Towards the Development of a Smart Photovoltaic-Powered Temperature Controlled Poultry Egg Incubator

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***Abstract* - A smart poultry egg temperature controlled incubation is an activity that requires sustainable energy supply for efficient performance, operation, and profitability. The egg incubation process involves the management of fertilized poultry eggs to a satisfactory development level that leads to regular chicks. This paper deals with a design of a poultry egg temperature controlled incubator system. The prototype is composed of an incubator, DHT22 temperature-humidity sensor, heater, and fan. The smartness of the system to maintain the parameter monitored inside the incubation chamber helps in the inverse proportionality of the ambient temperature and the temperature –humidity value inside the chamber. The proportionality may affect the fertility and hatchability of the eggs with an adverse effect on poultry chick production and sustain hatchery process. Sensors and actuators made up the Sensing-Actuation-Power Management Tier, all connected to the microcontroller unit as part of the characterization of the prototype.**

Keywords - smart incubator; solar-powered incubator; temperature controller; poultry

I. INTRODUCTION

Farming in the Philippines comprises of agricultural sub-sector such as crops, fisheries, livestock, and poultry. Poultry farming helps the agriculture industry through its commodities such as chicken, chicken egg, duck and duck egg that mainly starts from backyard farms. Poultry farming may cover egg hatching, brooding, and incubation. Egg hatching technologies is an egress for poultry farmer to transform chicks from an egg without the assent of the traditional warmth method of mother hen[1]. Poultry egg brooding according to [2] is a method that requires economic vitality supply for productive execution, operation, and benefit where egg incubation initializes from the handling of fertilized poultry eggs to ensuring a suitable development of chicks. Simulated brooding in aid with the traditional method uses powered hatcheries equipped with electronic business incubation facilities for cultivating chicken eggs [3]. Traditional incubation of chicken egg termed by [4] takes about three weeks or eighteen days for total growth and hatching. Growing process involves poultry eggs being placed in an incubator box ensuring optimal condition for chicken embryos development.

Natural incubation process involves a broody hen to fertile 14-16 eggs in optimum environmental conditions to stimulate embryonic development until hatching [5]. The broody hen rotates the eggs during incubation about 96 times in 24 hours and keeps the eggs at the correct humidity by splashing water on them from her break; eggs initially need a very controlled heat input to maintain the optimum temperature of 38^0C, because the embryo is microscopic. As the embryo grows in size, it produces more heat than it requires and may even need cooling. Moisture levels of 60-80% relative humidity stops additional moisture loss from the egg contents through the porous egg shell and membranes. A crucial factor for incubation is the maintenance of a constant environmental temperature of 37.5 or 38 degrees Celsius directly associated with the egg hatchability recognized in the work of [6]. Worldwide statistics show that about 8%-9% of all incubated eggs fail to hatch, which lead to massive waste of time, space, labor force and energy [7].

The traditional method of incubation includes candling or the practice of inspecting the eggs 5-7 days after their initial incubation by passing light through each egg. The current native practice in infertility egg detection depends on an outmoded and primitive method of candling or with the aid of light bulb. The candling technique is labor-intensive and can prolong the process of incubation and described by [8] that the outcome of the method is subjective and the correctness cannot be assured. In an average of 7, 10 and 18 days of egg incubation are the most comfortable time to differentiate an infertile egg from a fertile egg and identify any embryos that may have died [9]. The early detection of infertile and non-hatchable eggs would benefit hatcheries and poultry breeding farms by saving space, handling costs, and preventing contamination from exploder eggs [10].

An incubator defined by [1] is an enabling environment for the development of embryos present in fertilized eggs to imitate a bird's natural brooding ability by providing an artificial environment with the proper temperature. The temperature is controllable, and detection of egg fertility is an essential factor to increase efficiency in commercial hatcheries ensuring hatching rate and decreasing costs [11]. Lack of adequate control of the hatching process in commercial incubators has affected the high mortality rate in the incubation of bird eggs [12]. The moisture loss as an essential factor in the hatchability [13] necessitates the application of technology for a more efficient method of incubation. Monitoring the incubation process through conventional means demands continuous assessment of embryo status as mentioned by [14], which is usually a destructive intervention because of the required breaking of the eggs. Therefore, a noninvasive means to assess embryo development is of interest to research and industry. The need for artificial incubator lead to increase hatchability of eggs for the improvement and increase in the production of chicken eggs for human consumption and the economic market [14].

In this present age of information technology, the control and automation of devices, machines, and systems are achievable with the use of programmed microcontrollers and the use of renewable power sources. Artificial egg incubation systems is a significant technological and scientific development allowing the transition from manual incubation to large incubation machines and hatcheries, which incubate a much higher number of eggs using less labor, increasing chick production throughout the year[15]. The core concept of the research focuses on the design of a solar-powered incubator. The importance of the automated incubation system aims towards its relevance in improving the production capacity of poultry chicks for a sustainable economy.

II. METHODOLOGY

The development of any well-conceived and well-designed system must begin with a requirements definition. The initial stage of the study is to determine the software and hardware requirements needed for the realization of the prototype. The goal of the requirements identification process is to capture a formal description of the complete system and document these needs as written definitions. The output of requirement analysis phase is the requirement specification of the system.

In this study, the architectural design focused on the overall structure of the solar-powered poultry egg incubator and represented in figure 1. The design of the prototype is an embedded system in nature involving the transformation of identified requirements into a working prototype composed of hardware and software components.

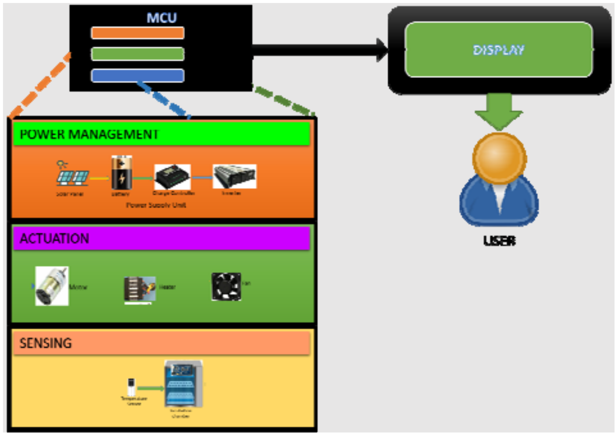

Figure 1. The architecture of the system

The system's architecture shows the actual representation of the system and the primary components for the solar-powered poultry egg incubator. Sensing-Actuation-Power Management Tier is all connected to the microcontroller unit. Sensing is a collection of sensors responsible for collecting data in the incubator. Actuation is the control part of the architecture enabling parameters such as fan, motor, and heater. Power management equips the solar panel, battery, controller and inverter of the system. The display allows the user to look into the gathered data. The incremental development approach allows constructing working parts of the hardware and software in incremental stages where each step through the cycle incorporates a little more of the intended functionality.

A. *Poultry egg incubator*

Incubators artificially provide the egg with the correct, controlled environment for the developing chick. Classification of incubators differs based on the source used for heat generation method. Electrical incubators or a still air incubator is an insulated chamber consisting of a heating element, temperature controller, and egg tray. A forced electrical type draft incubator has a fan used to circulate the air inside the chamber in the possibility of the temperature gradient. Incubators can be non-electrical incubators where the sources used for heat generation for maintaining the incubator temperature was different.

Non-electrical incubator example is a solar-based thermal incubator that uses solar thermal energy for egg incubation [16]. The egg incubation chamber of the study consists of trays, capable of handling 50 to 100 chicken eggs with each tray housing 25 to 50 eggs. Fiberglass material made up the casing of the chamber purposively used against the adverse effect of weather. Egg trays with tilting mechanism will be placed on the first two-layer while the temperature control unit is on the top layer of the incubator.

DOI 10.5013/IJSSST.a.19.03.19 ISSN: 1473-804x online, 1473-8031 print

B. *Temperature during incubation*

The work of [17] stresses that a developing egg embryo experiences a temperature dependent on the incubator temperature, embryo heat production, and thermal conductivity of the egg and the kind of birds to be hatched. Incubation is a process of transferring heat from the parent to an embryo with a constant temperature. The incubation temperature ranges between 37.0^{0}C and 38.0^{0}C and a little nonconformity from this optimum temperature can have a significant impact on hatching success and embryo development. With the egg at the correct temperature, the biological process of incubation commences, and the embryo begins to grow, so correct temperature range must be sustained throughout the incubation period to achieve a higher rate of hatchability.

The humidity is also a contributing factor where too dry air will lose too much water to the atmosphere making hatching difficult or impossible and results to a lighter egg where the airspace within the egg will become more substantial. The physical and pre-incubation conditions affect the physical relationship of the egg and the air of the incubator, heat transfer and the exchange of O^2, CO^2, and water. The optimal values of the physical agents in the incubator plays relevant factors to a smooth process characterized by embryo metabolism rate, and, may cause deviations from [18].

C. *Microcontroller unit*

The Arduino microcontroller unit will serve as the controller of the circuit and the integrator between the temperature sensor and the LCD for the display of the current measured temperature. The DHT22 temperature-humidity sensor sends the sensed value to the digital input pin of the microcontroller unit causing the digital output pin of the Arduino to send the temperature value to the LCD for the display. The microcontroller checks the data according to the determined threshold values, in this study, it ranges from 37 to 38 degree Celsius and sends the control signals to the relay to control the heater and fan [19]. The turning on and off of the heater and fan is dependent on the temperature read by the sensor. If the temperature is below 37 ^{0}C, the heater will turn on. Otherwise, it will turn off. However, if the temperature reading is above 38 ^{0}C, the fan will switch on, and the heater is switched off until the temperature decreases to 37 ^{0}C. The process of temperature reading is done continuously with the use of solar energy.

The egg incubation chamber equipped with temperature control system and a power supply unit shown in figure 2.

D. *Solar energy and photovoltaic cells*

Developing countries such as the Philippines have farmers who can breed small numbers of poultry, but unable to afford into a more efficient, productive and profitable market of artificial incubation. The artificial incubation in poultry farms are in junction with the growth of electricity demand, and environmental issues which discoursed by [20] stimulated the usage of decentralized energy generation using renewable sources. Solar energy is the most effective renewable source to convert the solar radiation into electricity based photovoltaic effect as cited in the works of [21][22][23] towards a remarkable significance in various applications.

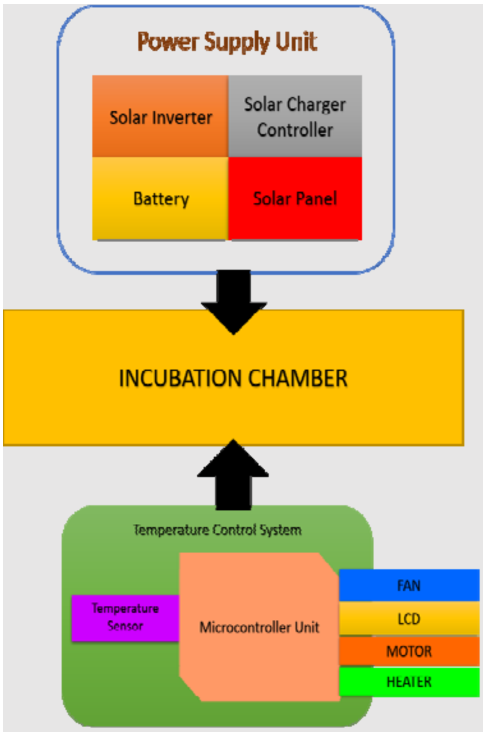

Figure 2. Block diagram of the prototype

The solar cell of the prototype considered in the prototype is mono-crystalline silicon (mc-Si) type due to low maintenance cost, high reliability, noiseless and eco-friendly [24]. The solar photovoltaic system is a technology to convert the sunlight into an electric charge. The collected charge from the solar panel is then transferred to an output terminal to produce 6 to 24 DC voltage [25].

To calculate the total power consumption of all components in the incubator, equation (1) will be used as a reference in the work of [26]. The total power is the summation of the power rating (P_H, P_F, and P_M) multiplied by the time usage (t_H, t_F, and t_M) of the heater, fan, and electric motor respectively.

$$Power_{total}=P_Ht_H+ P_Ft_F+ P_Mt_M \quad (1)$$

E. *Battery, Controller, and Inverter*

A deep cycle type of battery serves as the storage of energy harvested and backup storage regardless of the absence of solar input. An incubator system that can last for 24-hour operation according to the study of [27] has a 12V with 200 Ampere-hour deep cycle battery. The total energy required for the period without no sunlight and the nominal voltage of the battery are the factors adopted in this study in determining the size and capacity of the battery for the power supply unit of the incubator in referenced to the study of [26].

The solar charge controller regulates the proper charging voltage on the batteries and safeguards that the battery for overcharging or drained too far. The charge controller directly checks and controls the state of the battery between pulses and adjusts itself, each time [28]. The PWM-based charge controller is the most effective means to achieve constant voltage battery charging by adjusting the duty ratio of the switches [29].

The sizing of the solar inverter usually is equal to the total load power of the incubator, but for safety, it is advisable that the total capacity of the inverter be 25% to 30% [30] higher than the total load power of all electrical components of the incubator.

III. RESULTS AND DISCUSSION

The circuit design is simulated to test if the circuit will run according to the requirements define in the requirements specification. Proteus software simulates the circuit design, shown in figure 3 of the prototype's temperature sensor, LCD, relay, motor, fan, and heater. Proteus software allows a broad spectrum of project prototyping in areas with control and automation.

Temperature control system is an integral part of a poultry egg incubator. Selection of an appropriate temperature sensor is essential for effective control of temperature in the incubator. The temperature controlling methods available for poultry egg incubator is a combination of pure on-off control and PWM control systems. Sensing the temperature in the incubation chamber is a necessity before controlling it. A sensor placed in the compartment of the incubated eggs measures the temperature and humidity in the chamber.

The optimum incubation temperature is between 37^0C and 38^0C respectively. A Green LED indicator will switch ON whenever the temperature is between the optimum incubation temperature. A Red LED turns ON whenever the temperature is below 37^0C, and the heater switched ON until temperature reaches to 37^0C. A temperature reading more than 38^0C, the fan will be switched ON and until the temperature decreased to 37^0C. The heater is used to increase the temperature in the incubator. The fan is for cooling the incubator. Turning of the egg is necessary at least three times a day. Tilting at 45^0 angles prevents the embryo from sticking to the shell membranes if it is left in one position too long. Turning the eggs starts from day 2 to day 17 of incubation.

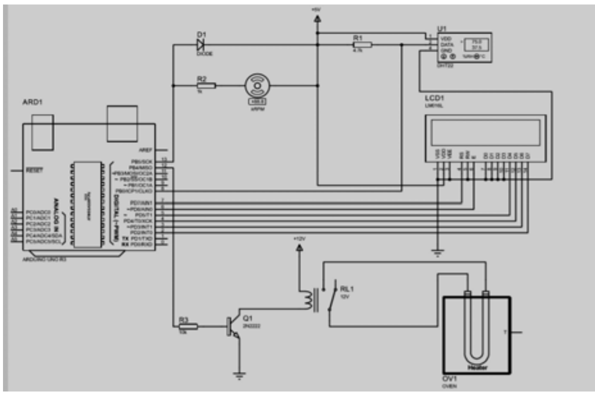

Figure 3. Circuit layout of the temperature controller using Proteus

Ambient temperature may affect the temperature and humidity inside the incubation chamber. The smartness of the system to maintain the parameter monitored inside the incubation chamber helps in the inverse proportionality of the ambient temperature and the temperature–humidity value inside the chamber.The proportionality may affect the fertility and hatchability of the eggs.

IV. CONCLUSION AND FUTURE WORK

The study is developed to assist the poultry farmers in technological perspective, to significantly increased their productivity. Small-Scale embedded systems designed with a single microcontroller have simplified the construction of the temperature control circuit. The prototype is realized in simulation using Proteus software. The optimum incubation temperature is defined and identified between 37^0C and 38^0C respectively. Sensors and actuators as part of the model made up the Sensing-Actuation-Power Management Tier, all connected to the microcontroller unit. A follow-up study is ongoing to incorporate an automatic egg detection unit using spectra-analysis methodology. An experimental method for the intended development of solar-based incubator system will further the study regarding reduction maintenance and installation cost of electrical incubators and aids in energy conservation.

ACKNOWLEDGMENT

The authors would like to acknowledge the Commission on Higher Education (CHED) for the funding of this work under their K12 Scholarship grant.

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