American Journal of
Computing and Engineering
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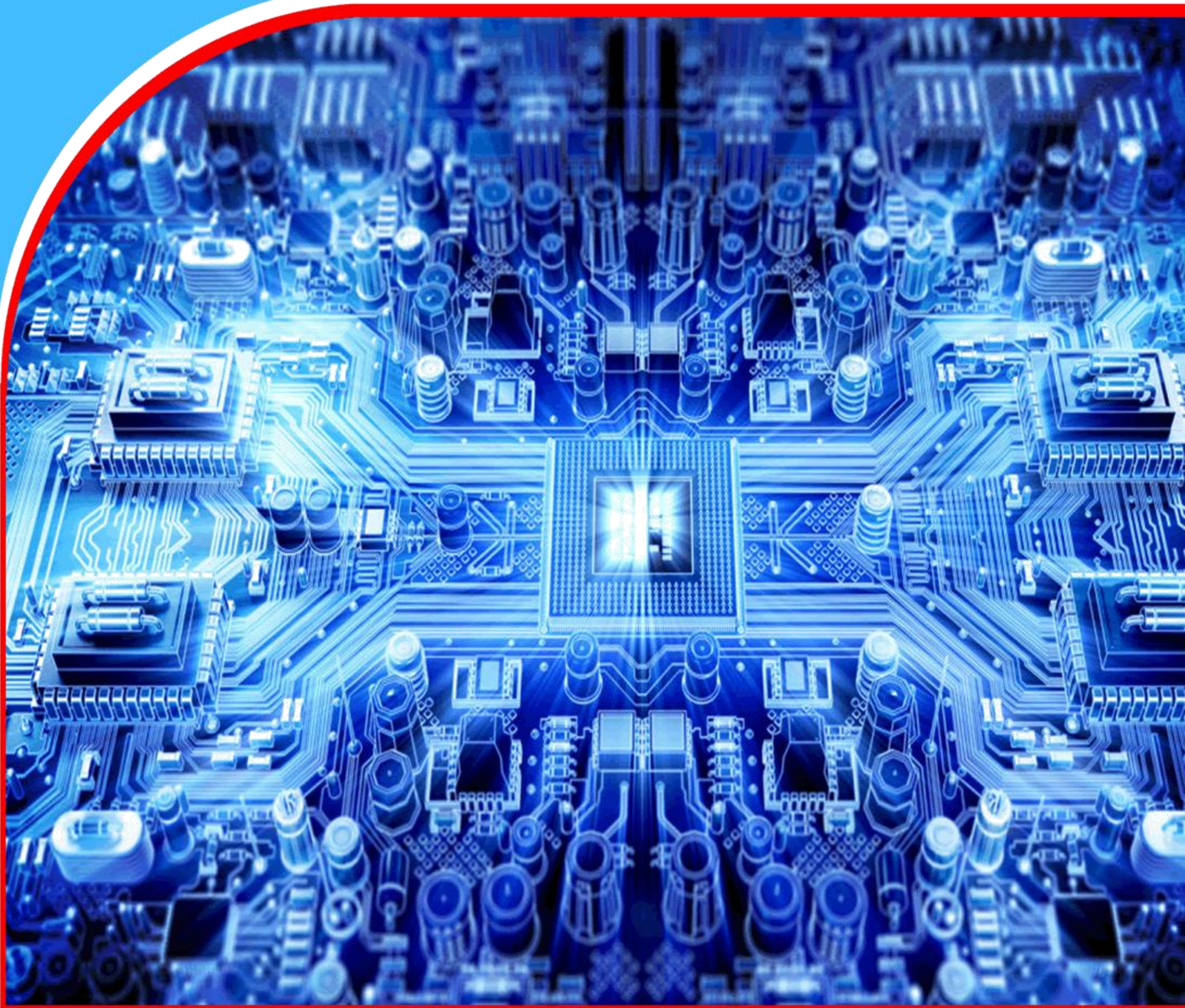

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American Journal of Computing and Engineering
ISSN 2790-5586 (Online)
Vol.8, Issue 1, pp 69-89, 2025
www.ajpojournals.org

Design, Production, and Performance Assessment of a Remote Monitored Automated Solar Powered Egg Incubator

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Crossref
Article history
Submitted 06.03.2025 Revised Version Received 01.04.2025 Accepted 02.05.2025

Abstract

Purpose: The research aimed to create an automated solar-powered egg incubator using locally available materials that can be remotely monitored and improve Zambia's poultry farming industry.

Materials and Methods: The design model was created using Solidworks, and the simulation was done using Ansys, MATLAB, and Proteus. The incubator was equipped with a DHT22 sensor to measure temperature and humidity, GSM-GPRS Sim 800 and Blynk IoT Cloud for remote monitoring, two Nano-Arduino for processing, and a solenoid valve for auto-refilling the water in the incubator. Limit switches also positioned the egg setter, ensuring the incubator door was airtight.

Findings: The operation and performance of a solar-powered, remote-monitored poultry incubator using the Blynk IoT cloud platform. The system enables real-time monitoring and control of critical parameters such as temperature, humidity, water level, egg turning, and door state. Data is visualized through the Blynk dashboard, including graphs and gauges accessible remotely. The incubator consistently maintained optimal hatching conditions, with alerts and automated responses triggered when parameters deviated from preset thresholds such as activating the water valve when water levels dropped. Reports generated by Blynk allow for effective performance assessment and troubleshooting, isolating issues related to either the incubator environment or egg fertility. Temperature and humidity readings occasionally skip data rows due to sensor sampling intervals, but overall, the system provides timely and accurate updates.Tests were conducted, and the incubator maintained a steady temperature and humidity of 37°C and 65% for chicken eggs, respectively. Despite being switched off for 5 hours, the incubator temperature remained stable, and its energy efficiency was attributed to the proper selection of fabrication materials.

Unique Contribution to Theory, Practice and Policy: This innovation has the potential to significantly improve the poultry industry in Zambia, especially in areas without access to grid power supply. Farmers can benefit from affordable and economically viable incubators with advanced managerial technologies despite their absence to directly manage the hatching process. The continent's abundant solar resources can solve farmers' challenges of low access rates and unreliable power supply and increase the marginal revenue from hatcheries.

Keywords: *O33 Remote monitoring, GSM, Q42 Solar energy, M15 Managerial technology, L86 Blynk IoT Cloud*

INTRODUCTION

The poultry industry plays a vital role in Zambia's economy, directly and indirectly employing approximately 80,000 people. It contributes significantly to the agricultural Gross Domestic Product (GDP), accounting for 4.8%, and constitutes 48% of the livestock sector. This growth is largely driven by an expanding middle-income class, population increase, and advancements in breeding, production, and processing technologies. Despite this progress, the sector faces numerous sustainability challenges that must be addressed (Poultry in Zambia Investors Guide, n.d.).

Small and Medium-sized Enterprises (SMEs) dominate poultry farming in Zambia, but most lack the financial and technological resources needed to modernise and scale up operations. Farmers operating on the outskirts of cities face further difficulties due to limited access to electricity, making poultry farming less viable in some regions. Many smallholder farmers struggle to effectively use incubators due to operational limitations, which often compels them to import day-old chicks from distant regions. This not only increases costs but also reduces productivity due to reliance on manual incubation processes. Additionally, full-time workers interested in poultry farming find it difficult to participate meaningfully, as the process requires constant supervision that clashes with their job commitments.

To address these constraints, efficient hatching technologies are essential for smallholder farmers to improve productivity and income. Remote monitoring and control of incubator parameters can offer a cost-effective and practical solution. The Internet of Things (IoT) enables access to artificial incubation systems over the Internet, allowing farmers to monitor and control conditions such as temperature and humidity from remote locations (Aldair et al., n.d.). Applications like Blynk, which integrate with IoT platforms, allow real-time monitoring and control through smartphones (Niranjan et al., 2021). Artificial incubators can precisely regulate temperature, humidity, and ventilation, enabling the hatching of more eggs than natural brooding methods.

As noted by (Benjamin & Oye, 2012), incubators replicate a bird's natural brooding ability by providing controlled environments optimal for embryo development. (Okonkwo & Chukwuezie, 2012), further explain that artificial incubators regulate environmental conditions to hatch a larger number of eggs than a hen can manage. This study, therefore, proposes the design of a solar-powered egg incubator capable of continuous operation, even without connection to the national grid. The incubator will be remotely monitored, offering farmers in off-grid areas a viable, energy-efficient hatching solution. If successfully implemented, this system could significantly enhance poultry farming technologies, reduce energy consumption, and improve the sustainability of poultry production in Zambia.

The Integration of Internet of Things (IoT) Technologies with Automated Poultry Incubators

The integration of Internet of Things (IoT) technologies with automated poultry incubators represents a significant advancement in modern agricultural practices. The passage by (Alsayaydeh et al., 2024) highlights the foundational role of IoT in creating intelligent, responsive systems that can automate tasks, collect real-time data, and provide analytics-driven insights. When applied specifically to poultry incubation, IoT frameworks, paired with platforms such as Blynk, enable a highly efficient and precise control over critical environmental variables such as temperature and humidity, which are pivotal to the success of embryo development and hatch rates. Emphasizes that IoT is a fusion of technologies such as big data, AI, planning, and real-time sensing, which can be tailored to improve operational transparency and performance across diverse domains.

In the context of poultry incubation, such technologies allow for real-time monitoring and adjustment of the incubator environment through sensors and embedded systems. These sensors, which are typically part of a low-power wireless IoT network, can detect minute changes in temperature or humidity and relay this data for instant action or analysis either locally or in the cloud (Durani et al., 2018).

Additionally, as (Kumar Srivastava, n.d.) Notes, IoT systems excel in automating repetitive agricultural tasks, reducing the need for constant manual oversight, and enhancing data accuracy with environmental sensors often yielding more than 99% precision. This level of accuracy is crucial in poultry farming, where even slight deviations in conditions can affect hatchability and chick viability.

The use of Blynk, as described by (Shanto et al., 2023), complements the IoT ecosystem by offering an intuitive mobile-based control interface. Blynk enables users to easily configure dashboards using widgets, upload relevant control scripts to microcontrollers (e.g., Arduino or Raspberry Pi), and gain real-time feedback and control from virtually anywhere. In an automated incubator setup, this means a farmer or operator can remotely adjust temperature settings, receive alerts for anomalies, or even automate certain functions based on pre-set thresholds.

Thus, the synthesis of IoT technology with platforms like Blynk creates a smart incubation environment where efficiency, remote operability, and data-driven control converge. This not only optimizes hatch rates and reduces human error but also aligns with broader goals of sustainable and precision agriculture.

Related Works

High hatchability and low energy consumption define efficient egg incubators (Yildirim I, 2004). Various studies have investigated alternative power sources for incubators, including solar, battery, grid-connected, and IoT-enabled systems.

For instance, (Oquiño et al., 2016) designed a microcontroller-based egg incubator powered by grid electricity. However, daily power outages lasting 2-6 hours reduced the hatchability rate to just 27%. Similarly, (Mansaray et al., 2015) implemented a solar-powered incubator for 30 eggs but recorded hatchability rates as low as 23.1%, due largely to the manual egg-turning process.

By contrast, (Peprah et al., 2022) developed an intelligent solar-powered incubator with integrated GSM and IoT capabilities, achieving hatchability rates between 95.24% and 97.14%. The high performance of this system underscores the advantages of automation and smart monitoring.

Building on this technological trajectory, the current study proposes the development of a remotely monitored, automated, solar-powered egg incubator. By leveraging smart IoT integration, this system aims to enhance reliability and hatchability while remaining energy-efficient and accessible to smallholder farmers.

Incubating Conditions

Successful incubation hinges on the precise regulation of key environmental parameters namely; temperature, humidity, ventilation, and egg turning frequency. These factors are critical to ensuring healthy embryonic development and achieving high hatchability rates. To facilitate consistent and remote management of these conditions, this study employs a dual microcontroller system (master and slave), integrated with the Blynk Cloud IoT platform. This setup allows for real-time monitoring and automated control of incubation parameters, thus minimizing the risk of deviation due to human error or absence.

Temperature is arguably the most influential factor in incubation. During the first 19 days (the setter phase), eggs must be maintained within a narrow temperature range of 37°C to 38°C, after which the temperature should be slightly reduced to approximately 36.8°C in the final days leading up to hatching (Peprah et al., 2022) .Accurate temperature regulation is essential not only for embryonic survival but also for influencing hormone activity, thermoregulation, and post-hatch development (French, 1997) .In addition (Aigbiniode Lawani et al., 2018) emphasize the necessity of using high-precision temperature sensors to avoid fluctuations that may impair development. Studies by (Boleli et al., 2016) and (Archer & Cartwright, 2018) reinforce this, showing that chicks incubated at consistent temperatures between 37.5°C and 38°C tend to exhibit improved health and vitality. Specific recommendations by (Sansomboonsuk et al., 2011) suggest maintaining temperatures at 37.5°C–37.64°C during the setter phase and lowering it to 36.94°C in the hatcher phase for optimal results.

Humidity also plays a pivotal role. Throughout incubation, the embryo loses moisture, resulting in the gradual expansion of the air cell inside the egg. By day 19, this air cell should occupy roughly one-third of the egg's internal space, facilitating successful pipping and hatching (A. Lourens et al., 2005) Maintaining relative humidity between 50% and 65% during the initial stages, followed by an increase to approximately 90% from day 19 onwards, aligns with findings from (Peprah et al., 2022) and recommendations by (Osanyinpeju et al., 2018a) , who noted improved hatchability with humidity raised to 70% during the final stage. Improper humidity can lead to elevated embryo mortality and developmental abnormalities (Okpagu & Nwosu, 2016), underscoring the importance of precise control.

Ventilation is another critical aspect, particularly in maintaining adequate oxygen levels and expelling carbon dioxide generated by the growing embryos. The optimal oxygen concentration is around 21%, while embryos can tolerate up to 5% carbon dioxide without adverse effects (Noiva et al., 2014) .As embryos produce metabolic heat, especially in the later stages, proper airflow is essential to maintain a stable incubator environment. Without sufficient ventilation, heat buildup and CO_2 accumulation can severely impair embryo development.

Egg turning is equally essential, especially during the early stages. Tilting the eggs at a 45° angle every four hour, prevents embryonic adhesion to shell membranes and supports the formation of the chorioallantoic membrane, which is vital for gas exchange and nutrient absorption (Oviedo-Rondón et al., 2009).It was (Elibol & Brake, 2003) demonstrated that eggs turned up to 96 times daily within an angle range of 20° to 45° show significantly higher hatchability than those turned less frequently.

By integrating all these environmental factors into an automated, remotely managed incubation system, this study not only aligns with established biological insights but also leverages modern IoT technologies to enhance consistency and reduce labor-intensive oversight. The dual-microcontroller architecture, coupled with Blynk Cloud, offers a scalable and user-friendly solution for small-to-medium scale hatchery operations, particularly in rural or resource-limited settings.

Materials and Methods

In line with previous research, this study combines energy efficiency with improved hatchability through technological innovation. While earlier models such as those by (Oquiño et al., 2016) and (Mansaray et al., 2015) were hampered by manual processes and unreliable power sources, (Osanyinpeju et al., 2018b) demonstrated improvement by using a solar-powered system that achieved hatchability and fertility rates of 44% and 64%, respectively.

This concept can be further improved by incorporating GSM and IoT technologies into solar-powered incubators, hence achieving hatchability rates exceeding 95%.

Drawing on these findings, this study proposes the development of a solar-powered, IoT-integrated egg incubator. The system will offer real-time monitoring and automated control over temperature, humidity, ventilation, and egg turning. The complete design is presented in Figure 1, with a focus on delivering consistent, high-quality hatching performance in off-grid or resource-limited settings.

The incubator was designed following the procedures described below, as depicted in Figure 1.

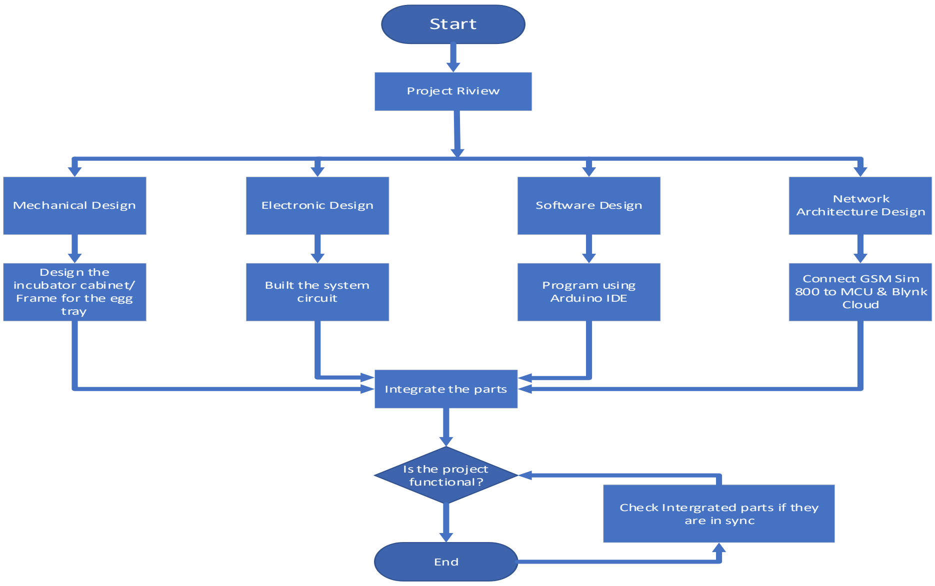

Figure 1: Design Process

Design Calculations

Creating a fully functional incubator requires careful consideration of several essential conditions. These include maintaining a precise internal temperature, ensuring optimal relative humidity levels, and ensuring the eggs are rotated at least once an hour. To achieve these conditions, the design of the incubator must also consider other critical factors, including the selection of appropriate materials, adherence to industry standards, and the necessary parameters.

The volume of the incubator is calculated from

$$V = l \times b \times h \qquad (3.0)$$

V = volume of the incubator cabinet (mm^3), L = length of the incubator (mm),

B = breadth = inside (mm), H=height= inside (mm)

Determination of the mass of air (Ma) in the cabin

$$\rho_a = \frac{m_a}{V} \qquad (3.1)$$

Where ρa = density of air = 1.23kg/m3 (Rajput, 1998)

m_a = mass of air (kg)

V = volume of air in the incubator cabinet

Heat calculation

Heat for the incubator cabinet (Q_c) is calculated from

$$Q_C = ((m_p \times C_p) + (m_w \times C_w) + (m_g \times C_g))\Delta T \tag{3.2}$$

$m_p = Mass\ of\ plywood$

$C_P = Speecific\ heat\ capacity\ of\ plywood$

$m_w = Mass\ of\ wool$

$C_w = Specific\ heat\ capacity\ of\ wool$

$m_g = Mass\ of\ window\ glass$

$C_g = Specific\ heat\ capacity\ of\ wool$

$\Delta T = Change\ of\ temperature$

Calculating heat capacity for egg tray

$$Q_t = (m_t \times C_t)\Delta T \tag{3.3}$$

Where

$Q_t = Heat\ capacity\ for\ egg\ tray$

$m_t = Mass\ for\ the\ egg\ tray$

$C_t = Specific\ heat\ capacity\ of\ an\ egg$

$\Delta T = 12.5$

Calculating heat capacity for eggs

$$Q_e = (m_e \times C_e)\Delta T \tag{3.4}$$

Were

$Q_e = Heat\ capacity\ for\ eggs$

$m_e = Mass\ of\ an\ egg$

$C_e = Specific\ heat\ capacity\ of\ an\ egg$

Calculating heat capacity for water

$$Q_{wa} = (m_{wa} \times C_{wa})\Delta T \tag{3.5}$$

$Q_{wa} = Heat\ capacity\ for\ water$

$m_{wa} = Mass\ of\ water$

$C_e = Specific\ heat\ capacity\ of\ an\ egg$

Calculating heat capacity for Egg turning equipment (Aluminium)

$$Q_{teq} = (m_{teq} \times C_{teq})\Delta T \tag{3.6}$$

$Q_{teq} = Heat\ capacity\ for\ water$

$m_{teq} = Mass\ of\ water$

$C_{teq} = Specific\ heat\ capacity\ of\ an\ egg$

Calculating heat capacity for Air inside cabinet

$$Q_a = (m_a \times C_a)\Delta T \tag{3.7}$$

$Q_a = Heat\ capacity\ for\ air$

$m_a = Mass\ of\ air$

$C_a = Specific\ heat\ capacity\ for\ air$

Electrical power required was calculated from

$$P = {}^{Q_T}/_{t} \tag{3.8}$$

Were

$Q_T =$ heat energy required by the incubator

P = electric power to be supplied by the heating element (W)

t = time

Heat loss through the composite wall of the incubator was calculated from

$$R_{Total} = R_{conv,1} + R_{plywd,1} + R_{wool} + R_{plywd,2} + R_{conv,2} \tag{3.9}$$

$R_{Total} = Total\ internal\ thermal\ reistance\ of\ thee\ composite\ of\ plywood\ and\ wool$

$R_{conv,1} = Convention\ resisstance\ of\ the\ surface\ inside$

$R_{plywd,1} = Thermal\ resistance\ of\ inner\ plywood\ layer$

$R_{wool} = Thermal\ resistance\ of\ wool\ layer$

$R_{plywd,2} = Thermal\ resistance\ of\ outer\ plywood\ layer$

$R_{conv,2} = Convention\ resisstance\ of\ the\ surface\ outside$

$$R_{Total} = \frac{1}{h_1 A} + \frac{L_{plywd,1}}{k_{plywd} A} + \frac{L_{wool}}{k_{wool} A} + \frac{L_{plywd,2}}{k_{plywd} A} + \frac{1}{h_2 A}$$

$h = convection\ heat\ transfer$

$k_{plywd} = Thermal\ conductivity\ of\ plywood$

$k_{wool} = Thermal\ conductivity\ of\ wool$

$L_{plywd} = Layer\ thichnes\ of\ plywood$

$L_{wool} = Layer\ thichnes\ of\ wool$

$A = Area$

Calculating heat loss through composite wall of the incubator

$$Q_{cw} = UA\Delta T \tag{3.10}$$

$Q_{cw} = Heat\ loss\ through\ composite\ wall$

$U = Overall\ heatb\ transfer\ coefficient\ (W/m^2.\text{°C})$

$A = Area$

$\Delta T = Temperature\ difference$

Design of the ventilation holes using the following equations

The amount of heat lost by the incubator to the environment through ventilation is expressed as:

$$Q_v = C \times V_e \times (T_2 - T_1), \qquad V_e = \frac{Q_v}{C \times (T_2 - T_1)} \tag{3.11}$$

Where

Q_v= heat loss

C= specific heat capacity of air = 1300J/kg°C (Easton, 1993)

V_e= ventilation rate (m^3/s)

T_1= room temperature

T_2= optimum temperature of the incubator

System sizing was calculated from

$$E_r = \frac{daily\ average\ energy\ consuption}{product\ of\ component's\ efficiencies} = \frac{E}{\eta_{overall}} \tag{3.12}$$

$E_r = daily\ energy\ requirement$

$E = daily\ average\ energy\ consuption$

$\eta_{overall} = Overall\ product\ fficiencies$

Solar module sizing was calculated from

$$Solar\ Size = \frac{E_r}{T} \tag{3.13}$$

$E_r = daily\ energy\ requirement$

$T = Sunshine\ hours$

Peak power was obtained by

$$P_p = \frac{E_r}{T_{min}} = \tag{3.14}$$

$P_p = peak\ power$

$T_m = minimum\ peak\ sun\ hours\ per\ day$

$E_r = daily\ energy\ requirement$

Total system current was determined by

$$I_{DC} = \frac{P_P}{V_{DC}} \tag{3.15}$$

$I_{DC} = total\ current$

$P_P = Peak\ Power$

$V_{DC} = System\ DC\ Voltage$

Determining the number of panels connected in parallel

$$N_p = \frac{I_{DC}}{I_r} \tag{3.16}$$

$N_p = number\ of\ solar\ panel\ modules\ connected\ in\ parallel$

$I_{DC} = total\ require\ system\ current$

$I_r = Maximum\ rated\ current\ output\ for\ solar\ module$

Determining number of connected panels in series

$$N_s = \frac{V_{DC}}{V_r} \tag{3.17}$$

$N_s = Number\ of\ panels\ conneected\ in\ series$

$V_{DC} = System\ DC\ Voltage$

$V_r = Solar\ module\ voltage$

Total number of modules

$$N_m = N_P \times N_s \tag{3.18}$$

N_m =*Total number of solar modules*

Sizing of the battery bank

$$C = \left(\frac{E_r}{\eta_b \times B_f \times V_{dc}}\right) D_{Aut} \tag{3.19}$$

$C = required\ battery\ bank\ Capaacity$

$E_r = daily\ energy\ requirement$

$\eta_b = Battry\ efficiency$

$B_f = battery\ bank\ factor$

$D_{Aut} = Days\ of\ autonomy$

$V_{dc} = Battery\ nominl\ voltage$

Determining number of batteries required

$$N_B = \frac{C}{C_B} \tag{3.20}$$

Therefore, the Battery bank size capacity will be

$N_B = Number\ of\ batteries\ required$

$C = required\ battery\ bank\ Capaacity$

$C_B = capacity\ per\ battery$

Sizing of the voltage controller

$$I = I_{SC} \times N_p \times F_{safe} \tag{3.21}$$

$I = Voltage\ regulator$

$I_{SC} = Short\ circuit\ current$

$N_p = number\ of\ solar\ panel\ modules\ connected\ in\ parallel$

$F_{safe} = Safe\ factor$

$$N_{controller} = \frac{I}{Amps\ of\ each\ controller} \tag{3.22}$$

Sizing of the inverter

$$Inverter\ size = \frac{Total\ intantaneous\ power}{inverter\ efficiency}$$

CAD Design and Simulations

Design and simulations of various incubator components were conducted in Solidworks, Matlab, Ansys, Proteus and Packet tracer.

Mechanical Parts

The following essential parts were assembled for the Incubator to successfully carry out its specified functions.

The Incubator Cabin

The cabin was constructed using three layers of materials. The sides were made of plywood while the middle layer was insulated with cotton wool. This design provides excellent insulation, thereby reducing energy loss and resulting in lower energy consumption. Figure 2 below shows the design of an incubator cabin.

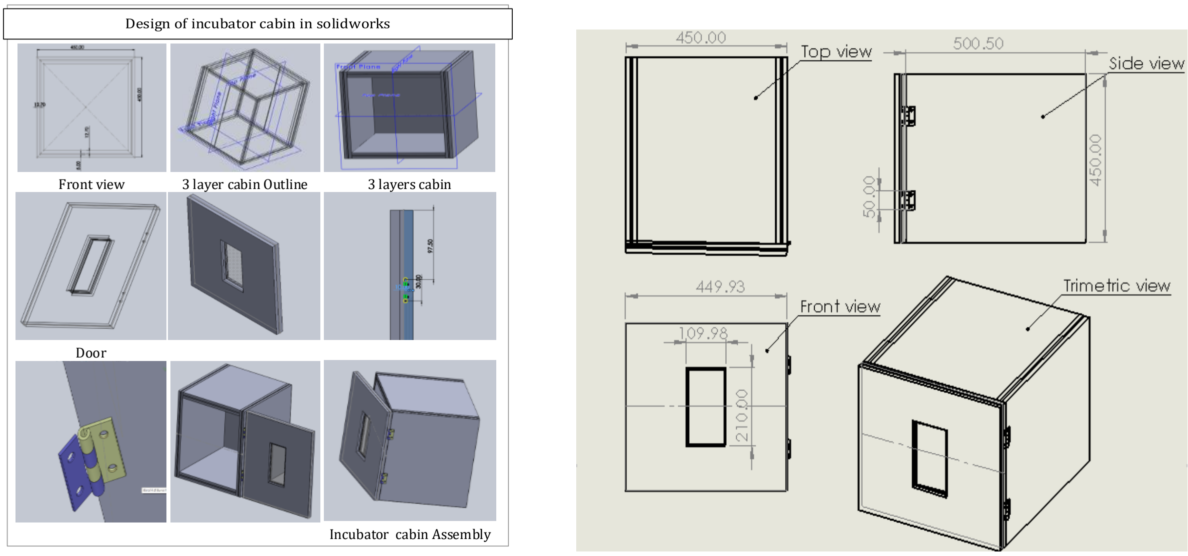

Figure 2: Cabin Desing in Solidwork

The construction of the incubator cabin is depicted in Figure 3 below.

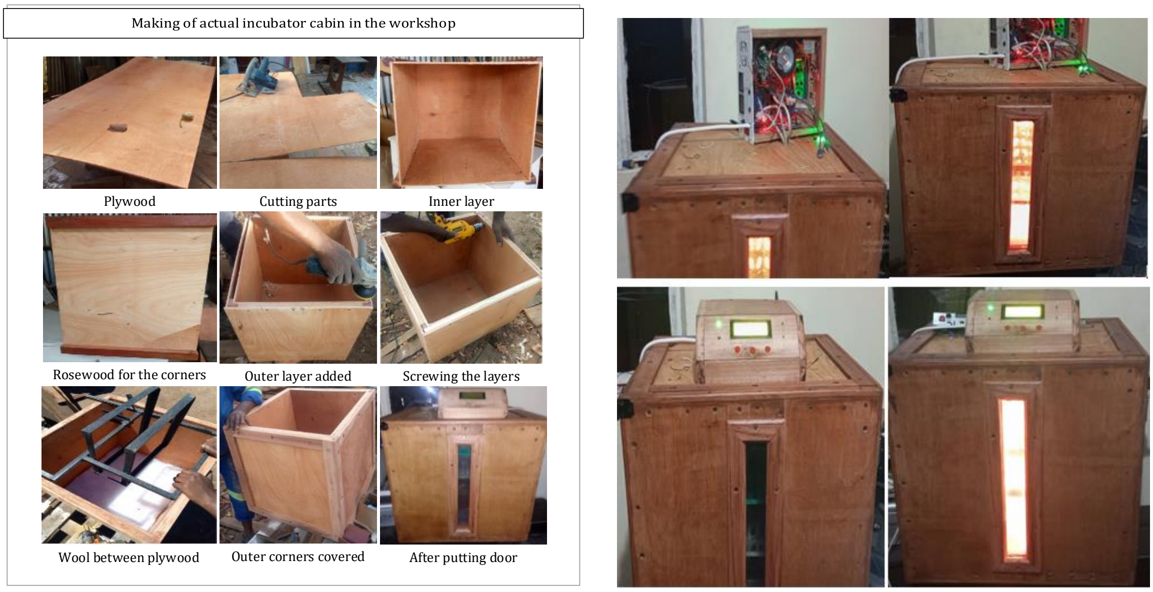

Figure 3: Fabricated Cabin

Simulation of the Axial Fan in Ansys Fluent

To evaluate whether a panel fan operating at 2000 rpm can maintain optimal temperature and oxygen levels within the incubator, a thorough airflow analysis was conducted by simulation. The objective of this simulation was to determine the fan's suitability for use in an incubator of

American Journal of Computing and Engineering
ISSN 2790-5586 (Online)
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the intended dimensions. A visual depiction of the axial fan's Ansys Fluent simulation is presented in figure 4 below, illustrating the results of the analysis.

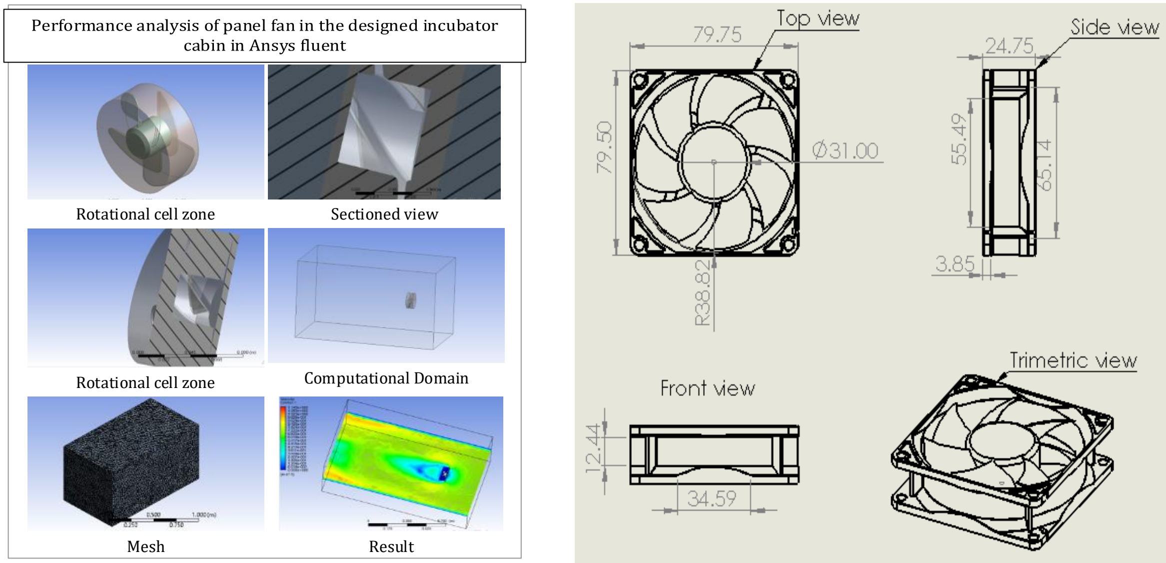

Figure 4: Analysis in Ansys

The panel fan successfully achieved uniform air distribution in the 450mm x 450mm x 500mm computational domain of the cabin. While a slight decrease in velocity was observed near the cabin boundary, the overall flow remained consistent, affirming that the panel fan is appropriately sized and capable of satisfying the incubator cabin's design specifications.

Electrical/Electronic Design

The pictorial design of the electrical circuit of the incubator is illustrated in Figure 5.

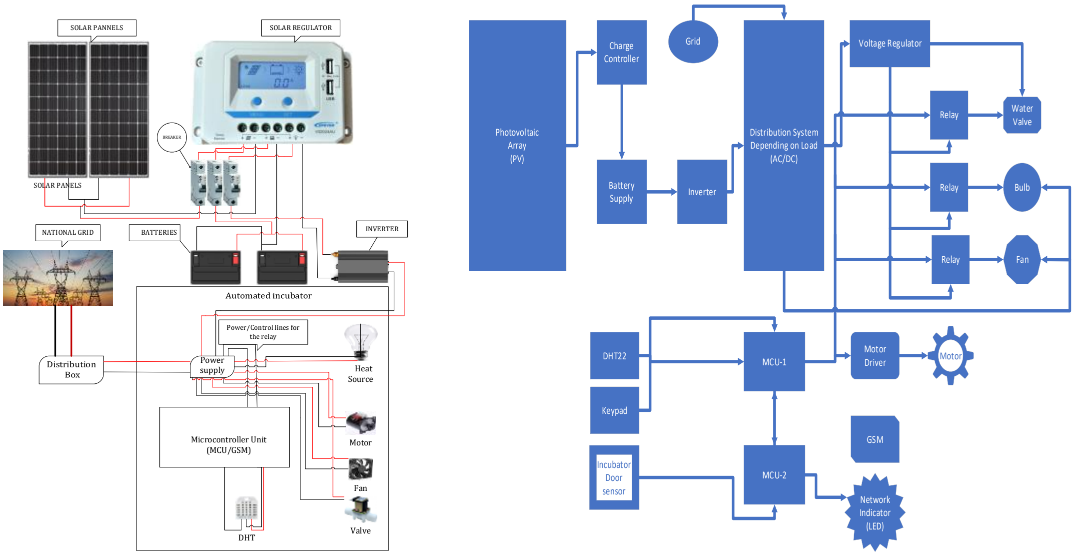

Figure 5: Electrical Circuit

The electronic circuit of the incubator is depicted in Figure 6

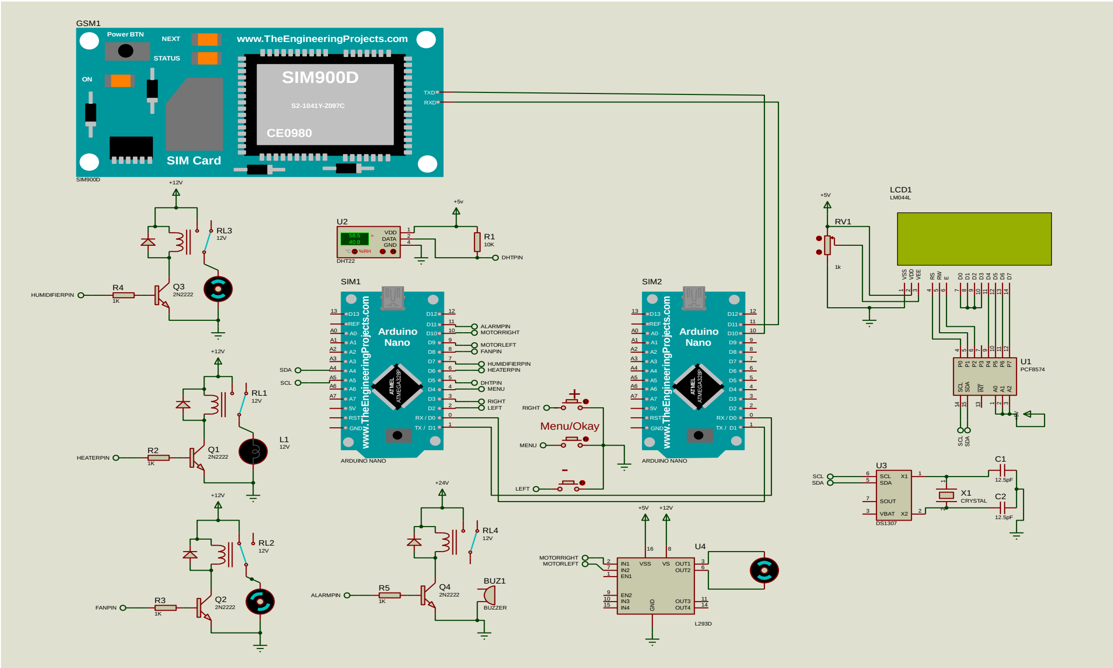

Figure 6: Electronic Circuit

Motor Control Circuits for Turning Eggs in Matlab Simulink

Below is the trajectory path generator circuit of the stepper motor in MATLAB Simulink, with forward and reverse control as well as step angle control, shown in Figure7.

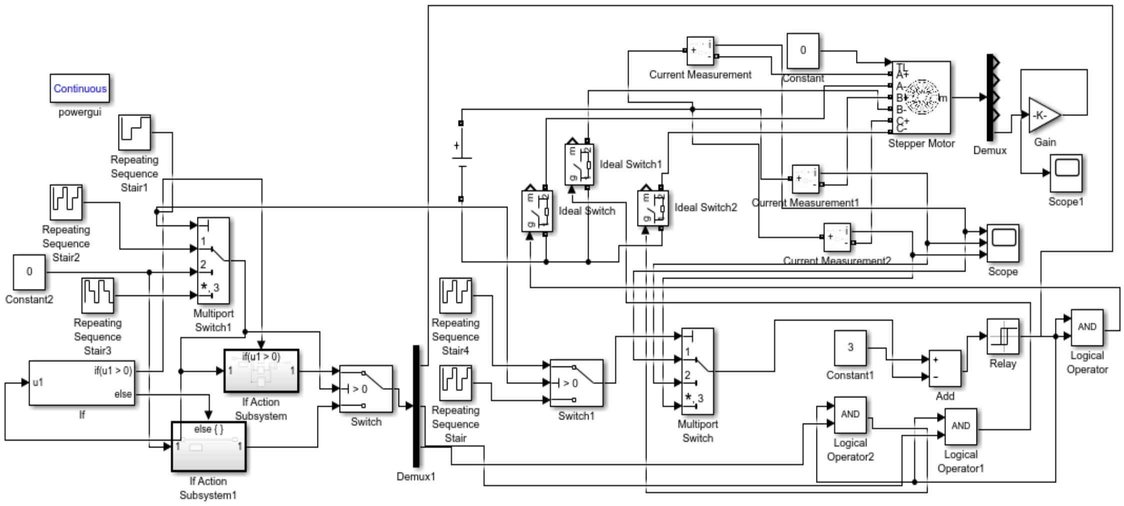

Figure 7: Motor Control Circuit

The "stair 1" sequence functions as the selector, tasked with managing the motor's movements, including stopping it. When the "if else" segment is activated, the selector will identify the correct lookup table to determine the appropriate course of action, whether it be to move forward, halt for an hour, or reverse.

The motor is programmed to run in a specific direction for a set period of time before switching directions. The intricate circuits responsible for the motor's movement were carefully designed to ensure seamless operation of the incubator. Any imperfections in the design could potentially cause delays. The motor moves precisely in 15-degree increments with each step of its execution.

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Code Design

The incubator code in Arduino IDE was developed following the flow diagram shown in Figure 8 to enable control of the incubator components.

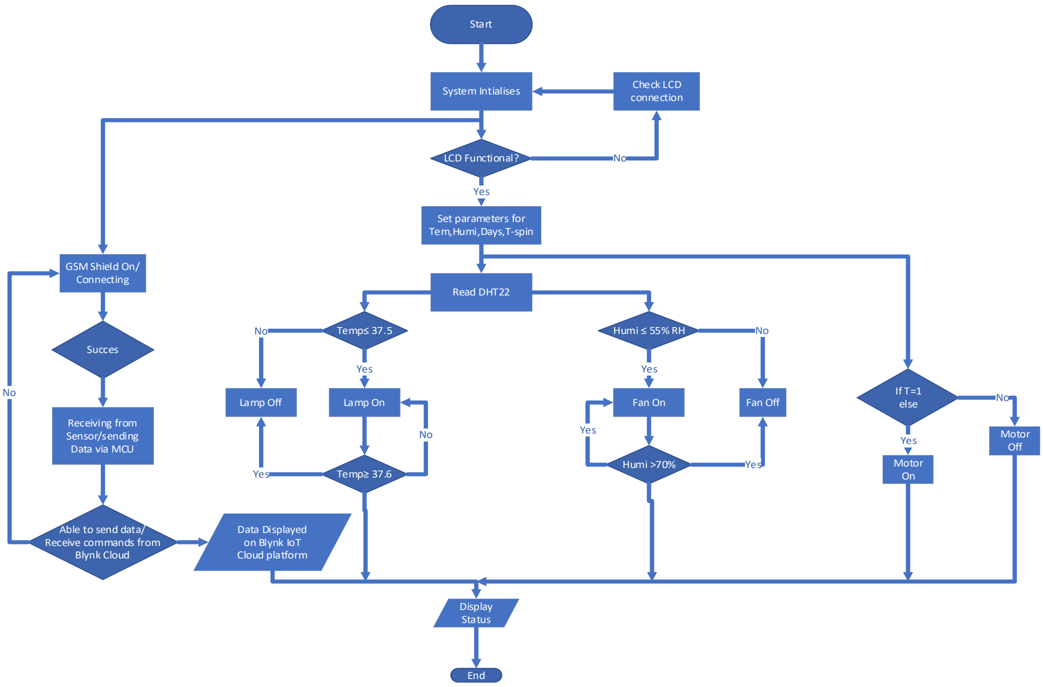

Figure 8: Incubator Operation

Network Design

As part of the process to enable the Internet of Things (IoT) component of the incubator and ensure its global accessibility, it was paramount to construct a coherent network design using Packet Tracer. The accompanying diagram, labelled "Figure 9," presents this design in detail.

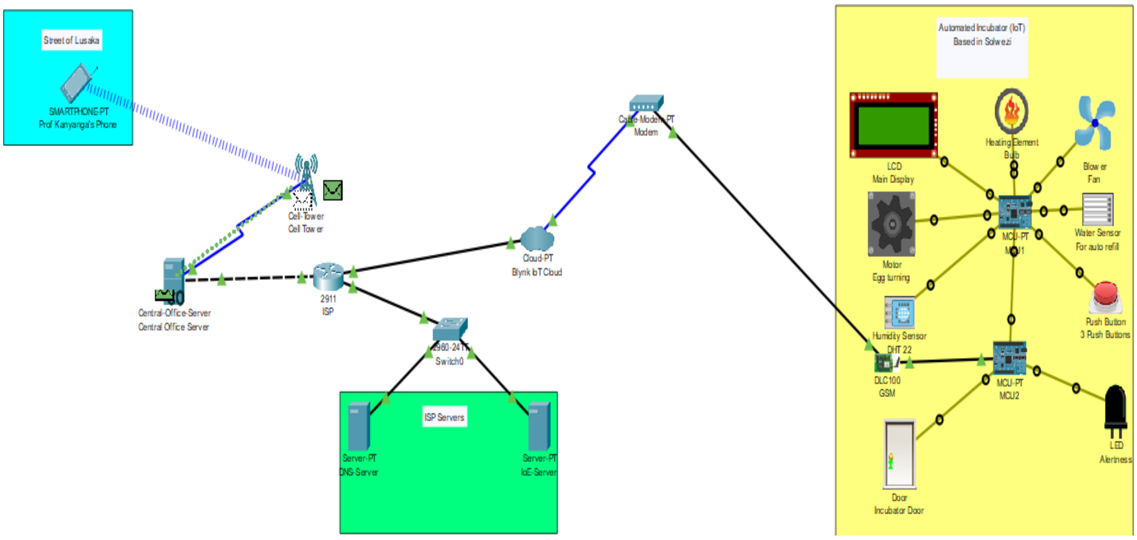

Figure 9: Network Layout

Below is a depiction of the node configuration in Packet Tracer, as illustrated in Figure 10

American Journal of Computing and Engineering
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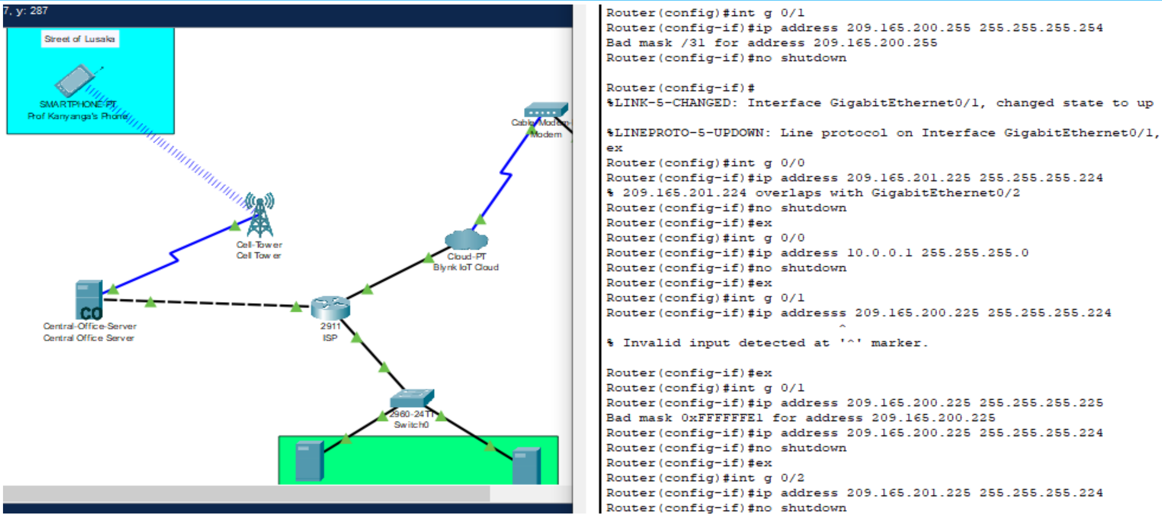

Figure 10: Configuring Routers in Packet Tracer

Blynk IoT Cloud

The Blynk IoT Platform is a versatile and user-friendly software solution that enables individuals and businesses to create innovative IoT projects and seamlessly connect them to the internet. Blynk allows for easy linking of a wide range of electronic devices to the web, collecting data from them, and monitoring and controlling them from anywhere in the world. The data can be stored, aggregated, and visualized effortlessly through mobile and web applications that are easy to construct. Blynk is a real-time system consisting of four primary components, one of which is the Blynk cloud. As seen in Figure 11, the incubator is connected to the Blynk IoT Cloud, enabling remote monitoring and control from a phone or computer. Blynk's impressive capabilities make all this possible.

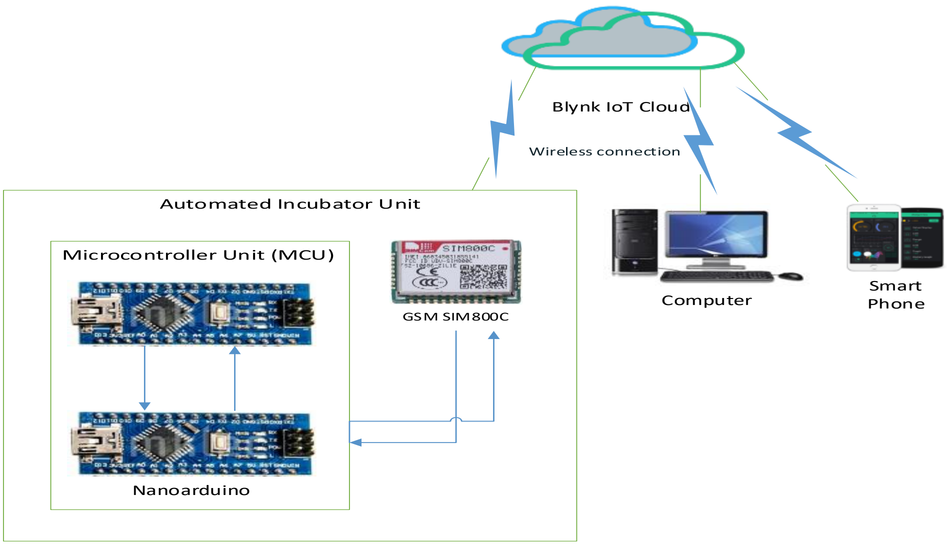

Figure 11: Blynk Layout

The GSM module connects the incubator to the Blynk IoT cloud wirelessly, allowing remote access from anywhere in the world.

American Journal of Computing and Engineering
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FINDINGS

This chapter provides an overview of the workings of a remote monitored incubator, with a particular focus on the insightful reports generated by Blynk IoT cloud. The remote incubator system allows for continuous monitoring and control of the incubator environment, leading to improved efficiency and accuracy during the incubation process. The reports produced by Blynk IoT cloud provide valuable data on crucial parameters such as temperature and humidity, which can be analyzed to make informed decisions and identify areas for improvement. It is essential to emphasize the significance of real-time monitoring and data analysis in optimizing incubator operations.

Operation and Performance of Incubator on Blynk IoT

The primary focus of this research was to assess the capabilities of the incubator in maintaining optimal temperature, humidity, and egg turning, as well as evaluate the performance of the solar-powered remote-monitored incubator. The incubator was successfully linked to Blynk, and its GSM was able to both send and receive data from the Blynk Cloud. The Blynk IoT platform allowed for constant monitoring of the door, egg turning motor, heater, fan, and GSM connection. Additionally, real-time monitoring of temperature and humidity was visualized on a graph via the Blynk dashboard. Table 1 presented the water level changes, which triggered the water valve to open when the level was low (indicated as 1) and provided the remaining days until the hatch date.

This reporting format allows for a thorough assessment of the performance of the poultry incubator. The report provides all necessary details for each parameter required for successful egg hatching. If the incubator's performance is subpar, the remote monitoring report generated by the Blynk IoT platform can easily identify the issue by reviewing all the captured parameters (temperature, humidity, ventilation, and egg turning). If all parameters fall within the required range, the focus can be narrowed down to the fertility of the eggs. In this case, the report shows that the incubator was able to maintain the ideal conditions for successful hatching.

Below is Figure 12 which displays the Blynk IoT cloud dashboard used to remotely monitor the incubator.

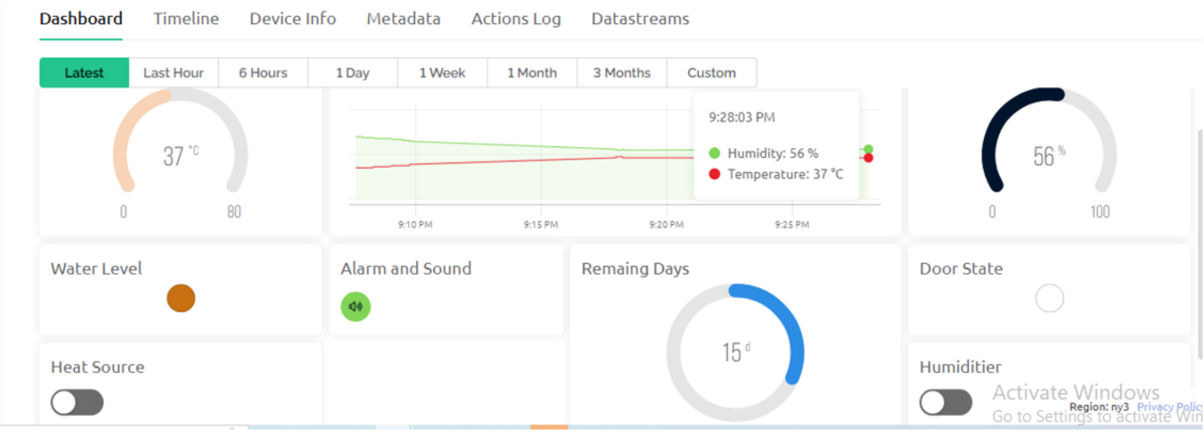

Figure 12: Blynk Dashboard

Displayed above is a glimpse of our Blynk IoT dashboard design. It features a real-time temperature gauge and humidity reading, accessible from any monitored location. The screenshot was taken while monitoring our incubator in Ndola from Solwezi, with the remote monitoring performance assessment yielding excellent results. The graph displayed real-time events occurring on the incubator, with no discrepancies between the readings and the graph. Other features include a water level pin, door state, heat source, humidifier, and remaining days. The current graph displays the latest data, but you can customize it to show data for any period you wish to assess the incubator's performance.

Below is Figure 13 displaying the temperature and humidity performance graph for a single day.

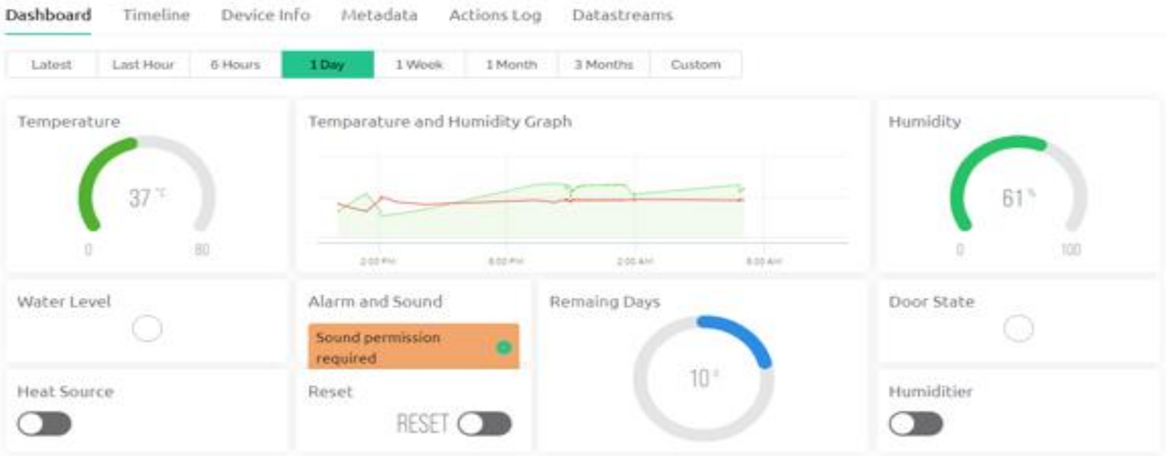

Figure 13: Incubator Performance for a Day

The remote monitoring report in the table below indicates that the fan and heater (bulb) will remain off, denoted by (0), and if the temperature exceeds the optimal level of 37°C and the humidity is above 62%. The door state is also continuously monitored, with any errors indicated by the error pin. The water level valve will remain in the "1" state if the water level in the container is below the lower limit. However, it is important to note that temperature and humidity updates may occasionally skip a row in the table due to the DHT sensor's average sampling time of approximately 2 seconds.

Once the optimal temperature and humidity levels are reached and the door is securely closed, the "1" will clear, and only "0s" will appear, indicating that no further action is needed.

Table 1.0 depicts changes in the water level state, which subsequently triggers the opening of the water valve, denoted by (1), indicating the "on" state. Additionally, it provides information on the number of days remaining until the hatch date. Note that humidity is measured in percentage (%) and temperature in degrees Celsius (°C).

American Journal of Computing and Engineering
ISSN 2790-5586 (Online)
Vol.8, Issue 1, pp 69-89, 2025

Table 1.0: Parameters Monitored Inclusive of Days

Time	Temperature	Humidity	Water Level	Door State	Error Pin	Humi-difier	Heat Sources	Egg Tray	Remaining Days
2/5/2023 4:52	37	65	1	0	1				
2/5/2023 4:52	37	65	1	0	1	0	0		10
2/5/2023 4:52						0	0		10
2/5/2023 4:52	37	65	1	0	1				
2/5/2023 4:52				0	1	0	0		10
2/5/2023 4:52	37	65	1						
2/5/2023 4:52		65	1	0	1	0	0		10
2/5/2023 4:52	37								
2/5/2023 4:52	37	65	1	0	1	0	0		10
2/5/2023 4:52				0	1	0	0		10
2/5/2023 4:52	37	65	1						
2/5/2023 4:52				0	1	0	0		10
2/5/2023 4:52	37	65	1						
2/5/2023 4:52						0	0		10
2/5/2023 4:52	37	65	1	0	1				
2/5/2023 4:52					1	0	0		10
2/5/2023 4:52	37	65	1	0	1				
2/5/2023 4:52						0	0		10
2/5/2023 4:52	37	65	1	0	1				
2/5/2023 4:52	37	65	1	0	1	0	0		10
2/5/2023 4:52	37	65	1	0	1				
2/5/2023 4:52	37	65	1	0	1	0	0		10

CONCLUSION AND RECOMMENDATIONS

Conclusion

To enhance the poultry industry and address challenges faced by small and medium-sized poultry farmers, a remotely monitored, automated solar-powered egg incubator was developed using cost-effective, locally available materials. These materials are not only easy to work with but also durable, giving the incubator a product life cycle of 10 to 12 years with proper maintenance. The incubator was designed with energy efficiency and accessibility in mind, featuring a multi-power system that allows it to run on solar power, grid electricity, or a generator, ensuring reliability in off-grid and rural settings.

One of the incubator's major innovations is its real-time remote monitoring capability, powered by GSM and the Blynk IoT platform. This system works with any mobile network, enabling users to monitor and control incubation parameters such as; temperature, humidity, egg rotation frequency, and hatching dates from anywhere using the Blynk app. These parameters are also displayed on a 20x4 LCD screen, allowing for local control and monitoring.

The incubator's performance assessment confirmed an efficiency rate of no less than 90%, meeting expectations for stable operation. The cabin materials were carefully selected for their thermal insulation properties, minimizing energy consumption and preventing unnecessary heat loss. Notably, the incubator could maintain a steady temperature of 35°C for up to 5 hours even when powered off, demonstrating its excellent thermal retention.

Flexibility is another strong point of the system, as it can be easily adjusted to accommodate various egg types, including chicken, turkey, quail, duck, and goose. This makes it a versatile solution for farmers with diverse poultry operations.

Compared to commercial incubators, which are often costly, energy-intensive, and reliant on grid power, this model stands out for its affordability, energy autonomy, and adaptability. Its use of open-source hardware like Arduino and GSM modules reduces both initial investment and operational costs. However, while suitable for small to medium-scale operations, the incubator can also be scaled up for industrial use. For this transition, enhancements such as modular tray expansion, industrial-grade materials, high-capacity battery storage, and centralized digital monitoring dashboards would be necessary.

With these improvements, the incubator could evolve into a commercially viable, industrial-scale system that supports large-scale hatchery operations. Its adoption could significantly boost productivity, reduce operational costs, and increase profit margins for poultry farmers. Moreover, it has the potential to create employment, stimulate local economies, and strengthen related sectors by improving the purchasing power of communities involved in poultry production. Ultimately, this innovation represents a sustainable, scalable solution for modernizing poultry farming in Zambia and similar developing regions.

Recommendations

Here are some recommendations for further research:

1. To scale up production in the poultry industry, increase GDP, and reduce production costs, it is crucial to introduce managerial technology that uses IoT in the day-to-day running of poultry businesses. This will enhance efficiency, lower production costs, and ultimately lead to increased profit margins.
2. The good design of the incubator cabin and the selection of appropriate materials are critical in the manufacturing of incubators. A 3-layer design that utilizes plywood and wool can make the incubators more power-efficient, thereby reducing production costs even further.

Recommendations for Further Research

Further research is necessary to integrate sensors that can effectively regulate oxygen and carbon dioxide levels. Additionally, it would be beneficial to explore other microcontroller options that can operate with Blynk IoT cloud without experiencing storage limitations.

To increase the competitive edge of the incubator, it would be wise to introduce value-added features, such as the Nexion TFT intelligent touch screen. This innovative technology eliminates the need for traditional control interface components, like buttons and LEDs, while also enhancing incubator ergonomic

REFERENCES

A. Lourens, H. van den Brand, R. Meijerhof, & B. Kemp. (2005). *Effect of eggshell temperature during incubation on embryo development, hatchability, and posthatch development, Poultry Science, 84*(6), 914–920. https://doi.org/doi.org/10.1093/ps/84.6.914.

Aigbiniode Lawani, S., Aigbiniode Sunday, L., Uzoamaka Benedette, C.-F., Omokhagbo, A., Ernest Olurotimi, I., Musa, A., Umar, A., & Author, C. (2018). *Technical Overview of a Microcontroller Based Room Temperature Fan Speed Regulator*. *7*, 164–171. www.ajer.org

Aldair, A. A., Rashid, A. T., & Mokayef, M. (n.d.). *Design and Implementation of Intelligent Control System for Egg Incubator Based on IoT Technology*.

Alsayaydeh, J. A. J., Irianto, Ali, M. F., Al-Andoli, M. N. M., & Herawan, S. G. (2024). Improving the Robustness of IoT-Powered Smart City Applications through Service-Reliant Application Authentication Technique. *IEEE Access*, *12*, 19405–19417. https://doi.org/10.1109/ACCESS.2024.3361407

Archer, G. S., & Cartwright, A. L. (2018). Incubating and Hatching Eggs. *Texas A&M Agri-life Extension Service, Agri-life Bookstore. Org*, *1*(7), 13.

Benjamin, N., & Oye, N. D. (2012). Modification of the design of poultry incubator. *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*, *1*(4), 90–104.

Boleli, I. C., Morita, V. S., Matos Jr, J. B., Thimotheo, M., & Almeida, V. R. (2016). Poultry egg incubation: integrating and optimizing production efficiency. *Brazilian Journal of Poultry Science*, *18*, 1–16.

Careghi, C., Tona, K., Onagbesan, O., Buyse, J., Decuypere, E., & Bruggeman, V. (2005). *Production, modeling, and education The Effects of the Spread of Hatch and Interaction with Delayed Feed Access after Hatch on Broiler Performance until Seven Days of Age*.

Durani, H., Sheth, M., Vaghasia, M., & Kotech, S. (2018). Smart Automated Home Application using IoT with Blynk App. *Proceedings of the International Conference on Inventive Communication and Computational Technologies, ICICCT 2018*, 393–397. https://doi.org/10.1109/ICICCT.2018.8473224

Elibol, O., & Brake, J. (2003). Effect of frequency of turning from three to eleven days of incubation on hatchability of broiler hatching eggs. *Poultry Science*, *82*(3), 357–359.

French, N. A. (1997). Modeling incubation temperature: the effects of incubator design, embryonic development, and egg size. *Poultry Science*, *76*(1), 124–133.

Kumar Srivastava, D. (n.d.). *IoT Based Systems Aquaculture For Fisheries Using IoT Sensor for Turbidity Estimation of Ph Value 10 Turbidity of Surface Water 13 Floating Sensors 16 Introduction to Streetlights*.

Mansaray, K. G., Yansaneh, O., Www, W. : Mansaray, K. G., & Yansaneh, O. (2015). Fabrication and Performance Evaluation of a Solar Powered Chicken Egg Incubator International Journal of Emerging Technology and Advanced Engineering Fabrication and Performance Evaluation of a Solar Powered Chicken Egg Incubator. In *Certified Journal* (Vol. 9001, Issue 6). www.ijetae.com

Niranjan, L., Venkatesan, C., Suhas, A. R., Satheeskumaran, S., & Nawaz, S. A. (2021). Design and implementation of chicken egg incubator for hatching using IoT. *International Journal of Computational Science and Engineering*, *24*(4), 363–372.

Noiva, R. M., Menezes, A. C., & Peleteiro, M. C. (2014). Influence of temperature and humidity manipulation on chicken embryonic development. *BMC Veterinary Research*, *10*(1). https://doi.org/10.1186/s12917-014-0234-3

Okonkwo, W. I., & Chukwuezie, O. C. (2012). Characterization of a photovoltaic powered poultry egg incubator. *In 4th International Conference on Agriculture and Animal Science*, *10*.

Okpagu, P. E. &, & Nwosu, A. W. (2016). Development and Temperature Control of Smart Egg Incubator System for Various Types of Egg. *European Journal of Engineering and Technology*, *4*(2). www.idpublications.org

Oladimeji Aliyu, S. (2014). *Agriculture and National Transformation Agenda: Faculty Staff Collaborative Invention of Models for Bird-Egg Incubator*. https://www.researchgate.net/publication/269984861

Oquiño, H., Paguntalan, R. B., Oquino, H., & Vinyl, &. (2016). *Design and Development of a Microcontroller based Egg Incubator for Small Scale Poultry Production Design and Development of a Microcontroller based Egg Incubator for Small Scale Poultry Production Design and Development of a Microcontroller based Egg Incubator for Small Scale Poultry Production*. https://doi.org/10.13140/RG.2.2.35273.42082

Osanyinpeju, K. L., Aderinlewo, A. A., Adetunji, O. R., & Ajisegiri, E. S. (2018a). Performance evaluation of a solar powered poultry egg incubator. *International Research Journal of Advanced Engineering and Science*, *3*(2), 255–264.

Osanyinpeju, K. L., Aderinlewo, A. A., Adetunji, O. R., & Ajisegiri, E. S. A. (2018b). Performance evaluation of a solar powered poultry egg incubator. *International Research Journal of Advanced Engineering and Science*, *3*(2), 255–264.

Oviedo-Rondón, E. O., Wineland, M. J., Funderburk, S., Small, J., Cutchin, H., & Mann, M. (2009). Incubation conditions affect leg health in large, high-yield broilers. *Journal of Applied Poultry Research*, *18*(3), 640–646. https://doi.org/10.3382/japr.2008-00127

Peprah, F., Gyamfi, S., Amo-Boateng, M., Buadi, E., & Obeng, M. (2022). Design and construction of smart solar powered egg incubator based on GSM/IoT. *Scientific African*, *17*. https://doi.org/10.1016/j.sciaf.2022.e01326

Poultry in Zambia Investors Guide. (n.d.). http://zimbabwe.nlembassy.

Sansomboonsuk, S., Phonhan, C., & Phonhan, G. (2011). An Automatic Incubator. *Energy Research Journal*, *2*(2), 51–56.

Shanto, S. S., Rahman, M., Oasik, J. Md., & Hossain, H. (2023). Smart Greenhouse Monitoring System Using Blynk IoT App. *Journal of Engineering Research and Reports*, *25*(2), 94-107. https://doi.org/10.9734/jerr/2023/v25i2883

Yildirim I. (2004). . Effects of Different Hatcher Temperatures on Hatching Traits of Broiler Embryos during the Last Five Days of Incubation. *S Afr J Anim Sci*, *34*(4), 211-216.