et al.* (2018) and Radhakrishnan *et al.* (2014). Most of them use the aid of a microcontroller to control the motors for egg turning, fan, heater etc. However, the aforementioned works all have their drawbacks, from being expensive to being less efficient. Hence, this work proposes a solar powered automatic poultry egg incubator system which addresses the inefficiencies associated with the manual and electrically operated incubators. To ensure all round production, renewable energy as alternative when the grid supply fails is considered since it is richly abundant in Nigeria.

2. METHODOLOGY

2.1. System Design Approach

The top-down approach (also known as stepwise design) which entails splitting a system into smaller units thereby aiding the designer get more detailed insight into the various compartments of the system was used (Bactra, 2012). Considerations were made on the type of platform, software component, hardware component and mode of operation of the solar power automatic poultry egg incubator. Also, low cost of components, availability, reliability, flexibility and simplicity were considered in the selection of components for the design (Okhaifoh and Ogbekhiulu, 2018).

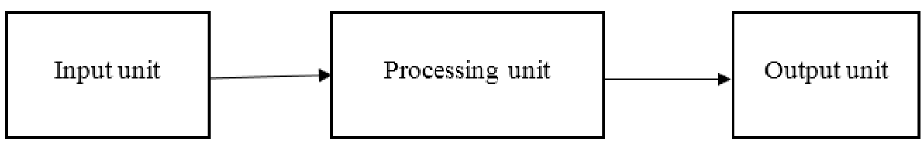

Figure 1: The block diagram of solar powered automatic egg incubator

Figure 1 shows the block diagram of the solar powered automatic poultry egg incubator. It consists of the following units:

a. Input unit: This unit comprises of the inverter, solar panel, charge controller, battery, transformer, rectifier and voltage regulators. The inverter changes dc (direct current) from the battery to AC (alternating current). The solar panel is used to charge the battery with the aid of the charge controller. The charge controller controls the amount of charges that goes to the battery. The transformer is used to step down the AC voltage from the mains or inverter. The rectifier rectifies the AC voltage to DC voltage. The voltage regulator is used to maintain a specified DC voltage.
b. Processing unit: The micro controller (PIC18F2620) makes up this unit. It is programmed to process data from temperature and humidity sensor, keypad, RTC (real time clock) to control the output unit (fan, heater and motor).
c. Output unit: This unit comprises of the LCD (20 × 4) and relays which are used to switch on and off the fan, heater and motor. The microcontroller was programmed to actuate these output devices with the help of relays and also make the date, temperature and humidity reading and what goes on in the system to display on the LCD.

2.2. Hardware Design

2.2.1. Electrical hardware design

The detailed block diagram of the input unit can be seen in Figure 2. The system needs both AC and DC voltage to work effectively.

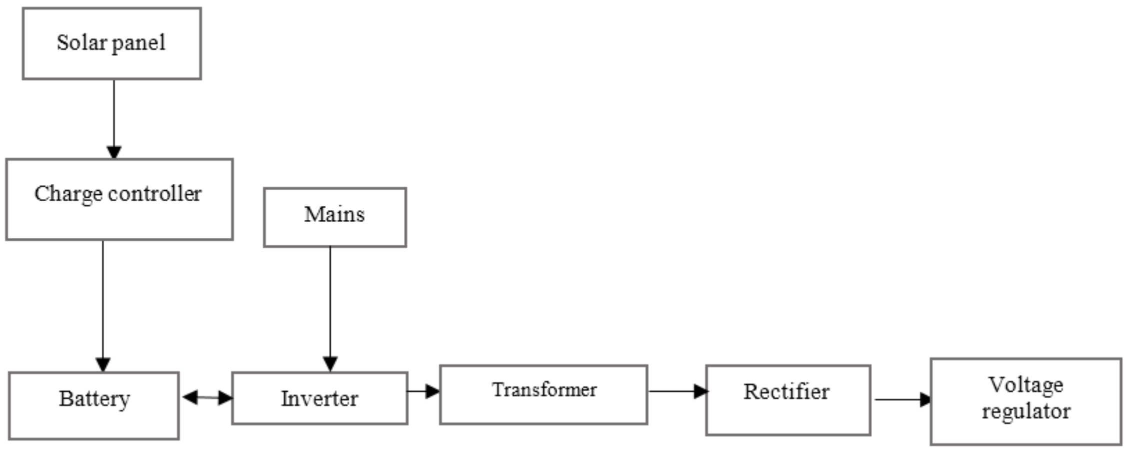

Figure 2: Power supply unit of the system

The solar photovoltaic (PV) system is made up of solar panel, charge controller and battery. The solar panel converts the solar energy from the sun to DC, while the charge controller controls the rate at which current charges the battery and when the battery is full it cuts off the supply. The battery stores the current from the solar panel with the aid of the charge controller. In this work, 250 peak watt panel, 20 Amps charge controller and 100 AH 12 V battery were utilised. These were chosen after due consideration of the load requirements, panel generation factor for tropical climate and the expected average active period of the backup power supply (Ofualagba, 2014).

Also, a 500 W inverter and 220 V/15 V transformer was chosen for the work. The voltage from a 12 VDC battery was inverted to AC voltage of 220 V by the inverter when there is no power supply from grid. However, when power supply from grid was restored, it switched automatically to the supply from grid and rectified the AC voltage (220 V) to DC voltage to charge the battery. KBL400 bridge rectifier integrated circuit (IC) was chosen for this work to successfully convert the AC voltage to DC voltage. The KBL400 bridge rectifier IC was used because its rectification efficiency is double that of half wave rectifier with higher transformer utilization factor (TUF). Lastly, a standard 1000 µf, 25 V capacitor was used to effectively carry out the filtering of the rectified signal to eliminate ripples while a KA7805 voltage regulator was chosen in this work since the microcontroller requires 5 V to operate effectively.

A PIC18F2620 microcontroller which is responsible for the processing of received information and general control of information flow within the system was chosen for this work. It features include a total power dissipation of 1 W, 32 MHz maximum clock frequency, 25 port input/output, 3968 bytes of data memory (RAM), 1024 bytes of EEPROM data memory and 4.2 V-5.5 V operating supply voltage. A 16 MHz crystal oscillator which acts as an external clocking unit for the microcontroller to carry out a stable operation was chosen.

A four-pin type DHT11 which is a basic, ultra-low-cost digital temperature and humidity sensor was chosen for this work. It has the ability to take in environmental variables and process them into a digital signal. This is because it uses a capacitive humidity sensor and a thermistor to measure the surrounding air and gives out a digital signal to the data pin. Its features include 3 to 5 V power and I/O, 2.5 mA max current use during conversion (while requesting data), good for 20-80% humidity readings with 5% accuracy and 0-50 °C temperature readings with ±2 °C accuracy.

A Hex keypad (4×4) which can collect input in decimal format for processing by the micro controller was chosen for this work. Its 4x4 matrix keypad has 16 built-in pushbutton contacts connected to row and column lines. A microcontroller can scan these lines for a button-pressed state with aid of their ASCII code the microcontroller can successfully process the input from the keypad.

The DS1307 real time clock (RTC) IC which is an 8 pin device that uses an inter-integrated circuit (I^2C) serial bus was chosen for this work. The DS1307 is a low-power clock/calendar with 56 bytes of battery backup SRAM. The clock/calendar provides seconds, minutes, hours, day, date, month and year qualified data. The end date of each month is automatically adjusted, especially for months with less than 31 days.

The output unit mainly comprises of relays, LCD (20 × 4), heater, DC motor and DC fan. In this work, a 12 V relay was chosen to turn on and off the heater, fan and motor with the aid of transistors. The relay specifications are as follows: Coil voltage = 12 V, Coil resistance = 155 Ω,

Switching capability = 30 A, Power consumption = 0.9 W.

The coil current (I_c) was determined by using Equation 1.

$$I_c = \frac{V_c}{R} \tag{1}$$

Where V_C is the coil voltage and R is the resistance of the coil.

The NPN transistor (2N2222) transistor was chosen for switching the relay controlling the output unit. The characteristics of the transistor are shown in Table 1.

Table 1: Transistor characteristic

Type	Material	P_T(W)	I_C(A)	V_{CBO}(V)	h_{FE}
2N2222	NPN	0.5	0.8	60.0	100.0

The value of the resistor that will limit the base current with respect to the supply voltage from the microcontroller to the base of the transistor was determined by using Equations 2 and 3.

$$\beta = \frac{I_c}{I_b} \tag{2}$$

$$R = \frac{V_{cc} - V_{be}}{I_b} \tag{3}$$

Where β is the transistor gain, I_c is the collector current, I_b is the base current, V_{be} is base emitter voltage, V_{cc} is the supply voltage and R is the base resistor.

The DC motor chosen for this work is the Nema17 stepper motor. It is a brushless DC electric motor that divides a full rotation into a number of equal steps. The stepper motor specifications are as follows:

Rated voltage:	12 V (DC)
Current:	1.2A
Step angle:	1.8^o
No. of phases:	4
Motor length:	1.54 inches
Operating temperature:	-10 to 40^oC
Unipolar holding torque:	22.2 oz-in

Also, a micro-stepping driver (DRV8825) was used to drive the stepper motor. DRV8825 allows higher resolutions by allowing intermediate step locations. This was achieved by energizing the coils with intermediate current levels. Its specifications are as follows:

Minimum operating voltage:	8.2 V
Maximum operating voltage:	45 V
Continuous current per phase:	1.5 A
Maximum current per phase:	2.2 A
Minimum logic voltage:	2.5 V
Maximum logic voltage:	5.5 V
Micro-step revolution:	full, ½, $^1/_4$, $^1/_8$, $^1/_{16}$ and $^1/_{32}$.

A 20×4 LCD (liquid crystal display) was used to display information to users. The 20×4 LCD has the ability to display 20 characters per line, and it has 4 lines for such display.

Four tungsten filament bulbs of 60 W each served as heat source, with two coming up simultaneously anytime the temperature falls below the set value. An AC power supply of 220 V powers the heat source with the aid of the transistor and relays. This was achieved by connecting the normally open (NO) of the relay to the 220 VAC voltage and the positive of the heater to the normally close (NC) while the negative was grounded. Also, the transistor's base was connected to the microcontroller while the collector and emitter was connected to the relays 12 V and ground respectively. When the micro controller sends high (5 V) to the base of the transistor, it automatically switches the 12 V connected to the relay to ground, thereby triggering the relay to on the heater.

2.2.2. Mechanical hardware design

A 3D CAD model of the incubator was developed using Solid Works 2018 software. The software allows for quick and easy development of 2D and 3D drawings as well as static, dynamic, thermal, fluid flow and heat transfer analysis. A detailed sketch of each of the components was made using the sketch tool in Solid Works and using feature tools such as extrude, cut extrude and patterns the sketch was transformed to 3D model for each of the components. The appearance tool was used to apply color and material to each of the components after which the components were assembled using the assemblies drawing tool. The Solid Works render tools were then used to obtain a realistic appearance of the complete model.

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The casing for the incubator was made with a high-density fiber board, with size of 61 cm × 61 cm and height of 28 cm as shown in Figure 3. The base of the housing was constructed with equally spaced wood to ensure proper positioning of the eggs during rotation, and also safely separate the hatched chicks from the tray.

At the top of the housing, a transparent glass was used to design the cover to ensure that an observer gets a clear view of the system operation as shown in Figure 4. The egg tray (46 cm x 32 cm) as shown in Figure 5 was sectioned into fifteen equal parts. Each part can carry two eggs and therefore, the tray can accommodate a total of thirty eggs. The egg tray was designed to aid the motion of the eggs. The designed complete housing is shown in Figure 6.

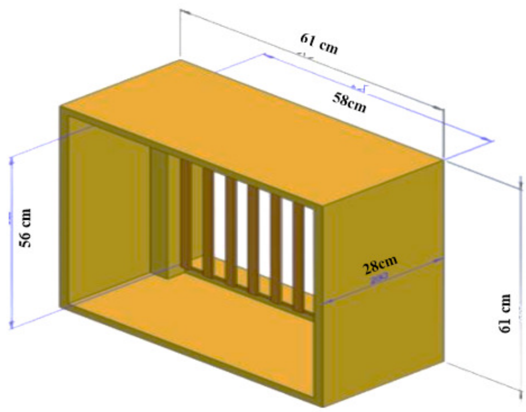

Figure 33: The body of the incubator with dimensions

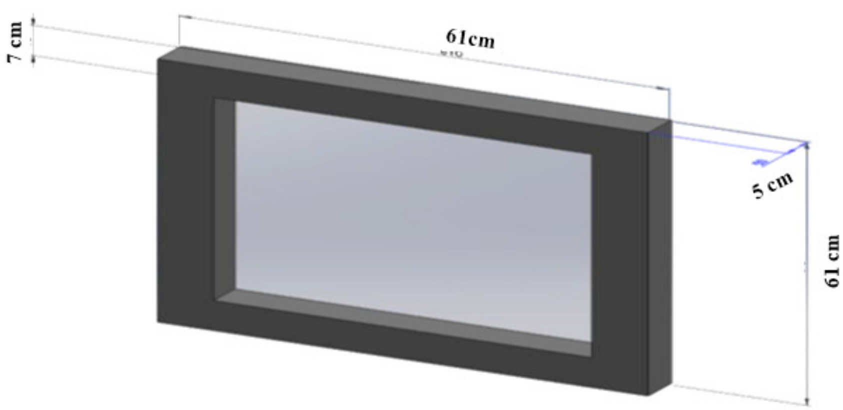

Figure 4: The cover of the incubator with dimensions

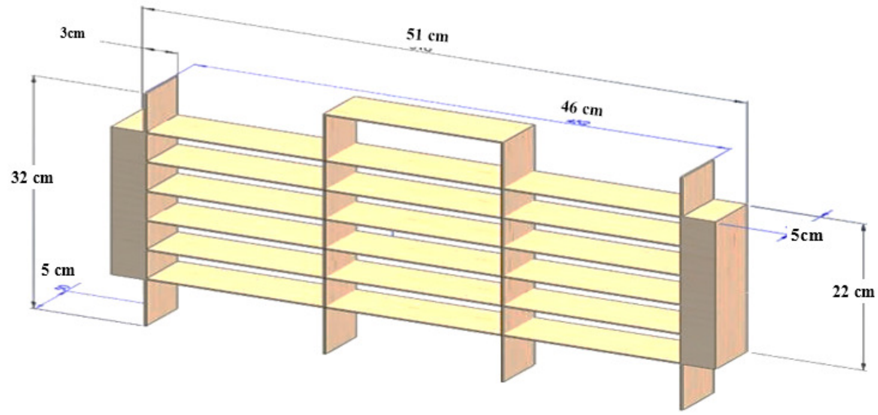

Figure 5: The egg tray design

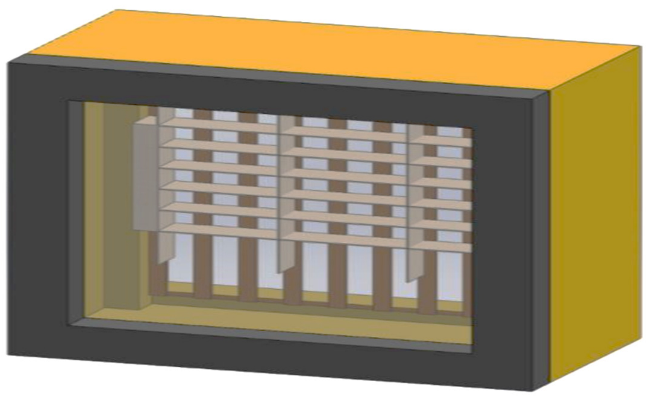

Figure 6: The complete housing design

2.2.3. Software design

The control algorithm of the designed solar powered egg incubator is represented by the flow chart shown in Figure 7. The software code implementation was written in micro C pro v6.6 and was used to program the PIC microcontroller.

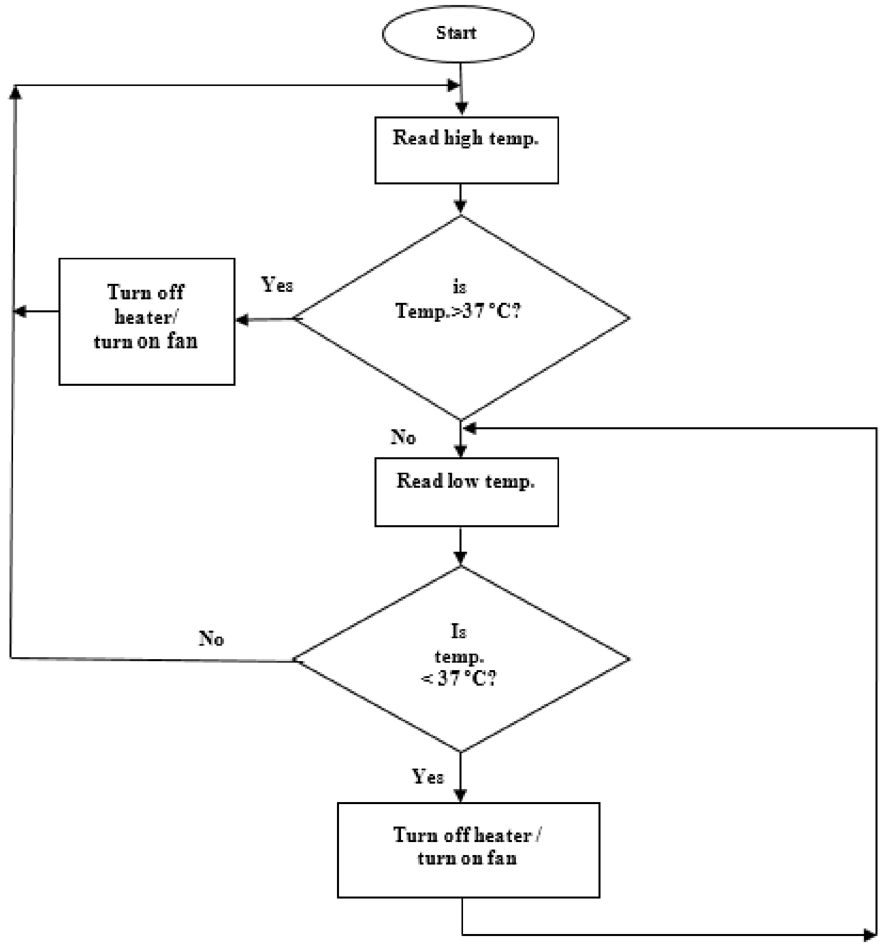

Figure 7: System flowchart

2.3. Principle of Operation

The complete circuit diagram of the solar powered automatic egg incubator is shown in Figure 8. A voltage of 12 V from a transformer is regulated to 5 V with the aid of a bridge rectifier, voltage regulator and capacitor to power the microcontrollers. The microcontrollers are clocked externally with a 16 MHz crystal oscillator to set the frequency of operation. Pin 3, 4 and 5 of the PIC microcontroller are the output pin assigned to the heater, fan and motor respectively. All output pins excluding the fan were connected to an Arduino atmega chip.

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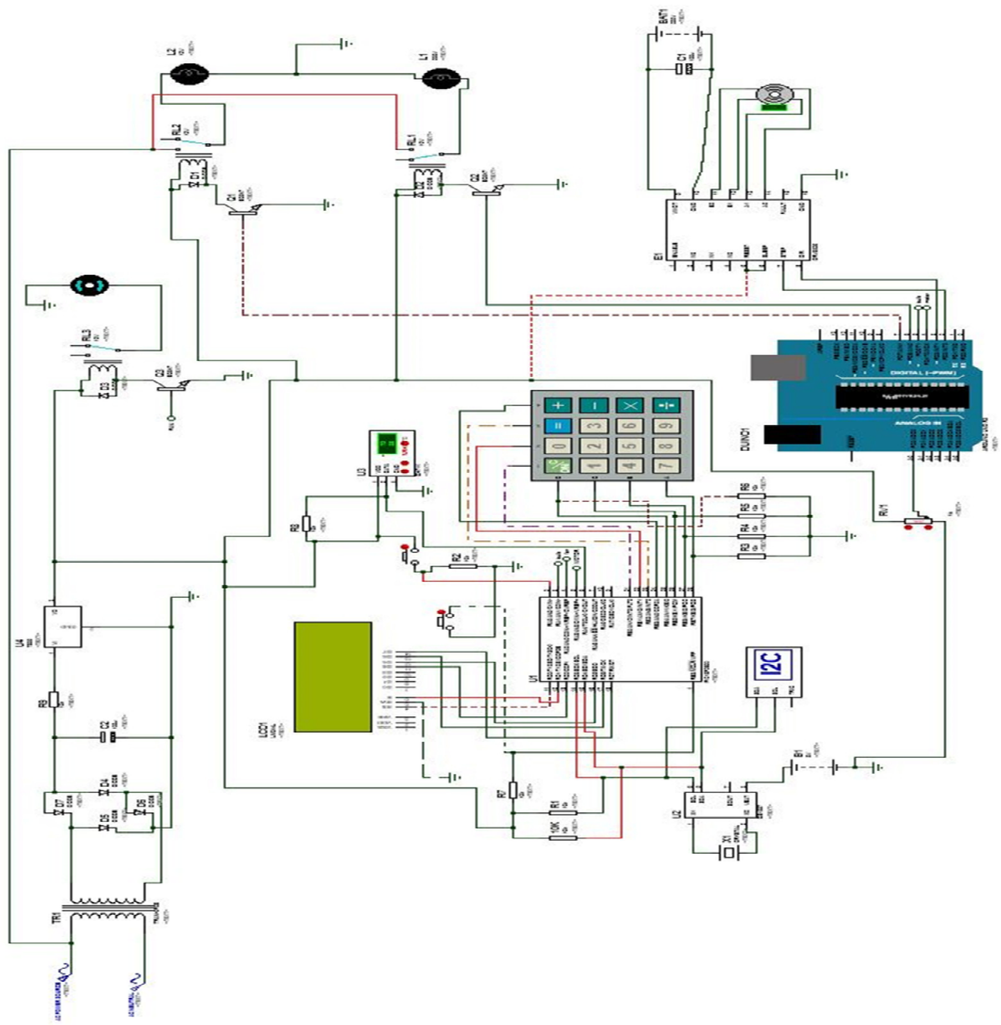

Figure 8: Circuit diagram of solar powered automatic egg incubator

Relays and transistors were used as switch to control the fan and heater. The temperature/humidity sensor (DHT11) is connected with the aid of a pull up resistor in order to work effectively. The data collected by the DHT11 is sent to microcontroller via pin 6, when the temperature reads higher than the set temperature the microcontroller send high (1) to pin 4 and low (0) to pin 3 in order to maintain the specified temperature of the incubator. Four tungsten filament bulbs of 60 W each served as a heater, with two coming up simultaneously anytime the temperature falls below the set value. The real time clock keeps track of time throughout the incubation period and is connected to pin 14 and 15. The 4x4 keypad is connected to pin 21 – 28 and used to set the temperature and humidity to be maintained, the date and motor rotating time in each day, and lastly to input the assigned password. The LCD displays what goes on in the system and makes the system user friendly. A clear button connected to pin 1 is use to clear the LCD and reset the system. The second button is used to access the main menu of the incubator. When the button is pressed the LCD displays a platform for setting temperature, humidity, date and the number of times of motor rotation, and the incubation operation begins. A 12V DC fan is included to cool and distribute the heat evenly. It comes on immediately the maximum set temperature is reached and goes off when it falls below the required minimum temperature. For the rotation of the egg, a NEMA17 bipolar stepper motor is used for sliding the wooden egg tray forward and backward, thus causing the eggs to rotate and change its position. The stepper motor gets its power and direction from a driver (DRV8825). The motor comes high every time system is reset and thereafter it rotates for thirty seconds every two hours.

3. RESULTS AND DISCUSSION

Several tests were conducted in order to verify the effectiveness and correct operation of the constructed solar powered automatic egg incubator in Figure 9. These tests were carried out with the aid of the temperature sensor to determine the effectiveness of the heating elements (four AC bulbs) and how the system responds to the input signal from the sensor. It was also to determine the positioning of the heating elements so as to ensure even distribution of temperature in the incubator. The heating elements were positioned diagonally opposite each other to ensure that every corners of the incubator receives equal heating. When temperature was below the specified value, the heater turned on while, when the temperature was above the specified value the heater went off and the fan came on. Hourly readings of temperature and humidity were taken for three weeks and tabulated. A mean average of 37.2^{o}C and 59.5% for temperature and humidity respectively was obtained. This showed that the system is effective for egg incubation because Abiola, (2014) stated that temperatures of between 36^{o}C – 39^{o}C and relative humidity of 50-70% are needed for effective incubation and hatching of eggs.

Figure 9: Solar powered automatic poultry egg incubator

Also, test was carried out in order to ensure that the motion of the egg tray was safe for turning the eggs without causing damage to them. The motion was achieved using a NEMA 17 stepper motor with aid of the driver (DRV8825) which offers 1/32 micro-steps per revolution. However, the step was adjusted to a desirable one (1/8 step). This value ensured that the motion of the egg tray was able to turn/roll the eggs round for a set period of time to ensure that every area of the eggs received equal amount of heat.

4. CONCLUSION

In this paper, a solar powered automatic poultry egg incubator system which replicates the conditions of natural incubation of poultry eggs was developed. It can be powered from the grid and renewable energy source especially solar energy which is richly abundant in Nigeria. It also incorporates automatic tuning of eggs thereby averting heat loss in the incubator which is a major shortcoming in the manually operated incubators. Performance evaluation of the system from test results showed that its portability, sensitivity, reliability and operational simplicity proved the system is a viable tool which can be deployed by farmers in poultry production.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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