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Design and Development of Poultry Farm Management Systems Based on IoT Systems

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Abstract

In response to the escalating impact of climate change on poultry health and the growing demands of an expanding poultry production industry, farming systems are evolving into automated solutions. This paper highlights the design and development of a poultry farm management system that is named ALG poultry farm management device. This poultry farm management device that is based on Internet of Things (IoT) technology to automate climate management in poultry farms remotely. The main goal of the ALG poultry farm management device is to regulate crucial environmental factors affecting poultry health, such as temperature and humidity. The device integrates seamlessly with a cloud-based database and an Android app, facilitating remote monitoring and controlling through IoT to establish an optimal climate for poultry farms. Battery system is used to ensure the operation of the poultry farm management when power blackouts happen. Different test profiles are conducted for validating the ALG poultry farm management devices that save resources and energy and improve poultry productivity.

1. Introduction

In recent decades, the poultry industry has witnessed a substantial increase in production. This increase is driven by standardized farming practices, the adoption of good manufacturing practices, and heightened consumer awareness regarding food safety and the nutritional benefits of poultry products. Chickens have emerged as the most consumed and sought-after source of nutrient-rich protein, characterized by its low fat and cholesterol content, they require a special environment for raising. As the demand for high-quality poultry products continues to soar worldwide, modern poultry farms have evolved to meet these expectations while imposing stringent requirements on the management of the henhouse environment (Onibonoje, 2021). Poultry farm management systems contribute into the production and environmental sustainability by helping reduce ammonia emissions and other environmental impacts. Efficient resource utilization, including feed and water, is facilitated by monitoring systems. This leads to reducing resource wastage and lower production costs (Lashari et al., 2018). These systems offer a wide range of advantages for poultry farmers, whereas reducing resource wastage and lower production costs. These systems offer a wide range of advantages for poultry farmers, whereas they provide real-time monitoring of critical environmental parameters such as temperature, humidity, air quality, and ammonia levels. This ensures that the conditions within the poultry house are optimal for the health and well-being of the birds. These systems enhance that chickens are raised in environments with controlled temperature and air quality, where they reduce stress and better overall health, resulting in improved animal welfare outcomes (Onibonoje, 2021., Lashari et al., 2018., Sitaram, 2018).

One of the transformative technologies facilitating the shift towards efficient and data-driven poultry farm management is Internet of Things (IoT) that represents a paradigm where various sensors and devices are seamlessly interconnected through the internet. These poultry farm management systems enable data acquisition, fusion, processing, and facilitating intelligent identification and management at the operating terminal (Zheng et al., 2021). Automation and remote monitoring can significantly reduce labor costs associated with traditional poultry farming practices. Poultry farm management systems generate valuable data that can be analyzed to make informed decisions. This data-driven approach enables farm owners to identify trends, detect issues early, and implement corrective actions, ultimately improving farm operations and profitability. This results in the production of high-quality poultry products that meet consumer expectations and regulatory standards (Lashari et al., 2018., Sitaram et al., 2018., Zheng et al., 2021., Bumanis et al., 2022). The benefits of using poultry farm management systems are well-documented in various research papers and studies. Literature studies in poultry farm management systems have showcased the implementation of IoT-based solutions, often focusing on system design with limited attention given to the reliable transmission of wireless data. Challenges such as data packet dropout during wireless transmission, data duplication, and missing data have surfaced as areas warranting improvement (Zheng et al., 2021., Bumanis et al., 2022., Handigolkar et al., 2016).

This work presents a solution for these challenges through design and development of ALG farm management device that controls poultry farm house 400 m^2 and meets the poultry farm management system and customers' requirements. Figure 1 illustrates the overview system architecture of the ALG farm management device, where the users can monitor and control the poultry farm through a mobile app. This ALG poultry farm management device is designed and manufactured by Electro Green company through R&D (research and development) methodology, as described in the following sections.

Figure 1. ALG farm management device architecture

This paper is structured as follows. Section I explains the purposes and benefits of using poultry farm management systems. Literature search in industry and academia is described in Section II. The system architecture of the ALG farm management device is illustrated in Section III. The system setup and test profiles are explained in Section IV. Discussion and future works are mentioned in Section V. The conclusion is drawn in Section V.

2. Literature Survey

In this literature survey, poultry farm management systems are explored in the academic and industry in the perspectives of current research and production. This section provides a concise overview of the diverse literature landscape shaping the poultry farming domain. Roxell company manufactures the iQon™ full house controller that provides measurements from sensors in poultry farms. The ventilation levels are adjusted according to the age of the chickens. The users can connect to the devices in the farm remotely via smartphone, tablet or laptop, where the users can make adjustments for the feed, water, heating, and ventilation (Roxell company, 2023). Skov company produces the SKOV control devices that acquire the temperature and humidity sensors, and manages ventilation, cooling, and heating for the poultry farm. It also calculates weight and feed consumption for chickens. The gathered data set is displayed on the screen of the device, the alarms can be sent as text messages or emails, or displayed on a smartphone via the Farm Online app (Skov company, 2023). Nybsys company builds automated smart poultry farm devices that consist of sensors and a gateway. The gathered data are monitored, which are temperature, fire, light intensity, dust, and gas sensors. These data are uploaded to a cloud-based dashboard via the Nybsys iG100 gateway, which are processed. The control system notifies the users of the status of the farm with respect to the processed data (Nybsys company, 2023). Stienen company produces the PL-9300 control systems that manage and control temperature, water, feed, weight, production, relative humidity (RH), carbon dioxide (CO_2), and ammonia (NH_3). The PL-9500 systems collect data of life bird weighing, feed weighing, silo weighing, egg counting, and heat exchangers. These data are processed and displayed into comprehensible tables and graphs that help the users to monitor the poultry farms (Stienen company, 2023). Microfan company manufactures ARGOS P_1 device that controls and manages temperature, humidity, CO_2, NH_3, air pressure, airflow direction, and light sensors. These controlled parameters are linked to ARGOS.CLOUD to monitor them remotely via a PC, tablet, or smartphone. Microfan produces other devices that share similar purposes and have different features, such as Nwe Bravo Touch devices (Microfan company,2023). Big Dutchman company produces ViberTouch and breezy devices that perform climate control and production for poultry farms. These devices control the fresh air, exhaust air, recirculating air, heating, heat exchanger, cooling, emergency opening, and alarm via relays. These devices acquire temperature, RH, CO_2, and NH_3 sensors (Big Dutchman, 2021).

Md. Islam, et. al, built a smart poultry farm device using an IoT system that is based on Wi-Fi module. They used Arduino UNO MCU (microcontroller) to control buzzer and relays, and acquire data from temperature, humidity, gas, and light sensors. The measurements were displayed on LCD and an UI (user interface) website simultaneously via ESP8266 Wi-Fi module. The device notified the users about any necessity of the maintenance through phone messages via the GSM technique (Md Islam et al., 2019). Geetanjali A. Choukidar and N. A. Dawande designed a smart poultry farm and monitoring system using IoT technology and general packet radio service (GPRS) network. Raspberry Pi MCU was used to control relays and buzzers, and communicate with temperature, humidity, ammonia, and gas sensors. Wireless sensors were used as well for water level measurements, which were connected to ADC interference (MCP, 3208). These sensors captured and sensed the environmental data in poultry farms, the processed data were displayed on LCD screen, and sent to phones of the users via messages. This information was streamed live through UI website page using Apache web server with PHP and MySQL database server (Geetanjali et al., 2017). Mondol et al (2020) designed and developed weather monitoring of poultry farms using IoT technology. They used ESP8266 MCU that acquired sensor data and controlled devices, the IoT was based on Wi-Fi systems. The application was developed using IFTTT platform, where the MCU transmitted the sensed data (from temperature and humidity sensors) to the server, analyzed the data, and made the decision based on the analysis. The used server system sent notification to smartphone app and signal to the buzzer to help the farmers/users to monitor the farm remotely (Mondol et al., 2020). Hambali et al (2020) designed smart poultry farms using IoT and mobile technology and RESTful web service. They used Arduino mega 2560R3 as the main MCU, an ESP 8266 kit was used for IoT system that is based on Wi-Fi system. The sensed values from the sensors were sent to the database (XAMPP), so the visual data were displayed to the device's screen (LCD) and mobile application for the users. The device had four types of sensors that were temperature, humidity, air quality and feeder sensor. The notifications of poultry system were communicated with the users through four different channels LCD & LEDs attached to the device, mobile phone, email, and WhatsApp (Hambali et al., 2020). Elham et al (2020) built automated poultry farms to monitor and store data. They used Raspberry pi 3B+ to measure temperature and humidity from the sensors. The sensed data from the sensors were transmitted and stored over internet of things application (IoTA) Blockchain and JavaScript Object Nation (JSON). The data could be viewed using IoTA Tangle explore, Adafruit Python DHT was installed for interfacing between the sensor and the board and IoTA Python for IoTA blockchain programming. Manshor et al (2019) used a Raspberry Pi as the central monitoring unit, continuously tracking temperature, humidity, and switch status, and enabling continuous data streaming for precise poultry house conditions. Integration of Firebase, a cloud-based service ensured seamless data transmission and real-time accessibility. They developed a user-friendly Android app for convenient monitoring of data on firebase. They employed a power bank as an uninterruptible power supply (UPS) to address power blackouts (Manshor et al., 2019). Raj and Jayanthi designed a sophisticated poultry health monitoring system to identify sick hens within a group. They used diverse data sources, including audio recordings, NH_3 sensor data, and images. Employing advanced techniques such as mel-frequency cepstral coefficients for audio feature extraction, the system analyzed hen noises. Additionally, image analysis, combined with movement patterns and temperature records, provided valuable data for accurate health evaluations. The authors' comprehensive methodology, incorporating audio, sensor data, and images, demonstrated significant contributions to poultry health monitoring (Raj et al., 2018). Lashari et al (2018) developed a poultry farm monitoring system based on a network architecture using Raspberry Pi nodes and various sensors, enabling real-time data collection from diverse locations. These nodes transmitted information to a central monitoring station or mobile app, providing unified oversight of hundreds or even thousands of farms. Integration of Sim900 GSM modules facilitated internet connectivity and SMS notifications, utilizing sensors measuring parameters such as temperature, humidity, CO_2, O_2, and NH_3. The system generated alerts for the users (Lashari et al., 2018). Dejeron, et. al, developed a farm management system in Philippine to automate and monitor the supply of food and water for farm animals. This system accurately gauged and tracked the levels of food, water, and energy from solar panels and batteries. The data was transmitted to a node MCU that updated a central database and sent alerts if level values exceeded the limits. The design system could function offline, automatically refilling containers without any user interfering (Batuto et al., 2020). Jayarajan et al (2021) presented a system for enhancing poultry farming in India, employing the IoT system for automating environmental monitoring and feed distribution. Key hardware components included an Arduino UNO, various sensors (temperature, gas, and IR), and a GSM module. The system aimed to improve egg quality and production efficiency by regulating factors like air quality and temperature, thereby increasing profitability. IoT and wireless sensor network systems enabled remote monitoring and control via UI web interface by Thing Speak for data display (Jayarajan et al., 2021).

These listed devices in industry and academia are analyzed and characterized with respect to system efficiency and cost, to design and build ALG Master devices. The devices from Roxell, Skov Nybsys, Stienen, Microfan, and Big Dutchman company are efficient and liable poultry farm systems; although, their cost values are high because of the IoT system subscription. The design devices in academia are suitable for research purposes, not applicable for mass production because of their structure limitations, such as including GSM, IoTA, various databases, etc. The following sections describe the proposed poultry farm system design.

System Architecture of ALG Master Device

The ALG farm management device is a cutting-edge and fully automated system design to revolutionize poultry farm management. It integrates IoT technology and sensor-based monitoring to create optimal conditions for the hens. It provides full-automatic control over the farm's climate while enabling remote monitoring and controlling. One of the standout features of the ALG farm management device is its low-cost, efficient remote monitoring, and control capabilities. With a dedicated mobile app, farmers and users can oversee and adjust farm conditions from anywhere. The system incorporates a multi-alarm system to provide farmers with prompt notifications of any emergencies. This proactive approach ensures that issues can be addressed swiftly, minimizing potential losses and helping to maintain the farm's productivity. The ALG farm management device contains a control unit (ALG Master), sensors, contactors, switches, actuators, and UI systems. The actuators present fans, alarms, and lights, where relays are used to activate these actuators. The UI options are cell phones, LCD, and LED indicators. ESP32 is used as the main control processor of the ALG Master control device, whereas it acquires data from the sensors, processes the data, controls the actuators, and communicates with the users via UI options, as illustrated in Figure 2. In addition to data acquisitions (DAQ) and control functions of the ESP32 MCU, the IoT system is based on Wi-Fi technology that is managed by the ESP32 MCU as well.

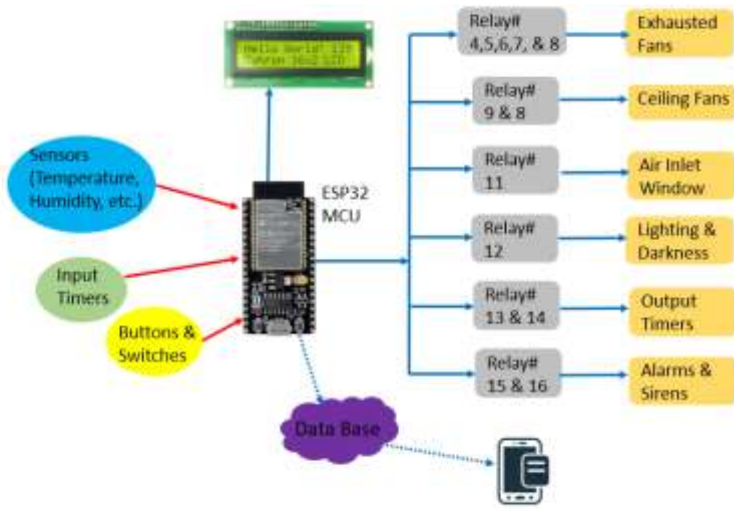

Figure 2. Block diagram of ALG control unit

The main functions and overview of the ALG farm management device are monitor and climate control remotely by either manual or automatic control modes. The users can access and manage the poultry farm's climate parameters from their smartphones, providing convenience and flexibility in farm management. The users have the flexibility to control various aspects of the farm environment, which are heating, cooling, humidity regulation, multiple exhaust fans, ceiling fans, air inlet windows, lighting, darkness, timers, and alarms. Figure 3 illustrates the wiring diagram of one power contactor, one fan, and one light, which are wired in a control panel enclosure. The control enclosure contains 16 channels that cover heating, cooling, humidity regulation, exhaust systems, lighting, and timers. These fans, lights, and other elements are controlled by the ALG Master control unit through a relay module. An external sensor provides ambient temperature and humidity data, so this comprehensive sensor array ensures that the farm's conditions are accurately monitored. The ADC readings of these sensors are sampled at 50 milliseconds, which is executed in the firmware (FW) development in ESP32 MCU. The device features the LCD screen that serves as the main interface. It displays sensor readings, current time, date, data, and the device's Wi-Fi connectivity status, providing users with essential information immediately. The settings menu allows users to configure various parameters, including temperature and humidity settings, timers, alarms, air quality thresholds, and sensor calibration. Users can easily navigate through these menus and adjust values as needed via physical buttons in the ALG Master control unit or mobile app. The system includes a timer setup menu that covers different timers, such as those for exhaust fans, ceiling fans, lighting, and more. Users can set specific time intervals for these functions to operate automatically. The poultry farm system is very sensitive to any parameter changes, where the hens and production will be affected immediately. Therefore, the device is equipped with batteries (UPS) to ensure continuous operation even during power outages for 3 hours, so the users can access sensor data via mobile devices as well. The UPS is used to address power concerns, which ensured uninterrupted operation even during blackouts, and preserved system functionality and data integrity. The device also has a built-in alarm that triggers if any of the connected sensors become disconnected, where this feature provides immediate alerts, specifying the type of sensor that has been disconnected.

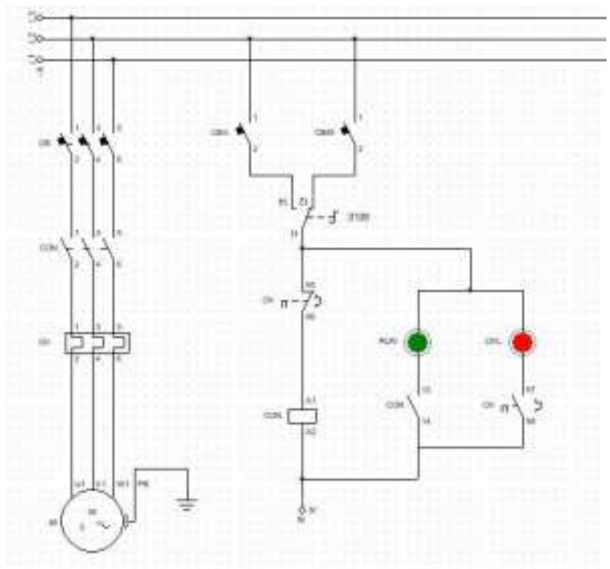

Figure 3. System configuration control panel

The farmers can actively track key parameters such as temperature and humidity by linking the farm's control unit to a smartphone application via the Firebase cloud database. The developed IoT system does not only allow the users to establish upper and lower thresholds of the variables and parameters, it prescribes specific corrective measures if these set boundaries are breached. Furthermore, farmers have the advantage of programming alarms or schedules to activate or deactivate various devices within the poultry facility, including windows and ceiling fans. Figure 4 shows the system architecture of the IoT that is based on Wi-Fi. Firebase, a robust cloud-based platform, is instrumental in the data management process. The ESP32 continuously relays information to this database around the clock, ensuring a seamless flow of real-time data. However, it's worth noting that the uninterrupted transmission was contingent upon stable internet connectivity and uninterrupted electricity supply. The developed FW in ESP32 MCU includes these software features, including ADC, timer, IoT, and processing data, which are executed in a continuous while loop.

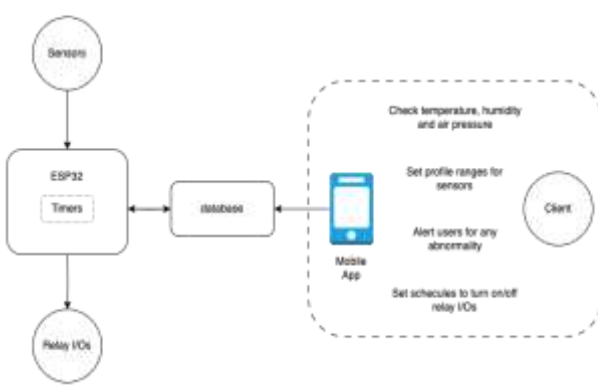

Figure 4. System software architecture

ALG Master System Setup

This section describes the system setup and test profiles of ALG farm management device, which is deployed for production. The proposed poultry farm management system has been purposefully designed to cater to a broad spectrum of functions, ranging from DAQ to environmental monitoring and control. These main functions are achieved through the ALG Master control unit that is driven by the ESP32 MCU. Furthermore, the system's functionality is amplified by components such as sensors for environmental monitoring, amplifiers, voltage regulators, and interface modules. The system is equipped with user-friendly features, including a 5-inch TFT LCD module, fostering interaction and data presentation, and showcasing the versatility and potential of this intricate electronic setup. The device includes Lithium-Ion battery (12V & 2.2A) and BMS (battery management system) to power the system including the sensors and actuators when the main power supply is lost. The battery package is configured as four battery cells in series to provide 2200 mAh & 12V for the poultry farm system. Figure 5 illustrates the system architecture of the developed ALG farm management device, where a full-bridge rectifier (KBL406) is used to rectify the AC voltage to DC voltage, as capacitors (1mF) are used to smooth the rectified voltage. LEDs are used to provide visual feedback and indicators to the users. Push button switches (4-pin switches) are used as user input buttons for interacting with the device and facilitating user interaction and control. The boards are fabricated and manufactured using two layers PCBs (printed circuit boards). Printed fennel stickers are designed and built to protect the electronic and the device for ESD (electrostatic discharge) and provide information to the users as well. Table 1 lists the electronic components in the ALG farm management device system.

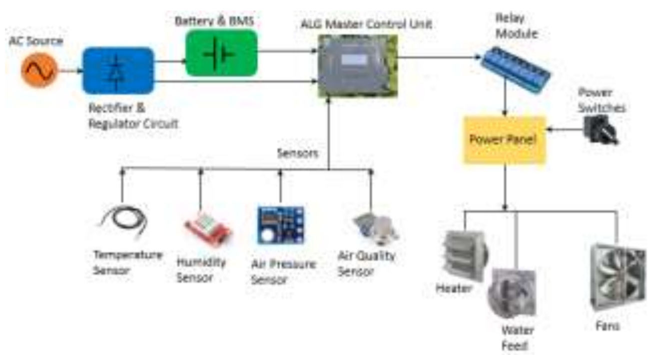

Figure 5. ALG farm management device system architecture

Table 1. List of the component in ALG device

Component	Description
Step-Down Regulator (MP1584)	Regulate and stepdown the voltage from 12V to 5V
Logic Level Converter (Bi-Directional)	Interface between components with different voltage levels
RTC & Temperature Sensor (RTC3231)	Provide timestamp and temperature data via I2C protocol
Temperature & Humidity Sensor (DHT22)	Provide temperature and humidity in digital signal form.
Optocoupler (PC817)	Isolate and protect electronic components from external voltage and current fluctuations
Shift Registers (HC595D SOP-16)	Expand output pins multiple device

The primary core of the ALG farm management device is to achieve seamless connectivity and robust functionality. This happens by linking the ALG Master control unit with an Android smartphone application that is facilitated by a cloud database. This configuration allows farmers to actively monitor and regulate essential environmental parameters such as temperature, humidity and air pressure directly from their phones. Within the application, farmers can set specific thresholds, enabling automatic adjustments, like operating ceiling and exhausted fans, to maintain these parameters within the desired range. These functionalities are thoroughly tested and refined in an actual poultry house to ensure the system's effectiveness in a realistic setting. The Google cloud database forms the technical foundation of our system, selected for its reliability and effective data management capabilities. The developed poultry farm management device focuses on establishing a smooth interaction between the client and the database. The system is designed so that when the client uses the app to interact with the database, it prompts the ESP32 MCU to begin data transmission. This mechanism is heavily dependent on stable internet and consistent electricity supply to ensure continuous operation. Part of the task involves calibrating the ESP32 for accurate response to client commands, guaranteeing prompt and precise data flow. The interface of the Android app is presented in Arabic language, where the users can interact with it. It offers various settings, including a 'Window Timer', a 'Cooling Fan Timer', and various timers for the relay pins of the device. The interface also presents a screen to allow users to enter the profile ranges for both temperature and humidity, as shown in Figure 6.

Figure 6. Setting page in the mobile application

The device is tested for several hours after the hardware components are properly assembled and the appropriate firmware is flashed into the ESP32 MCU. Extensive testing profiles are conducted to evaluate the device, including the IoT system's responsiveness, ensuring the precise recording of real-time sensor data and the proper operation of the relay pin timers. Two test stages are performed for the poultry farm management device, which are ICT (in-circuit test) and function test. ICT is done visually, where the locations of the electronic components, their number, and places of installation are checked, and installation and soldering errors and deficiencies in the main board are detected. In the function test, electrical tests are performed for each part separately to ensure the performance of this element and to ensure that it does its function properly. The function test is done in three phases that are boards & module level test, high voltage operation test, and low & battery operation test. The test profiles are conducted in offline and online modes without and with activating the control unit (ESP32 MCU), respectively. In the first phase (board & module level test), the voltage and current values of the input & output from each part of the elements are examined and compared to the reference values separately without loading, to ensure that each individual part works well without errors and the integrity of the PCB and soldering. These profiles are done in sequences, where the power source is connected, the incoming and outgoing voltages and currents are calculated, then the rest of the parts are loaded in succession. These sequences are done while measuring the values of the voltage and current coming out of each part to ensure the quality of these parts without operating the MCU (offline mode). Then, the PCBs are connected to the ALG Master control unit (online mode), where the voltage and current measurements are repeated to ensure the safety of the boards and internal components. The developed boards have some test points to measure the current and voltage values, but they do not have any test points for bed of nails (BoN) testing because of the low production quantity. High voltage tests are carried out on the relays and contactors, where the device is connected to $220V_{AC}$ and each relay is loaded with a current around 2 A for an hour. Some adjustments are executed to stress the relays by switching over the course of this hour. In the last third phase, the sensors and the rest of the device's parts, including the screen, buttons, and batteries are tested. The sensors are connected to the control unit via a 100m cable, this setup is being tested to ensure that operations of the sensors without any noise interference, whereas the communication protocol of the sensors is serial. This test is performed for at least 48 hours and connects the build system to the server to ensure that no problems occur. When problems occur due to the sensors being cut off or any other problem, alarm signals are flagged on the server. The BMS and battery system are tested as well, whereas their functions are confirmed. These test profiles are performed considering the EMI (electromagnetic interference), especially the relay switching operation, where the shield is wired and connected to the cabinet of the control panel.

Discussion and Future Works

Poultry farm management systems generate valuable data that can be analyzed to make informed decisions. This data-driven approach enables farm managers to identify trends, detect issues early, and implement corrective actions. Farmers can access real-time data and make adjustments from anywhere with an internet connection, improving overall farm management efficiency and flexibility. Currently, the ALG farm management devices are being built and conducted test profiles for production (10-20 pcs per month). Electro Green manufactures and sells the ALG farm management devices in Egypt and Middle East because of the high-quality poultry products that meet consumer expectations. Some recommendations are considered and listed for the mass production in this section.

Test points are included in the design of the PCBs, where these test points are placed in appropriate locations and space between points, so flying probes are used to measure the current and voltage. The PCBs should be re-designed to include more test points and vias to test many features, where BoN would be designed and built to access these test points. A proper test setup would be needed to measure the required parameters, where external DAQs and other equipment should be integrated. This test setup should be automated to perform function and manufacturing tests in 2-3 minutes, where these recommendations are considered for mass production. The current design of the ALG farm management device is applicable for 4000 m^2 poultry houses because of the limitation of the serial communication. The current sensors communicate with the ALG Master control unit via serial protocol that is sensitive to noise and limited cable length (100 m). Controller Area Network (CAN) Bus should be incorporated within the devices, which promises to revolutionize the poultry farming industry. CAN bus technology is particularly well-suited for long-distance (more than 100 m wiring system) data communication. By leveraging CAN bus technology, the farm management device can facilitate seamless communication among various components and sensors, overcoming the constraints of short distances and sensitivity to noise.

4. Conclusion and Recommendations

The implementation of real-time climate monitoring and control is paramount for ensuring the healthy and efficient growth of poultry farms. This paper presented a low-cost and efficient approach to transforming traditional poultry farms into smart farms through the integration of IoT technology. The system architecture of the ALG poultry farm management device has been successfully developed and implemented, with a prototype mobile application created to remotely monitor poultry farms. The integration of a cloud-based database and an Android app further enhanced the system's capabilities, enabling remote regulation of temperature, humidity, and connected devices. The ESP32 MCU performed reliable real-time data transmission, and the user-friendly mobile app interface facilitates seamless control. Rigorous testing in authentic farm environments has confirmed the system's responsiveness and sensor accuracy. The inclusion of a battery backup guaranteed the continuity of the device's operation in the event of a power outage, while alarm sensors promptly notify users of any malfunctioning sensors, providing comprehensive details about the farm's conditions. This transition to smart farming did not only reduce the need for manual effort, minimize time and manpower requirements, but it also contributed to the preservation of environmental resources, ultimately leading to increased production efficiency with reduced energy consumption. The ALG poultry farm management device emerges as a promising tool for modernizing poultry farming and meeting the evolving demands of sustainable and efficient agricultural practices.

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