Faculty of Electrical Technology and Engineering

DEVELOPMENT OF AN INTERNET OF THINGS (IOT) – BASED DEVICE FOR MONITORING AND CONTROLLING A CHICKEN COOP USING PHOTOVOLTAICS SOLAR

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Bachelor of Electrical Engineering Technology with Honours

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DEVELOPMENT OF AN INTERNET OF THINGS (IOT) – BASED DEVICE FOR MONITORING AND CONTROLLING A CHICKEN COOP USING PHOTOVOLTAICS SOLAR

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A project report submitted
in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled Development of an Internet of Things (IOT) – Based Device for Monitoring and Controling a Chicken Coop using Photovoltaics Solar is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Sigature :

Student Name : Zulhanif Bin Rozali

Date : 04/01/2025

DEDICATION

To my beloved family and my beloved supervisor,
Datin Dr. Fadzilah Binti Salim and to all my fellow friends.

ABSTRACT

The poultry industry faces challenges in maintaining optimal environmental conditions, impacting animal welfare and productivity. This project addresses these issues through the development of an IoT-based device for monitoring and controlling chicken coops, powered by a photovoltaic (PV) solar system. The device, built with an ESP32 microcontroller and sensors for temperature, humidity, and ammonia levels, ensures real-time monitoring and automated control of ventilation and lighting systems. Sustained by renewable solar energy, the system aligns with the United Nations Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy) and 13 (Climate Action). The project achieved its objectives by successfully designing and developing the IoT device, integrating solar power systems, and evaluating performance. Results showed accurate environmental monitoring, effective automation of coop conditions, and reliable operation in diverse scenarios. By reducing energy consumption, enhancing animal welfare, and promoting sustainable farming practices, this innovation contributes significantly to modern poultry management and sustainable agricultural advancements.

ABSTRAK

Industri ternakan ayam menghadapi cabaran dalam mengekalkan keadaan persekitaran yang optimum, yang memberi kesan kepada kebajikan haiwan dan produktiviti. Projek ini menangani isu-isu tersebut melalui pembangunan peranti berasaskan Internet of Things (IoT) untuk memantau dan mengawal reban ayam, yang dikuasakan oleh sistem tenaga solar fotovoltaik (PV). Peranti ini, dibangunkan menggunakan mikropengawal ESP32 dan sensor untuk suhu, kelembapan, serta tahap ammonia, memastikan pemantauan masa nyata dan kawalan automatik sistem pengudaraan dan pencahayaan. Dikuasakan oleh tenaga solar yang boleh diperbaharui, sistem ini selaras dengan Matlamat Pembangunan Mampan (SDG) Pertubuhan Bangsa-Bangsa Bersatu (PBB) 7 (Tenaga Mampu Milik dan Bersih) dan 13 (Tindakan Iklim). Projek ini berjaya mencapai objektifnya dengan merancang dan membangunkan peranti IoT, mengintegrasikan sistem tenaga solar, dan menilai prestasi. Hasil menunjukkan pemantauan persekitaran yang tepat, automasi keadaan reban yang berkesan, dan operasi yang boleh dipercayai dalam pelbagai senario. Dengan mengurangkan penggunaan tenaga, meningkatkan kebajikan haiwan, dan mempromosikan amalan pertanian mampan, inovasi ini memberi sumbangan yang signifikan kepada pengurusan ayam moden dan kemajuan pertanian lestari.

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%	- Persent
°C	- Degree Celcius

LIST OF ABBREVIATIONS

IoT	-	Internet of Thing
HVAC	-	Heating, Ventilation, and Air Conditioning
PV	-	Photovoltaic
NH3	-	Gas Ammonia
PLC	-	Process Logic Control
LDR	-	Light Dependent Resistor
RTC	-	Real-Time Clock
ECPMS	-	Environment Controlled Poultry Management System
USDG	-	UN Sustainable Development Goals
PIR	-	Passive Infrared
LCD	-	Liquid Crystal Display
DC	-	Direct Current
FSR	-	Force-Sensing Resistor
GPRS	-	General Packet Radio Service
AC	-	Alternative Current
ppm	-	parts per million
V	-	Voltage
IDE	-	Integrated Development Environment
PCB	-	Printed Circuit Board
BDP	-	Bachelor Degree Project

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CHAPTER 1

INTRODUCTION

1.1 Background

The poultry industry performs a vital role in the global agricultural sector, providing an essential source of protein through the production of meat and eggs. The industry is under pressure to boost production and efficiency while upholding strict guidelines for animal care and environmental sustainability as consumer demand for chicken products grows. In order to meet these demands, modern poultry farming has evolved to incorporate different technical innovations. Specializing in climate-controlled facilities and automated feeding systems, the industry is always looking for new and creative ways to increase productivity and enhance service quality.

Despite these advancements, controlling environmental conditions within chicken coops remains a challenge. Poor ventilation, fluctuating temperatures, and unsuitable humidity control may result to stress and health issues in poultry, impacting growth rates and egg production. Furthermore, the accumulation of ammonia gas from chicken excrement can seriously endanger the health of farm workers and the chickens. While some farms have installed simple automated systems to track humidity and temperature, these systems frequently lack the sophistication and integration required to properly address the entire range of environmental conditions. Moreover, these systems may be made much more accurate and responsive, as they now have limited remote management and real-time data accessible.

The Development of an Internet of Thing (IoT) – Based Device for monitoring and controlling a chicken coop using Photovoltaic Solar project offers a creative solution that makes use of recent advancements in IoT technology in conjunction with renewable energy sources to address these issues. The project offers extensive real-time monitoring of environmental conditions within chicken coops by integrating cutting-edge sensors with the ESP32 module microprocessor, such as the DHT22 for temperature and humidity and the MQ-135 for ammonia gas levels. Photovoltaic solar panels, which power the system, guarantee a dependable and renewable energy source that lowers operating expenses and its environmental effect. Farmers can access this wirelessly sent data and get fast insights and notifications using a simple smartphone application.

1.2 Problem Statement

The poultry industry struggles to maintain the right conditions inside chicken coops, which are crucial for the health and productivity of the birds. Accuracy and efficiency are often lacking in the current technologies used to monitor and control these situations. This may result in changes in temperature, problems with humidity, and ineffective control of dangerous gas levels.

In order to figure out long-term solutions to decrease the environmental impact of chicken production is increased by global warming. Energy-intensive heating, ventilation, and air conditioning (HVAC) systems are widely used in this business, and their use increases greenhouse gas emissions. Poultry farms consume a lot of electricity, which causes costs and environmental issues. Therefore, it is critical to identify solutions that promote SDG 7, Affordable and Clean Energy.

New technology that can increase monitoring precision, make better use of available resources, and reduce the environmental effect of chicken farms are required. This can be accomplished with the use of Internet of Things (IoT) technology, which enables automated control of important environmental elements, remote monitoring, and real-time data collecting.

The primary issue that this project attempts to solve is the dearth of effective and long-lasting methods for keeping an eye on and managing the levels of dangerous gases, temperature, and humidity in chicken coops. The objective is to develop an IoT-based solution that, according to with SDG 7, improves the health and well-being of the chickens, lowers energy consumption, minimises emissions, and supports environmental sustainability in the poultry business.

1.3 Project Objective

The main aim of this project is to design and implement an IoT-based monitoring and control system for optimizing environmental conditions within chicken coops. Specifically, the objectives are as follows:

a) To design an IoT based device to monitor and control the chicken coop using ESP32 module microprocessor.

b) To develop the proposed prototype powered by a photovoltaic (PV) solar system.

c) To eveluate the perfomance of the IoT based device for monitoring and controlling a chicken coop.

1.4 Scope of Project

The scope of this project are as follows:

a) This project is targeted for use in poultry farms to monitor and control environmental conditions within chicken coops as well as in outdoor areas.

b) The sensors used for monitoring environmental conditions are the DHT22 sensor for temperature and humidity and the MQ-2 sensor for ammonia gas levels.

c) The type of solar panel used in this project is monocrystalline photovoltaic solar panels.

d) The type of battery chosen for storing power is a Rechargeable Sealed Lead Acid (VRLA) Battery.

e) The microcontroller used in this project is the ESP32 module.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Providing a substantial source of food and revenue for many people all over the world, chicken farming is a crucial aspect of the agricultural industry. With the increasing demand for poultry products, there is a growing need for more efficient and sustainable farming practices [1]. The implementation of Internet of Things technology in chicken farming has the potential to bring about a transformation in the sector. This is because it provides increased monitoring and control capabilities, which can lead to an increase in the total efficiency and production of chicken coops [2]. This chapter examines the ways in which these technologies can be utilised to construct a smart chicken poultry farm system that makes use of photovoltaic solar power to monitor and manage important environmental parameters [3]. The purpose of this review is to demonstrate how the Internet of Things (IoT) and solar energy might improve chicken farming by analysing previous research and identifying potential areas for further investigation to make the business more environmentally friendly and productive.

2.2 Energy Management and Sustainability

Modern chicken farming operations must priorities efficient energy management because it can take a significant amount of energy to keep chicken coops at ideal environmental conditions. In order to power all the different monitoring and control systems within the coop, renewable energy sources like photovoltaic solar power can help address this difficulty by offering a sustainable and environmentally friendly energy source [4]. The

Internet of Things (IoT) technology and sensors can be powered by solar energy, and solar energy is another option to supply lighting and ventilation. This reduces the farm's dependency on conventional energy sources and reduces the farm's overall carbon footprint [5].

2.2.1 Photovoltaic Systems

In recent years, photovoltaic systems have gained a lot of popularity in agricultural applications, including chicken farming, because of their ability to create electricity that is both clean and renewable [6]. The design of an independent sensor node is shown in Figure 2.1. The photovoltaic panel converts solar energy into electrical energy. The DC-DC converter fulfils two functions: it implements Maximum Power Point Tracking (MPPT) to optimise power extraction in all environmental situations, and it regulates energy flow to charge the battery. Subsequently, the energy contained within the battery will be applied to power the main microcontroller and all the integrated circuits inside the system. Temperature, humidity, a camera, and a WSN communication module are the instruments used by each node to take out several measurements. By monitoring this data, we ensure optimal plant growth while minimising the wastage of resources such as fertiliser and water. The sensor nodes of the WSNs consist of the ESP32 microcontroller, developed by Espressif, which is equipped with a dual-core CPU. It supports two wireless communication protocols, Bluetooth and WiFi, and can interact with multiple sensors. To ensure a reliable power source for the system, three essential components are employed: a photovoltaic panel, a DC-DC converter, and a battery.

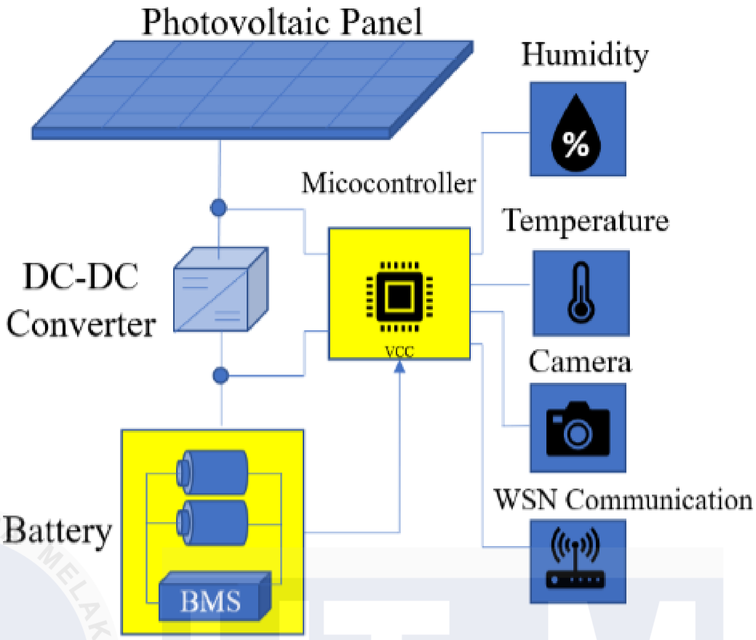


Figure 2.1 Architecture of the stand-alone sensor node [6]

Creating a chicken farming firm that is both self-sufficient and efficient can be accomplished through the integration of photovoltaic systems with Internet of Things-based monitoring and control systems [7]. In this situation, the energy that is generated by the solar panels is used to power the various components of the system. It is also possible for the use of solar energy to contribute to the overall sustainability of the farm. This is because the use of solar energy helps reduce the impacts of global warming and reduces the environmental impact generated by the operation.

The Internet of Things technologies that are powered by solar energy represent a significant advancement in sustainable and efficient systems, particularly in remote and off-grid locations [8]. Solar power makes it possible to achieve the highest level of dependability and affordability in terms of energy production on farms. Irradiation results in the production of this useful form of energy. Photovoltaic panels are utilised in solar pumping systems to generate the current that is then used to drive the pumps that are responsible for lifting water and delivering it to the gardens. This is shown in Figure 2.2 below. It has the capability to provide real-time monitoring and management of important environmental elements, such as temperature, humidity, and lighting, to guarantee that the chickens are kept in the best possible conditions [9].

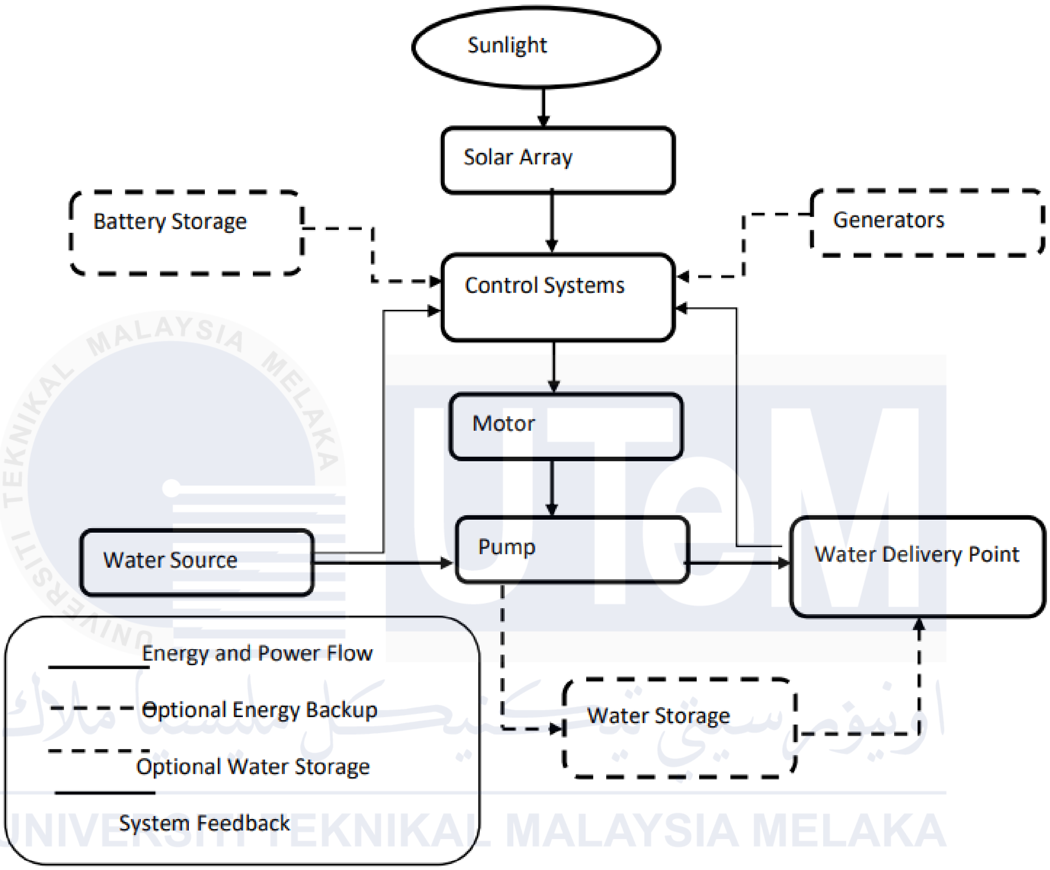


Figure 2.2 Solar-powered irrigation system concepts [8]

2.2.2 Energy-Efficient IoT Devices

The development of Internet of Things devices that are efficient in terms of energy consumption is absolutely necessary for the deployment of a sustainable smart chicken coop system. These devices should be designed to consume as little power as possible while currently delivering the functionality that is required for monitoring and controlling the environment of the chicken coop [9]. It is possible to optimise the energy consumption of Internet of Things devices by utilising low-power microcontrollers, sensors, and wireless communication modules. This will ensure that the system can be driven by the photovoltaic solar system in an effective way [10].

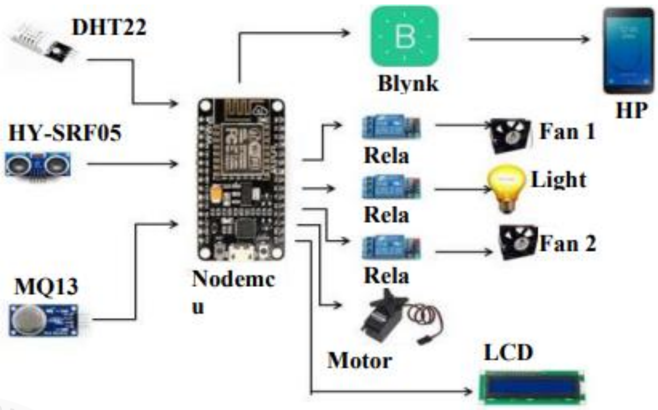


Figure 2.3 Tools Design [10]

Figure 2.3 shows a tools design that use a DHT 22 sensor to monitor temperature and humidity, an Ultrasonic Sensor HY-SRF05 to measure feed distance, and a Sensor MQ-135 to detect ammonia gas. Using a Blynk application, the three sensors are processed by the Nodemcu ESP8266 and the notifications are sent to a smartphone with a 20x4 electronic display. If the temperature and humidity are both below the range, the indicator lights will turn on, and the fan will turn on if the temperature is higher than the range that has been chosen. When the feed distance reaches 13 centimetres, the servo motor begins to function. The valve rotates 13 degrees automatically, and after ten seconds, the servo motor returns to its initial position of 0 degrees.

This is also possible for the Internet of Things-based smart chicken coop system to benefit from the advancements that have been made in energy storage technologies, such as batteries and ways for energy harvesting [11]. The Internet of Things-based smart chicken coop can be constructed to function in a sustainable and cost-effective manner by adding these energy-efficient technologies. This will result in a reduction in the overall energy consumption and environmental impact of the chicken farming operation.

2.2.3 Sustainability Considerations

The implementation of Internet of Things (IoT) and renewable energy technology into chicken farming has the potential to have a substantial impact on the industry's general perception of sustainability. Numerous research has demonstrated that the utilisation of solar energy in agricultural settings has a significant impact on both the environment and the economy. These studies have demonstrated that solar energy may reduce emissions of greenhouse gases, lower operational costs, and boost the profitability of farms [7]. Maintaining optimal environmental conditions within the coop, such as temperature, humidity, and air quality, can also help to the wellbeing and health of the hens. This can be accomplished through the utilisation of monitoring and control systems that are based on the Internet of Things-based technology.

The long-term advantages of sustainable energy solutions for small-scale farms include higher profitability, decreased impact on the environment, and the possibility of developing of new business prospects and employment opportunities in the renewable energy sector [12].

Industrial solar energy technologies are simultaneously incorporated into agricultural activities, where they are utilised either as a source of direct energy or to improve the energy requirements of farms [13]. Solar power is also applied in rural water pumps (refer to Figure 2.4). Photovoltaic (PV) systems would be the most economical water pumping system in locations without an existing electrical line [14]. Photovoltaic systems are cost-effective for remote livestock water sources, swamp aeration, and limited irrigation systems. Most water pumps that are presently available have been designed to be powered by a photovoltaic panel. However, any direct-stream motor pump can be operated on photovoltaic panels [15].

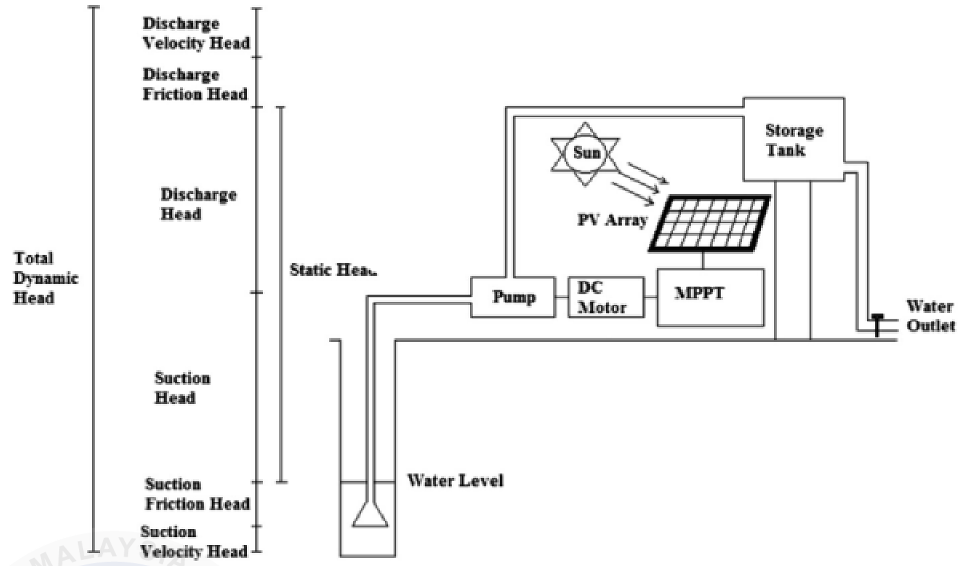


Figure 2.4 Schematic diagram of photovoltaic water pumping system [12]

2.3 Automated Monitoring and Control Systems

The poultry industry is encountering an increasing demand for sustainable and efficient agricultural practices to satisfy the expanding demand for food production. Creating smart chicken coops that are equipped with improved monitoring and control capabilities is one potential solution that may be implemented through the integration of Internet of Things technologies [16]. Internet of Things (IoT) in the automation of agricultural environment monitoring and control. The system that is being proposed makes use of a network of sensors to continuously monitor vital environmental parameters within the chicken coop. These parameters include temperature, humidity, and ammonia levels [10].

2.3.1 Sensor Technology

The central component of the proposed Internet of Things (IoT) system is a network of sensors strategically positioned throughout the chicken coop to monitor crucial environmental variables [17]. Ammonia sensors are utilised to determine the quality of the air, while temperature and humidity sensors are utilised to monitor the surrounding conditions [18]. The data collected by these sensors are subsequently sent to a central control unit by wireless communication protocols, such as Bluetooth or Wi-Fi, which enables real-time monitoring and analysis [19]. There are several different sensors that are utilised in chicken coops for the purpose of monitoring environmental conditions. These sensors include temperature, humidity, light, and air quality sensors [20]. The incorporation of these sensors into an Internet of Things system makes it possible to conduct a full monitoring of the surroundings of the chicken coop. This provides farmers with useful information that can be used to improve their operations and increase their production.

Various sensors are employed to monitor environmental conditions in a chicken coop, ensuring the health and welfare of the chicken flock. Temperature sensors are employed to measure the surrounding temperature, contributing to the preservation of a consistent and healthy habitat for the chickens. Humidity sensors are crucial for monitoring the amount of water in the air, to make sure humidity maintains within an ideal range to prevent breathing issues and the growth of harmful microorganisms. In addition, ammonia sensors are used to measure the level of ammonia in the coop, which provides crucial information about air quality and aids in avoiding of the accumulation of harmful gasses. These sensors collectively help to ensure a safe and ideal environment for the chickens' health.

The sensor data is transmitted to a central control device, where it is analysed and employed to make informed decisions regarding the coop's environment [21]. The primary hardware and software instruments employed in the design process were as follows: (1) the NodeMCU ESP8266 V3 microcontroller, (2) the DHT22 sensor, (3) the MQ-135 sensor, (4) the relay, (5) the fan, (6) the lamp, (7) the real-time clock (RTC), (8) the Arduino IDE, and (9) the social networking platform Telegram. Figure 2.5 shows a block diagram that illustrates the architecture design of the system, beginning with the sensors and ending with the display of the mobile device.

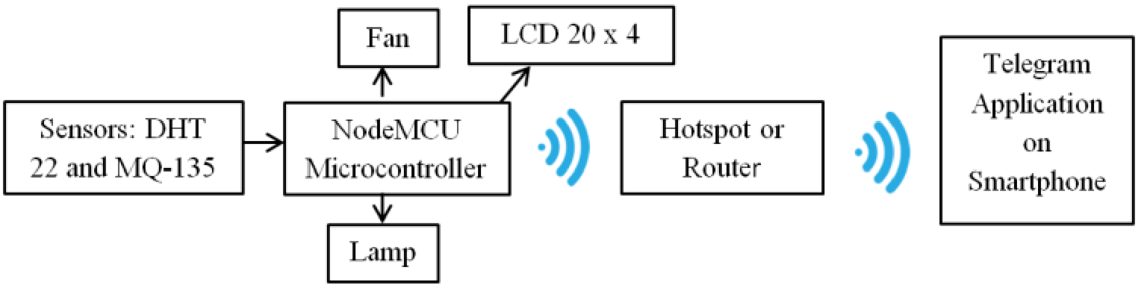


Figure 2.5 Blok diagram representing systems architecture [18]

The NodeMCU microcontroller serves as the primary processor for monitoring temperature, humidity, and NH3 levels, as well as controlling fans and lights directly. The DHT 22 components are used to detect temperature and humidity, while the MQ-135 components are used to detect the level of NH3 gas. The data from the sensors is then analysed using the NodeMCU microcontroller.

The resulting data is subsequently displayed on the LCD 20x4 (20 columns and 4 rows) and on an Android smartphone through the use of the Telegram social networking application for remote monitoring. In addition to displaying the resulting data, the Telegram application is also employed to remotely control the fan and lights to ensure that the poultry coop's temperature and humidity are maintained at a suitable level. The formation of ammonia will be impeded by the lower humidity of the poultry coop.

By activating the fan, the fowl coop is supplied with fresh air through ventilation. The concentration of ammonia in the poultry coop's atmosphere will be reduced by the fresh air. A reduction in the amount of ammonia in the poultry coop will result in a reduction in the number of deaths and the production of healthier chicken, which will improve the profit [18]. Figure 2.6 shows a wiring diagram that illustrates the hardware components that are instrumental in implementing the system architecture that is shown in Figure 2.5.

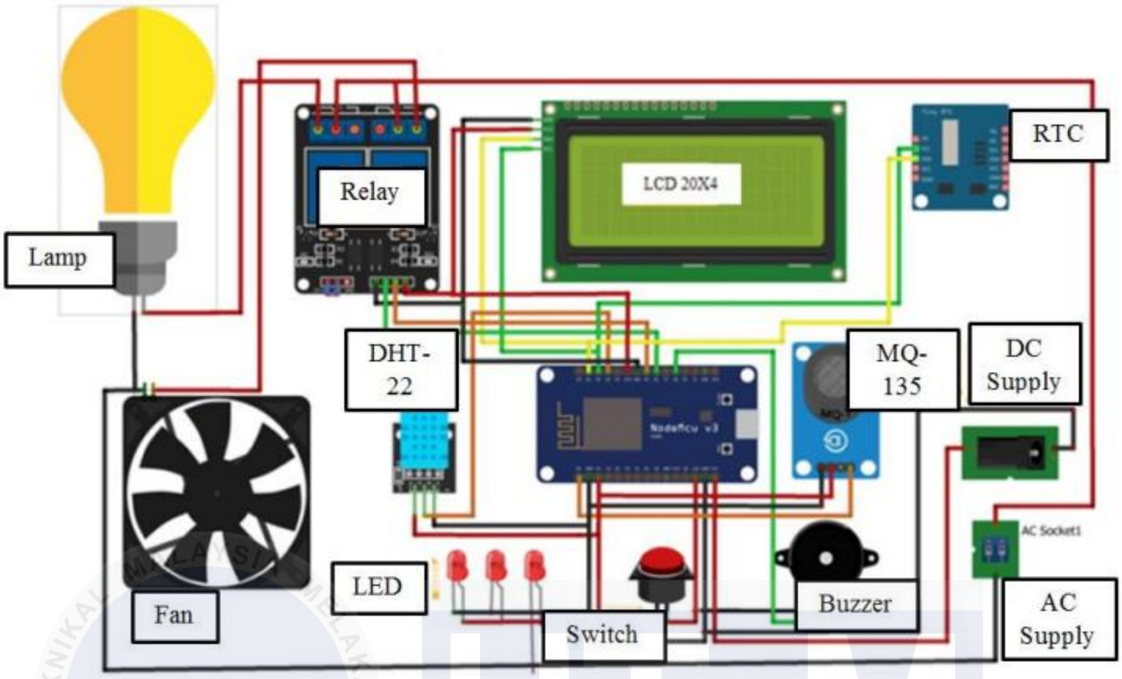


Figure 2.6 Wiring of hardware components [18]

The precision, dependability, and integration of these sensors with Internet of Things platforms are very necessary for efficient monitoring and management of the environment of the chicken coop [22].

2.3.2 Control System

The data that is collected by the sensor network is analysed by the central control unit, which then takes the right actions to ensure that the chicken coop continues to have the best possible environmental conditions. The control unit is accountable for the automatic adjustment of the temperature, humidity, and air quality. This is accomplished by the utilisation of a variety of actuators, which include fans, heaters, and ventilation systems [20]. In addition to the environmental management, the system also includes components for automatic feeding and watering systems. These components ensure that the fundamental requirements of the hens are satisfied without the need for the farmer to always be present [23]. These control systems, when combined with the sensor network and a user-friendly interface, make it possible for farmers to remotely monitor and change the environment of the coop. This not only increases productivity but also reduces the amount of time and effort that is required for manual administration [24].

Automated control systems for the management of ventilation, lighting, and feeding in poultry coops. It is possible to combine these devices with the Internet of Things platform to provide remote monitoring and control capabilities [25]. This will allow farmers to optimise the environment of their chicken coops and increase the overall productivity of their respective poultry enterprises. In the chicken farm industry, they used different type of chicken which is broiler chicken that usually used for meat production. This broiler is different with hen chicken, they rise specifically for its meat. The reason for this is that they can swiftly gain weight and grow, and they can reach the desired weight in a short period of time, typically 6 weeks or 40 days [26].

For the first week, the temperature of the chicken farm needs to be controlled and adjusted so that it stays at approximately 35 degrees Celsius [21]. In the following step, the temperature must be lowered by around two to three degrees Celsius on a weekly basis until it reaches the optimal temperature range. This temperature range is normally the target temperature range for the conclusion of the growth phase, as this temperature is regarded to be excellent for the health and productivity of the chickens. Once the chicken is able to regulate its own body temperature, then maintain the temperature equal to the room temperature as shown in Table 2.1. In the traditional control system of chicken farms, the heat is produced by a 200-watt lamp. To regulate the temperature of the chicken, the bulb will be deactivated if the temperature exceeds the specified limit, or the distance between the chicken and the bulb will be adjusted to either raise or lower the temperature [2].

Table 2.1 Temperature control references [2]

Chicken Age (day)	Temperature (°C)
0 – 6	35
7 – 13	33
14- 20	30
21 -27	28
28 – 35	26

A relative humidity of over 70% should be avoided, as the air is too arid and hot for the chicken to survive. Conversely, a relative humidity of less than 50% indicates that there are too many of airborne microorganisms and dust particles, which is damaging to the chicken's growth. Low humidity can cause respiratory difficulties and dehydration in hens, while high humidity can contribute to the growth of bacteria and fungi. Both of these conditions can be damaging to the health of chickens. The control system that was built as part of this project is responsible for monitoring the levels of humidity and automatically adjusting the operation of ventilation systems and humidifiers to maintain the ideal range of humidity as much as possible. Table 2.2 show the humidity control range.

Table 2.2 Humidity control references [2]

Chicken Age (day)	Humidity (%)
0 – 6	30-50
7 – 13	40-50
14- 20	40-60
21 -27	50-65
28 – 35	50-70

2.3.3 Data Analytics and Remote Monitoring

The Internet of Things-based system not only automates the regulation of environmental factors, but it also collects and analyses sensor data to provide the farmer with important insights [27]. The data collected by the sensors is compiled by the central control unit, which then sends it to a cloud-based platform, where it is stored and analysed [28]. Farmers can remote access the data and monitor the functioning of the coop over time through this. Farmers are able to improve the overall productivity and efficiency of their poultry operations by utilising the data analytics capabilities of the system, which can assist them in recognising trends, optimising the administration of the coop, and making decisions based on such data [29]. The farmer can be informed of any abnormal conditions or critical events within the poultry coop, such as sudden temperature spikes or poor air quality, by the IoT-based system, which can also provide real-time alerts and notifications [30]. This enables the farmer to promptly address issues and prevent prospective problems from escalating. In addition, the system can be integrated with other intelligent farming technologies, such as automated feeding systems or disease detection algorithms, which will in turn further improve the overall management and efficiency of the chicken coop.

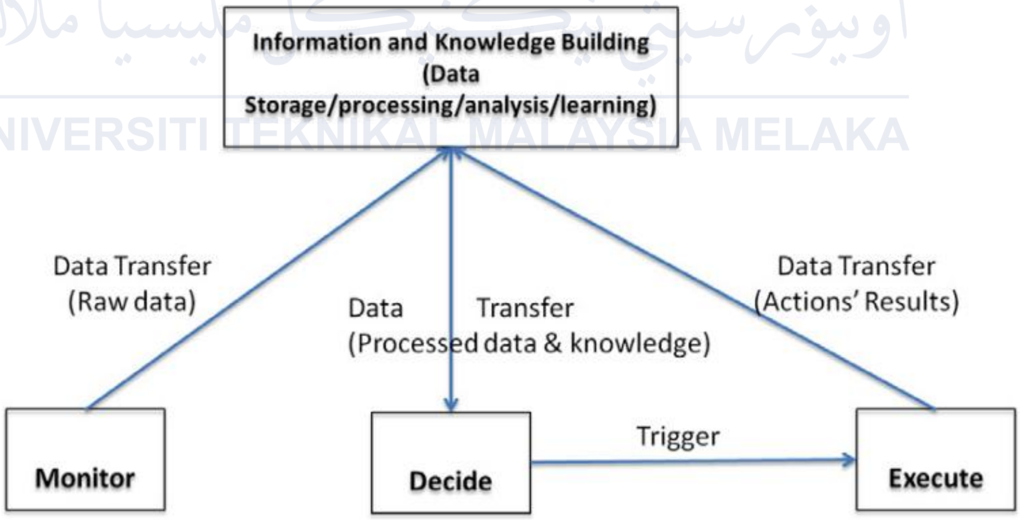


Figure 2.7 Generic operation principles [31]

The smart farming system was established and its main functional entities were determined based on an analysis of practical requirements. The initial observation is that all use cases follow to a standard pattern. The initial step includes gathering data to monitor the farm, providing the current condition of plants and animals, as well as the status of equipment. The data is mostly gathered via sensors, tracking systems, agricultural machinery, and Internet services. This raw data must undergo processing, including filtering, collection, and analysis. Furthermore, the system retains this information and proceeds to analysed and process the gathered data, which involves the creation of information and knowledge. Then, based on the examined data, the system decides either basic or more complicated actions for purposes and carries out them. Finally, it is necessary to preserve all the information, including the performed actions and their outcomes, for future utilization. By utilizing suitable methods such as data mining, we can gain deeper insights into the overall performance of the farm management system and enhance the decision-making process [31]. Figure 2.7 shows the mentioned processes that make up a typical autonomic and cognitive management loop.

2.4 Animal Welfare and Health Management

The poultry industry is increasingly prioritizing the improvement of animal welfare and the management of health [32]. Smart sensors have the capability to collect data instantly on different factors, including the conditions inside the poultry house, the health of the chicken, accurate feeding, and quick identification of diseases [16]. This data can be utilized to improve the housing situation, monitor the health and well-being of the chicken, and implement early measures to avoid or minimize disease outbreaks.

2.4.1 Behavioral and Health Monitoring

Ensuring the well-being and production of chickens needs constant monitoring of their behaviour and health [17]. Systems based on the Internet of Things are able to monitor characteristics such as temperature, humidity, and lighting in order to keep the conditions within the chicken coop at their optimal level [33]. Through the monitoring of these environmental variables, it is possible to identify and address any distortions that may have an effect on the health and production of the chickens. Additionally, sensor data can be utilized to identify early signs of illness or discomfort, which enables quick veterinarians care and intervention to be provided [18]. Poultry manufacturers can now automate an array of farm procedures by utilizing IoT technologies, including the regulation of temperature and humidity levels, as well as the regulation of lighting and feeding schedules.

2.4.2 Environmental Impact on Animal Welfare

The poultry industry is increasingly realizing the significance of improving the environmental conditions within chicken coops to improve the welfare and productivity [34]. Monitoring systems that are based on the Internet of Things are able to collect data in real time on temperature, humidity, and other parameters to guarantee that the environmental conditions of the chicken coop remain within the ideal range for the chickens' health and comfort. Temperature, humidity, and lighting are three environmental elements that have a significant impact on the general well-being of chickens. Chickens are extremely sensitive to environmental influences. Chickens can experience significant strain because of high temperature variations, which can result in a reduction in the amount of feed they consume and, as a result, a fall in the number of eggs they produce [32]. In the same way, it is vital to maintain optimum humidity levels to prevent respiratory disorders and to control the growth of diseases in the coop [10]. Both factors can have a serious effect on the health. In addition, the natural circadian cycles of chickens can be influenced by the lighting conditions, which in turn affects their behaviour, the amount of feed they consume, and the amount of eggs they produce. All these environmental parameters, when taken together, are essential to ensure that the conditions for chicken welfare are ideal.

Environmental factors may perform significant effects on the well-being of chickens, giving rise to many critical concerns in unfortunate situations. Heat stress poses a significant risk as chickens are especially sensitive to high temperatures, leading to decreased food consumption, decreased egg output, and in extreme cases, death [35]. Heat stress in chickens leads to many behavioural, physiological, and biochemical changes that impact their health and performance shown in Figure 2.8. Higher humidity levels also provide a danger by establishing an environment that promotes the growth of microorganisms that cause illness, leading to breathing issues inside a group of animals [36]. Moreover, variations in lighting and temperature might disturb the natural habits of hens, so impacting their feeding, nesting, and other important behaviours [37]. These environmental factors underscore the importance of maintaining optimal conditions for the health and well-being of chickens.

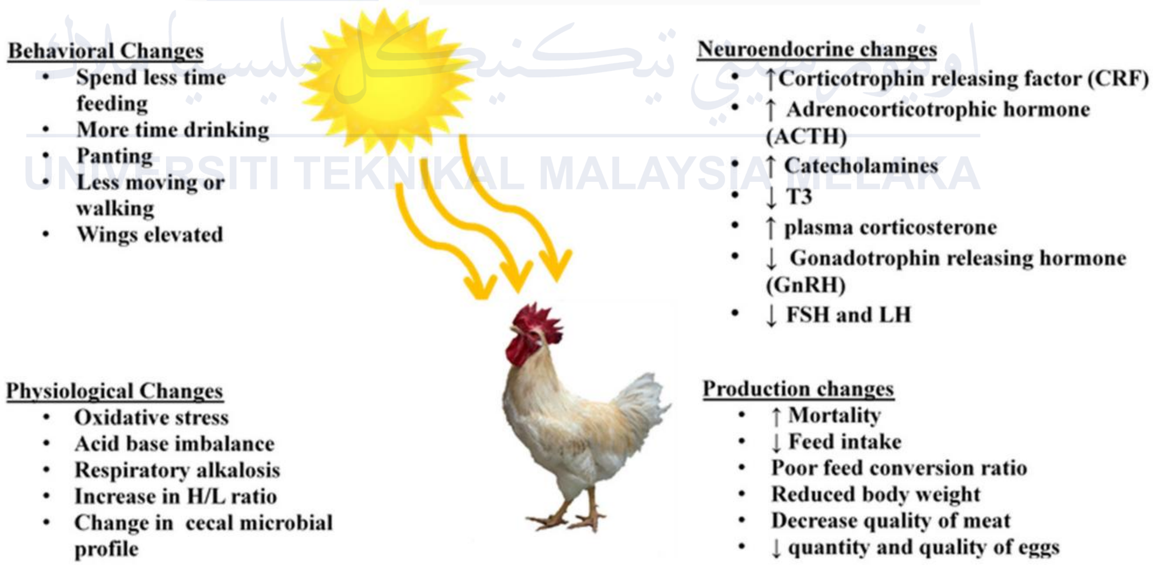


Figure 2.8 The effect of heat stress on behavioural, physiological, hormonal, and production features [36]

The introduction of IoT technology in automated control systems has the potential to significantly improve the living conditions of chickens and reduce stress. These systems can ensure the chicken coop maintains ideal conditions by constantly tracking and adjusting environmental factors such as temperature, humidity, lighting, and air quality [10]. Automated ventilation systems can effectively control temperature and humidity levels, so avoiding chickens from being exposed to excessive circumstances that may cause heat stress or respiratory problems. Intelligent lighting controls can imitate natural circadian rhythms, ensuring that the chickens receive the optimum lighting for their behavioural requirements [38]. Furthermore, monitoring based on the Internet of Things (IoT) can identify initial indications of illness or dissatisfaction allowing immediate action and healthcare. Through the establishment of a secure, pleasant, and health-promoting environment, these automated systems have the capacity to improve the general welfare of the chickens, resulting in improved productivity, decreased mortality rates, and eventually, more favourable economic results for the poultry farmer.

2.4.3 Alert Systems and Preventive Health Management

Alert systems are essential components of IoT-based poultry monitoring systems since they play an essential part in quickly detecting health problems. This enables timely action and minimizes the chances of disease transmission. Studies in this area highlight the significance of continuous monitoring of environmental variables and poultry behavior, utilizing automated systems that generate alarms when detecting abnormal patterns [16]. The use of sensors to monitor characteristics such as temperature, humidity, air quality, and chicken activity levels, which are essential markers of poultry health, has been demonstrated in several research [27]. The system may automatically notify the farm manager through text messages, email, or application alerts when certain parameters depart from specified standards, allowing for immediate action [21].

Several studies have demonstrated the efficacy of real-time alert systems in preventing an increase of health issues in poultry farms. The mortality rate in poultry farms was significantly decreased by IoT-based systems that were equipped with alert functionalities. This was achieved by enabling a rapid response to environmental changes, such as temperature spikes or drops, which are known to cause stress and illness in chickens [39]. The study also evaluated the application of machine learning algorithms to analysed sensor data and determine potential health issues before they escalate, thereby improving the ability of the system to issue early warnings[40]. It is difficult to manually monitor the health of each individual chicken in large-scale poultry operations, which is why these alert systems are particularly beneficial.

2.5 Comparison of Previous Work

Significant progress has been made in numerous critical areas when comparing previous research on IoT-based devices for agricultural monitoring and control, particularly in poultry farming. At the outset, research focussed on fundamental alert systems that were reactive, notifying producers when environmental conditions exceeded safe parameters. Nevertheless, recent advancements have shifted towards predictive alert systems that utilise real-time data analytics and machine learning, which allows for proactive interventions. The initial works in preventive health management were restricted to the monitoring of fundamental indicators. In contrast, modern systems provide continuous analysis of a variety of health parameters to predict and prevent issues, frequently incorporating AI for personalised health management. Traditional systems guaranteed fundamental environmental conditions in the context of animal welfare, whereas contemporary solutions prioritise holistic welfare, which includes stress monitoring and behaviour. Furthermore, the energy efficacy of these systems has been enhanced, because of a growing emphasis on the integration of renewable energy sources such as photovoltaics, which is indicative of a broader trend towards sustainability. In general, these developments illustrate a transition from reactive to proactive, data-driven, and energy-efficient methodologies in agricultural IoT applications.

2.5.1 Comparison of previous work energy management and sustainability

The explanation provided in Table 2.3 is essential for organizing the literature review on automated monitoring and control systems within agricultural IoT applications. This table not only categorizes the existing research but also highlights the comparative strengths of different automation techniques. The structured summary serves as a foundation for further research and development in IoT-based systems, aiding in the identification of the current state of the art and guiding the future direction of advancements in automated agricultural monitoring and control technologies.

Table 2.3 Comparison of energy management and sustainability

No.	Author(s)	Title	Functional	Advantages/Disadvantages
[6]	Alessandro Bartolini, Fabio Corti, Alberto Reatti, Lorenzo Ciani, Francesco Grasso. (2020)	Analysis and Design of Stand-Alone Photovoltaic System for precision agriculture network of sensors.	• Develop and optimize a stand-alone photovoltaic system for a wireless sensor network (WSN) used in precision agriculture.	Advantages: • Cost efficiency. • Environmental sustainability. • Scalability.
[7]	Ghulam Hasnain Tariq, Muhammad Ashraf, Umar Sohaib Hasnain. (2021)	Solar Technology in Agriculture.	• To integrate and scale up the use of solar energy technologies in agriculture.	Advantages: • Sustainability. • Energy efficiency. • Food security. Disadvantages: • Initial costs. • Maintenance requirements.

[8]	Denis Obura, Derrick Dadebo, Julius Odeke. (2022)	Optimized Designing of Solar Powered Direct Pumping Small Scale Sprinkler Irrigation Pipe Networks.	• To design an efficient solar-powered sprinkler irrigation system that optimizes the use of scarce water resources.	Advantages: • Water efficiency. • Cost-effective operation. • System reliability.
[10]	Syamsudduha Syahrorini, Achmad Rifai, Dwi Hadidjaja Rasjid Saputra, Akhmad Ahfas. (2020)	Design Smart Chicken Cage Based On Internet Of Things.	• Monitors and controls temperature, humidity, and ammonia levels in the chicken coop to ensure optimal conditions for broilers. • To enables remote monitoring and control of the coop environment via IoT and smartphones.	Advantages: • Optimal environmental control. • Automation and efficiency. Disadvantage: • Dependence on internet connectivity. • Technical complexity.

[11]	Saswat Kumar Ram, Sauvagya Ranjan Sahoo, Banee Bandana Das, Kamalakanta Mahapatra, Saraju P. Mohanty. (2021)	Eternal-Thing: A Secure Aging-Aware Solar-Energy Harvester Thing for Sustainable IoT.	• Utilizes a self-sustainable solar-energy harvesting system (EHS) to power IoT devices, addressing the challenge of limited battery life. • Employs a control unit to monitor computational load, manage battery recharging, and ensure continuous power supply.	Advantages: • Self-Sustainable power supply. • Efficient power management. • Energy conversion efficiency. Disadvantages: • Initial cost • Complexity • Energy conversion efficiency.
[12]	D Kodirov, Kh Muratov, O Tursunov, E I Ugwu, A Durmanov. (2020)	The use of renewable energy sources in integrated energy supply systems for agriculture.	• To highlight the role of renewable energy systems. • To provide alternative energy solutions to meet the high energy needs of agricultural operations while mitigating the	Advantages: • Environmental benefits. • Sustainability. • Feasibility for remote areas. Disadvantages: • Initial cost.

			negative environmental impacts of fossil fuels. • To balance increased crop production with resource conservation and environmental protection.	• Intermittency issues.

2.5.2 Comparison of previous work automated monitoring and control systems

The explanation provided in Table 2.4 is essential for organizing the literature review on automated monitoring and control systems within agricultural IoT applications. This table not only categorizes the existing research but also highlights the comparative strengths of different automation techniques. The structured summary serves as a foundation for further research and development in IoT-based systems, aiding in the identification of the current state of the art and guiding the future direction of advancements in automated agricultural monitoring and control technologies.

Table 2.4 Comparison of automated monitoring and control systems

No.	Author(s)	Title	Functional	Advantages/Disadvantages
[17]	Joy G. Bea, Josephine S. Dela Cruz. (2019)	Chicken farm monitoring system using sensors and arduino microcontroller	• Develop a system architecture for smart chicken farming that integrates various sensors. • Conduct a comprehensive review of existing research to identify effective, low-cost sensors and materials suitable for monitoring factors affecting chicken growth.	Advantages: • Enhanced monitoring. • Improved productivity. • Cost-Effective Solutions Disadvantages: • Complexity. • Technology dependence.

[18]	H Supriyono, U Bimantoro, K Harismah. (2020)	Design, Construction and Testing of Portable Systems for Temperature, Humidity and Ammonia Monitoring of Chicken Coop	• The chicken coop system measures ammonia, temperature, and humidity. • Controlling fans and lighting stabilizes temperature and humidity, improving chicken environments.	Advantages: • Improved health and welfare. • Automated control. • Remote access. Disadvantages: • Initial cost. • Technical complexity.
[19]	Huirong Luo, Li Wang, Xiangcheng Wu. (2018)	Design of indoor air quality monitoring system based on wireless sensor network	• Measures and tracks indoor air quality. • Alerts users and activates air purification when air quality exceeds set thresholds.	Advantages: • Real-time monitoring. • Accurate results. • Convenient system. Disadvantages: • Dependency on GPRS.

[20]	Abdul Muiz Fathi Md. Abas, Nur Anis Azmi, Nur Syamimi Amir, Zulkifli Zainal Abidin, Amir Akramin Shafie. (2016)	Chicken Farm Monitoring System.	• Monitors and controls temperature, humidity, light, and water levels in the chicken farm to improve the quality and quantity of chicken production.	Advantages: • Reduces labor. • Cost-effective. Disadvantages: • Initial setup. • Technical complexity.
[21]	Raden Budiarto, Nur Kholis Gunawan, Bagas Ari Nugroho. (2020)	Smart Chicken Farming: Monitoring System for Temperature, Ammonia Levels, Feed in Chicken Farms.	• Monitors ammonia levels, chicken food weight, and room temperature in chicken farms using sensors and provides SMS notifications for immediate issues.	Advantages: • Real-time monitoring. • Immediate alerts. • Enhanced management. Disadvantages: • Dependence on SMS.

[22]	Qing Dua, Yanhua Miao, Yunhui Zhang. (2018)	Design of Intelligent Monitoring System of Chicken House Environment Based on Single-chip Microcomputer.	• Sensors measure light intensity, temperature, humidity, and carbon dioxide, and operate the exhaust fan and illumination lamp. Real-time environmental parameters.	Advantages: • Real-time monitoring. • Automated control. Disadvantages: • Single control unit.

2.5.3 Comparison of previous work animal welfare and health management

The explanation provided in Table 2.5 is crucial for organizing the literature review on animal welfare and health management within IoT-based agricultural systems. This table not only organizes the existing research but also highlights the comparative strengths of various methods used to enhance animal health and welfare. The structured summary offers a solid foundation for further research and development, facilitating the identification of the current state of the art and guiding future advancements in the monitoring and management of animal well-being in agricultural settings.

Table 2.5 Comparison of animal welfare and health management

No.	Author(s)	Title	Functional	Advantages/Disadvantages
[32]	Neila Ben Sassi, Xavier Averós, Inma Estevez (2016)	Technology and Poultry Welfare	• Utilizes advanced technologies and mathematical modeling to automatically monitor and assess	Advantages: • Enhanced animal welfare. • Technological integration.

			animal welfare and health in poultry flocks.	Disadvantages: • Implementation challenges. • Cost and complexity.
[33]	Noridayu Manshor, Amir Rizaan Abdul Rahiman, Muhammad Kamil Yazed (2019)	IoT Based Poultry House Monitoring.	• . Utilizes IoT to continuously monitor and manage temperature and humidity in a poultry house from any location, 24/7.	Advantages: • Continuous monitoring. • Remote access. Disadvantages: • Dependency on connectivity.
[35]	Lucas J. Lara, Marcos H. Rostagno. (2013)	Impact of Heat Stress on Poultry Production	• Analyzes the impact of heat stress on poultry production and welfare, with a focus on broilers and laying hens, and evaluates various intervention strategies.	Advantages: • Improved understanding. • Focus on welfare. Disadvantages: • Inconsistent interventions.
[36]	Sanjeev Wasti , Nirvay Sah and Birendra Mishra. (2020)	Impact of Heat Stress on Poultry Health and Performances, and Potential	• Examines the impact of heat stress on poultry health and performance and evaluates	Advantages: • Comprehensive overview. • Practical solutions.

		Mitigation Strategies.	various strategies to mitigate its effects, including nutritional and genetic approaches.	Disadvantages: • Variable effectiveness
[37]	Miloš Kapetanov, Marko Pajić, Dragana Ljubojević, Mi loš Pelić. (2015)	Heat Stress in Poultry Industry	• Investigates the effects of global warming on poultry heat stress, focusing on changes in disease patterns and mortality related to temperature fluctuations.	Advantages: • Long-term study. • Geographic relevance. Disadvantage: • Region-specific. • Focus on past trends.
[40]	Irving V Paputungan, Abidurrahman Al Faruq, Fitri Puspasari, Furqaan Al Hakim, Imam Fahrurrozi, Unan Y Oktiawati, Iing Mutakhiroh	Temperature and Humidity Monitoring System in Broiler Poultry Farm.	• Develops a prototype system using DHT11 sensors and Arduino DUE microcontroller to automatically monitor temperature and humidity in broiler chicken cages.	Advantages: • Improved monitoring. • Integrated applications.

2.6 Summary

According to the findings of several studies, technology has significantly transformed various fields, including farming, with the chicken industry benefiting notably from these advancements. Improving farm productivity while maintaining animal welfare and environmental sustainability is crucial as demand for chicken products rises. This chapter looks at the advantages and drawbacks of the technology now used in chicken farming. The objective is to show how IoT and solar energy might enhance chicken farming by examining current research and identifying topics for future study to make the sector more efficient and sustainable.

Systems for monitoring and managing chicken coops that are based on the Internet of Things greatly increase farming output and efficiency. Conventional manual techniques for controlling temperature and humidity can lead to health problems for hens as well as financial losses. Scholars suggest employing computers, sensors, and actuators in smart farming systems to automate environmental regulation and furnish instantaneous data. Farm activities and environmental conditions can be efficiently managed by integrating IoT and automation technology. In the end, these systems improve animal health and productivity by ensuring reliable monitoring, prompt alarms, and automated control.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The techniques and procedures used to construct this project will be covered in this chapter. This crucial chapter will describe how the second and third objectives of this project are met using the hardware and software. This chapter will explain how to build an Internet of Things device for monitoring and managing the environment in chicken coops by choosing and utilising various components, including sensors, microcontrollers, and solar panels. It will describe how to programme the microcontroller and construct the firmware for the system using software tools like the Arduino IDE. Simulation software that will be used to test and verify the device's functionality will be highlighted.

3.2 System Design and Development

The design and development of the Internet of Things (IoT)-based chicken coop monitoring and control system necessitate a systematic methodology to guarantee optimal functionality and efficiency. The selection of core hardware components, such as the ESP32 module microcontroller, is based on their capacity to effectively handle numerous sensors responsible for monitoring essential environmental variables, including temperature, humidity, and ammonia concentrations. The system additionally incorporates techniques for environmental regulation, such as initiating the operation of fans or heaters in response to sensor data. The process of software creation plays a crucial role in facilitating the gathering, processing, and transmission of data to remote monitoring stations or mobile devices. The flowchart provides a clear visual representation of the overall project, outlining each step in the process of monitoring and controlling the chicken coop. Figure 3.1 shows Flowchart overall project.

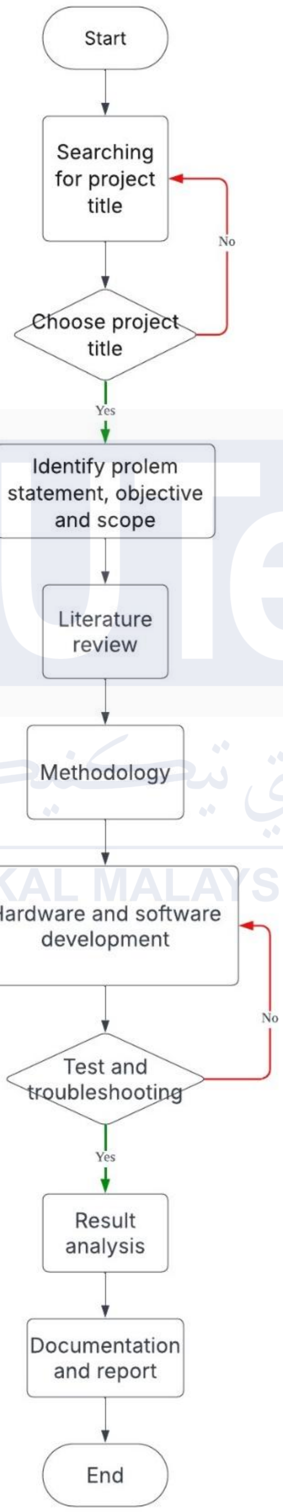


Figure 3.1 Flowchart overall project

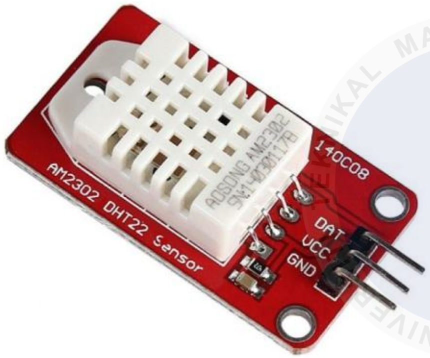
3.2.1 Design Specification

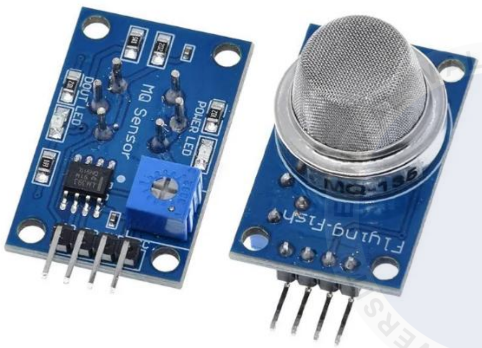
The design specification for the Internet of Things (IoT)-based chicken coop monitoring and control system outlines the comprehensive requirements and criteria essential for achieving the project objectives. The system is constructed based on the ESP32 module microcontroller, which was selected because to its extensive input/output functionalities, enabling it to establish data connections with many sensors continuously. The monitoring system includes sensors for temperature, humidity, and ammonia, that have a crucial part in maintaining an ideal environment inside the chicken coop. The design should prioritize the integration of accurate real-time information collection and analysis capabilities, consequently improving the system's ability to automatically react to ambient conditions, such as managing fans or heaters.

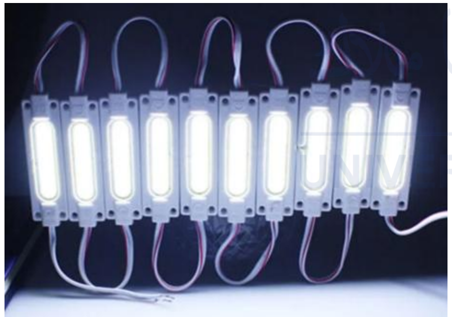
The designated power source for the system is a photovoltaic (PV) solar panel, which facilitates the availability of a sustainable and reliable energy supply, especially in locations where conventional power sources are not accessible. In order to maintain continuous operation during periods of low sunlight, it is essential for the solar power system to have a battery storage solution. The design additionally highlights the communication protocol employed for the transmission of data to a central monitoring unit, potentially via Wi-Fi or another wireless communication method. This framework guarantees that farmers are able to access real-time data and have control over various operations via a mobile application or online interface. Table 3.1 gives a thorough overview of how hardware contributes to the success of this project by separating down the applications and descriptions of each component used.

Table 3.1 Description of the components used

Component	Application	Description
1. ESP32 Module. 	• In IoT, the ESP32 is the processor that handles hardware communication. • The ESP32 is ideal for remote monitoring and control due to its strong processing power and Wi-Fi and Bluetooth capabilities. • It efficiently manages temperature, humidity, motion, and other sensor inputs for real-time data collecting and analysis. • Motors, pumps, and lights are controlled by the module using sensor data and programmable logic.	• Dual-core processors provide the ESP32 more processing power than simpler microcontrollers. • With 34 digital and 18 analog I/O pins, it allows versatile connectivity and sensor integration. • Its built-in Wi-Fi and Bluetooth make it excellent for IoT devices. • Programmable using the Arduino IDE, it simplifies application creation and testing.

2. DHT22 Sensor.  	• Measures temperature and humidity levels in the surrounding environment. • Used in weather stations, HVAC systems, and indoor climate control for accurate environmental data. • Integrates into smart home systems for monitoring indoor climate conditions. • Monitors temperature and humidity levels in greenhouse or indoor gardening setups.	• DHT22 is a digital sensor capable of measuring temperature and humidity. • Provides accurate readings with low drift over time. • Uses a single-wire digital interface for easy integration with microcontrollers. • Works within a wide range of temperature and humidity levels. • Consumes minimal power, suitable for battery-powered applications. • Reliable performance in various environmental conditions.
3. MQ-2 Sensor.	• Detects various harmful gases in the air, such as ammonia, benzene, and carbon monoxide.	• Detects a wide range of gases, including ammonia, benzene, and carbon monoxide.

	• Used in HVAC systems and indoor environments to monitor air pollution levels. • Integrated into gas leak detectors and safety alarms for early warning of hazardous gas levels. • Employed in factories and industrial settings to monitor workplace air quality and ensure worker safety.	• Provides analog output signals proportional to the concentration of detected gases. • Offers high sensitivity to a variety of gases, allowing for accurate detection. • Covers a broad range of gas concentrations for versatile applications.
4. Relay 5V. 	• Used for switching electrical circuits on and off based on control signals from a microcontroller. • Provides isolation between low-voltage control circuits and high-voltage loads.	• Operates using an electromagnet to mechanically switch contacts and control the flow of electricity. • Requires a control signal to activate the electromagnet, which then closes or opens the electrical circuit.

	• Enables automation of devices such as heating elements or fans. • Acts as a safety mechanism to control power supply to various components in the system.	• Typically consists of a coil, contacts, and a housing that encases the components. • Can handle high-current loads, making it suitable for controlling devices with significant power requirements.
5. LED Lamp. 	• Provides lighting in various low-voltage settings. • Security or for plants in controlled environments	• LED lamp offers energy-efficient lighting. • ideal for use in off-grid solar powered system. • Simulate daylight for animals. • Providing a consistent lighting schedule.

6. DC Brushless Fan. 	• Provides cooling by moving air within the chicken coop to maintain optimal temperature conditions. • Ensures ventilation to prevent overheating and improve air circulation. • Operates quietly and efficiently, making it suitable for use in a controlled environment.	• A direct current (DC) motor without brushes lowers friction and wear, improving efficiency and longevity. • Uses electronic commutation to control motor speed and direction. • More reliable and low maintenance than brushed motors.
7. Monocrystalline Silicon Solar Panel. 	• Converts sunlight into electrical energy. • Ideal for powering small devices, IoT systems, or as part of larger solar setups in off-grid or remote locations.	• The Monocrystalline 10W solar panel is made from high-quality silicon crystals, offering superior efficiency and higher energy output than other solar panel types.

	• Helps maintain continuous operation by generating clean energy even in areas with limited access to the power grid. • Can be integrated with an Intelligent Charge Controller to optimize energy production, storage, and system performance.	• Characterized by a uniform black appearance due to the single crystal structure, ensuring better light absorption and performance. • Offers high efficiency and performs well in low-light conditions, making it a suitable choice for energy harvesting in various environments.
8. LM2596 DC-DC Adjustable Step-Up. 	• Switching voltage regulator that steps up (boosts) an input DC voltage to a higher output DC voltage. • Highly efficient buck-boost design to ensure minimal energy loss.	• Used in photovoltaic (PV) solar systems to boost solar panel voltage for battery charging or device power. • Provides stable and adjustable voltage for low-voltage battery charging and device power.

9. Intelligent Charge Controller. 	• Manages solar-powered IoT device battery charging and discharging for energy efficiency and extended life. • Regulates energy flow from solar panel to battery for safe and efficient charging. • Monitoring battery state using voltage and current to prevent overcharging and deep draining. • Provides energy usage and battery health statistics for system diagnosis and optimization.	• Adapts charging process based on battery type, state of charge, and ambient conditions. • Enhances efficiency and lifetime through bulk, absorption, and float charging modes. • Comes with protections against overvoltage, overcurrent, and short circuits. • Often has communication ports for system integration and remote monitoring.
10. 12V 7AH Rechargeable Sealed Lead Acid (VRLA) Battery.	• Stores solar energy for use out of sunlight.	• Uses nickel and metal hydride electrodes for higher energy density than nickel-cadmium batteries.

	• Ensures long-lasting power for IoT devices and components. • Ideal for moderate energy density and long battery life applications. • Works with Intelligent Charge Controller to optimize charging and discharging cycles.	• Rechargeable with minimal self-discharge for longer energy storage. • Has a consistent voltage output and less memory effect than other rechargeable batteries. • Eco-friendly and free of heavy metals, making it safer for many applications.

3.2.2 Project System Monitoring Design

The project system design, shown in Figure 3.3 below, includes several important components such as Exhaust Fan, Heating Lamp, and Cooling Fan. The diagram helps in understanding the configuration and interaction of these components through the system.

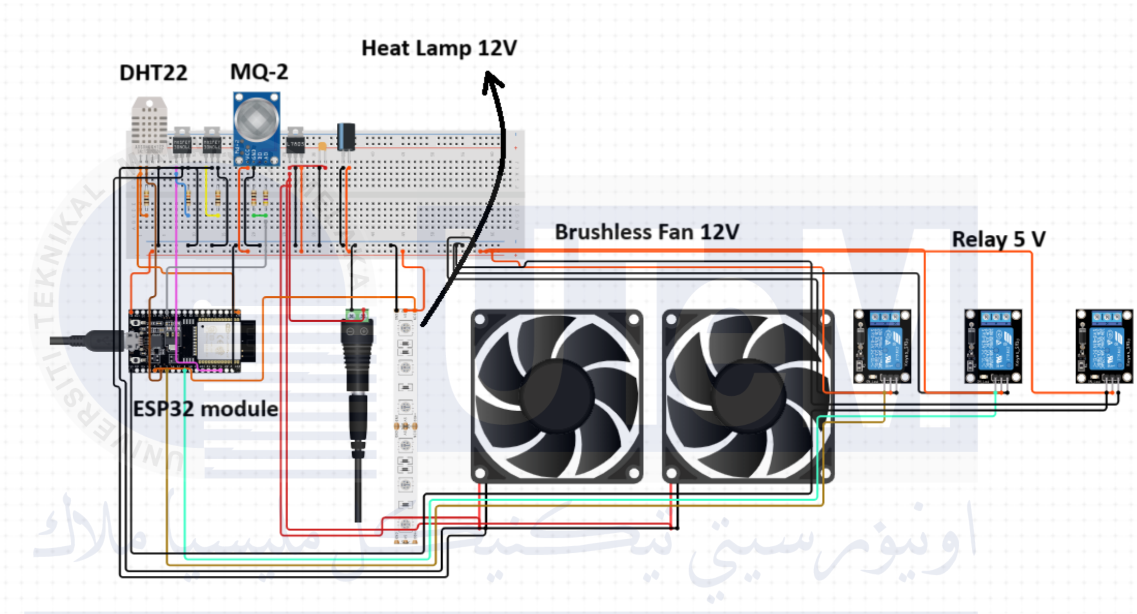


Figure 3.2 Design of a chicken coop monitoring system

The DHT22 sensor measures air temperature and humidity, while the MQ-2 sensor detects flammable and hazardous gases such as methane, propane, and smoke. An ESP32 module is used as the primary microcontroller for data processing, communication, and control of the system. Additionally, three relays are integrated to control the operation of the Exhaust Fan, Heating Lamp, and Cooling Fan. This configuration enhances automation and efficiency within the system.

The DHT22 sensor provides digital measurements of ambient temperature and humidity. The sensor's memory, recognised for its accuracy and stability, stores verification data for accurate measurements. It operates with a supply voltage of +3.3V or +5V and presents an accuracy variance of ±2 °C for temperatures ranging from 0 to 50 °C and ±5%

for humidity levels between 20 and 90% RH. The 20-meter signal transmission range matches the monitoring requirements of this system.

The MQ-2 sensor identifies gases such as methane, propane, and smoke, proving it appropriate for safety assurance in the monitored area. This sensor functions on a +5V power source and delivers analogue output signals that the ESP32 analyses for gas concentration measurement.

The ESP32 module is important to the system. It interfaces with the sensors and relays, enabling real-time data processing and control. The ESP32 provides wireless connectivity through Wi-Fi or Bluetooth, allowing for remote monitoring and control via a mobile or web application. This facilitates accessibility and management of the system.

Three relays are utilised to activate or deactivate the Heating Lamp, Exhaust Fan, and Cooling Fan according to sensor readings. The relays are triggered by signals from the ESP32 module, automating the control of these components to sustain optimal environmental conditions.

3.2.3 Software Development

This section focuses on the software used to build the project, which is Proteus 8 Professional and the Arduino IDE. These programmes are essential for applications like circuit design, coding, and simulation.

First of all, Arduino boards may be programmed using the Arduino IDE. Writing, assembling, and uploading code to regulate Arduino microcontroller behaviour is made easier by it. The Arduino IDE makes coding easier for a range of projects, from simple ones like flashing LEDs to more intricate ones like creating Internet of Things (IoT) devices.

Second, circuit design and simulation are performed with Proteus 8 Professional. Before being implemented, circuits can be designed and tested in a virtual environment. With a diverse range of electronic components available in its library, Proteus enables users to design intricate circuits and simulate their behavior in real-time. This facilitates the early detection and resolution of any possible problems during the development process.

The Arduino IDE and Proteus 8 Professional work together to enable effective coding and thorough circuit testing, which is a critical component of the development of the project. To make sure the project works and is successful, they are essential tools.

3.2.3.1 Arduino IDE

The Arduino IDE is a useful tool created by Arduino.cc that facilitates the writing, compilation, and uploading of code to a variety of Arduino modules. Numerous Arduino module libraries, including UNO, Mega, Leonardo, and others, are supported. The Arduino IDE converts your code into a Hex File, which is a particular format that the Arduino module can read, when you write code. This simplifies the process of uploading and enable your code to run on the module.

The Editor and the Compiler are the two main components of the Arduino IDE. You write and change your code in the Editor, which also provides you with assistance as you type by identifying important sections and making suggestions. The component that transforms your code into a project the module for Arduino can use is called the compiler. Common programming languages C and C++ are supported by the Arduino IDE. The Arduino IDE is shown in Figure 3.3, with its user-friendly interface and practical capabilities that facilitate writing of Arduino modules.

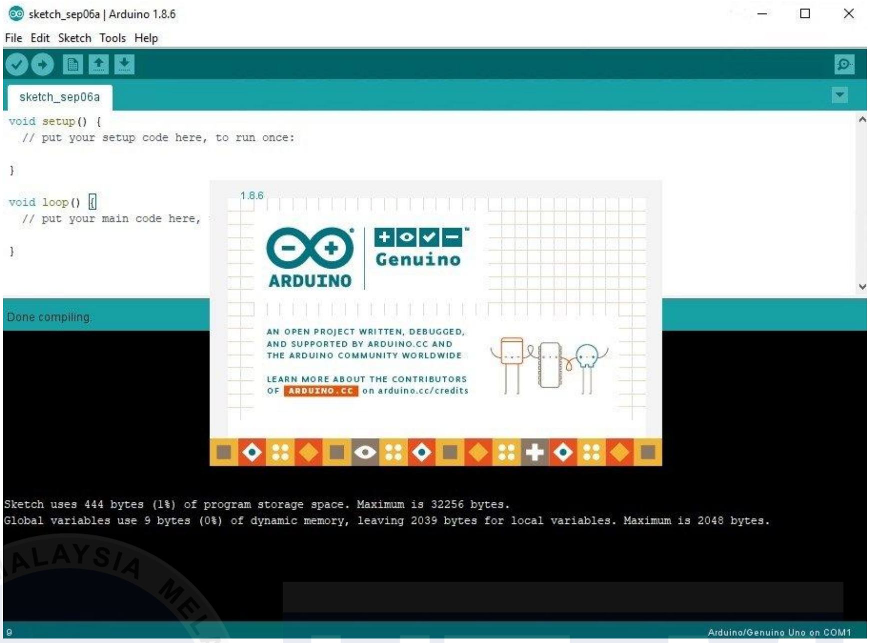


Figure 3.3 Arduino IDE Software

3.2.3.2 Blynk

Blynk.Console is a robust IoT platform enabling users to monitor and control their devices in real time. It provides a user-friendly interface for dashboard creation, allowing users to visualise sensor data and remotely interact with hardware components. Developers can modify the layout according to particular project requirements using basic drag-and-drop tools, integrating widgets for data visualisation, control, and notifications. Blynk facilitates the integration of IoT systems by providing effortless connectivity over Wi-Fi or cellular networks.

The dashboard, as shown in Figure 3.4 Blynk web console and Figure 3.5 Blynk mobile application, ensures that all system interactions can be managed efficiently and remotely. The green indication represents the temperature value, indicating safe environmental conditions, while the red indicator signifies gas levels, warning users of potential hazards. The mobile app interface Figure 3.5 features colour-coded labels: green for "Normal" temperature and humidity conditions, blue for gas detector status, and yellow for heat lamp status, which provides clear and quick feedback on system functionality.

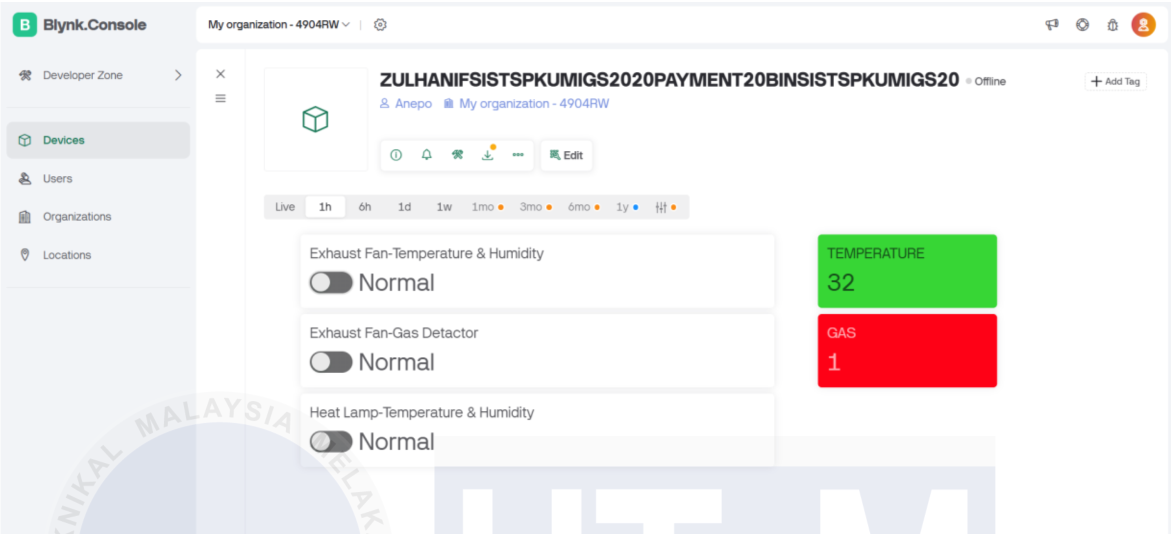


Figure 3.4 Blynk web console

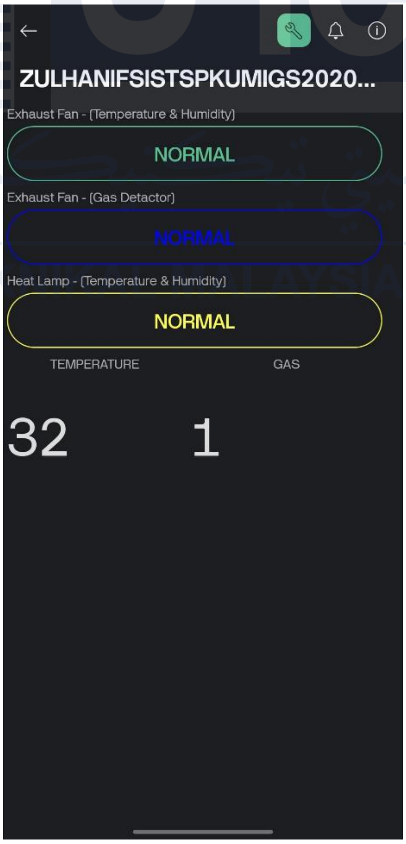


Figure 3.5 Blynk mobile application

Blynk optimises our development process by facilitating real-time engagement and monitoring, ensuring that the solution functions as designed. The platform's dependability and ease of use provide the confidence required to implement resilient IoT-based solutions for monitoring the environment and control.

3.3 Prototype Development

The PV Panels are the starting point of the standalone photovoltaic (PV) solar generation system, as they convert sunlight into direct current (DC) electricity. The Charge Controller regulates the voltage and current to ensure the Battery Bank is securely charged by the DC electricity that is generated. This energy is stored in the Battery Bank for use during periods when sunlight is unavailable. The DC-DC Converter subsequently processes the stored DC electricity, adjusting the voltage level to satisfy the DC Load's specifications.

3.3.1 Solar Power System Design

The design of the solar power system is a fundamental aspect of this project, ensuring that the IoT-based device for monitoring and controlling a chicken coop operates efficiently and sustainably. The PV Panels are the starting point of the standalone photovoltaic (PV) solar generation system, as they convert sunlight into direct current (DC) electricity. The Charge Controller regulates the voltage and current to ensure the Battery Bank is securely charged by the DC electricity that is generated. This energy is stored in the Battery Bank for use during periods when sunlight is unavailable. The DC-DC Converter subsequently processes the stored DC electricity, adjusting the voltage level to satisfy the DC Load's specifications. Lastly, the DC Load ensures that the energy generated by the PV panels is effectively harnessed and utilized by utilizing the regulated DC power for a variety of applications. The optimal configuration of this system guarantees a consistent and reliable provision of power through the strategic management of energy generation, storage, and usage. Figure 3.6 shows the process by which a photovoltaic (PV) solar panel transforms solar energy into direct current (DC) power when exposed to sunshine.

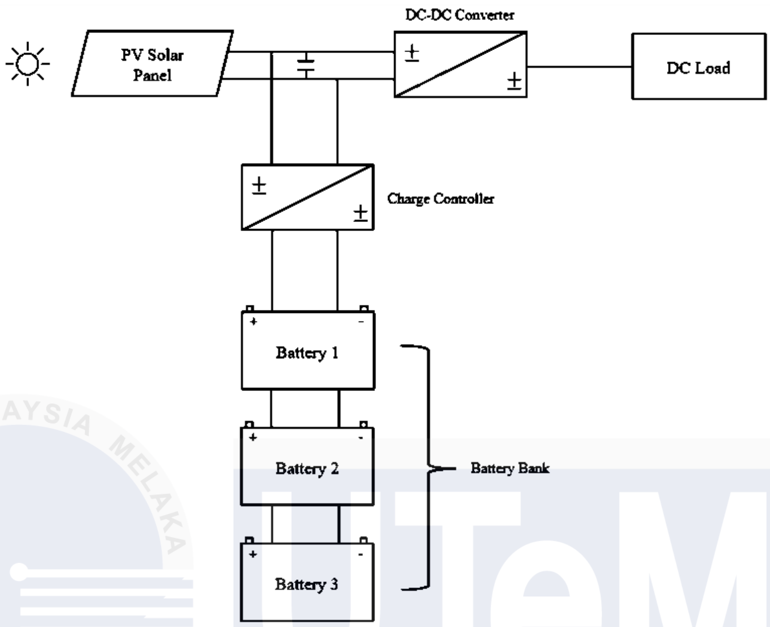


Figure 3.6 Block diagram of Standalone PV Solar Generator

3.3.2 Size of Solar Panel

Load details:

1-unit DHT22 sensor uses approximately 0.0003Wh × 24 hours = 0.0072Wh (since it runs 24 hours).

1-unit MQ2 sensor would consume approximately 0.1Wh × 24 hours = 2.4Wh (since it runs 24 hours) watts 1 hour per day.

1-unit ESP32 Module operate in transmitting mode 0.528Wh × 24 hours = 12.672Wh (since it runs 24 hours).

3-unit Relay 5V would consume approximately (3× 0.35Wh) × 1 hour = 1.05Wh (since they run 1 hour).

1-units LED Lamp would use 1.5Wh 1 hour per day.

2-units DC Brushless Fan use (2 × 3.6Wh) × 1 hour = 7.2Wh.

Total load per day = 0.0072Wh + 2.4Wh + 12.672Wh + 1.05Wh + 7.2Wh + 1.5Wh = 24.83Wh.

System specific requirement:

Energy usage (per day) = 24.83Wh

Battery voltage = 12V

Depth of Discharge (DoD) = 50%

Days of Autonomy (DoA) = 1 day

Battery Bank Temperature Multiplier (BBTM) = 1

Peak Sun Hour (PSH) = 4 hours

Solar panel size:

The output power of solar panel

= Energy usage (per day) ÷ PSH ÷ system efficiency

= 24.83Wh ÷ 4 hours ÷ 0.6

= 10.35W

Monocrystalline panel size = 6V, 10W

Therefore, 10.35W ÷ 10W ≈ 1 solar panel

Hence, 1 Monocrystalline silicon solar panel is needed for the whole system to operate.

3.3.3 Size of Solar Charge Controller

The output power of the solar panels = 10W

Battery voltage = 12V

Suitable size of the charge controller = 10W ÷ 12V = 0.8333A

Size of the charge controller due to safety regulation = 0.8333A x 1.2 = 1A

Therefore, the minimum size for the charge controller is 1A. Since the smallest size of solar charge controllers available in the market is 10A, 20A and 30A, the selected size of the charge controller used is 10A.

3.3.4 Size of Battery Bank

Average daily:

Energy usage (per day) = 15.0475W x 1 hours = 15.0475Wh

Battery bank capacity (Wh):

= (Daily average usage x DoA x BBTM) ÷ DoD

= (15.0475Wh x 1 day x 1) ÷ 0.5

= 30.095Wh

Battery bank capacity (Ah):

= Battery bank capacity (Wh) ÷ system voltage

= 30.095Wh ÷ 12V

= 2.58Ah, 12V

Rechargeable Sealed Lead Acid (VRLA) battery size = 7Ah, 12V

Therefore, 2.58Ah ÷ 7Ah ≈ 1 battery

Hence, this project only needs 1 battery of Sealed Lead Acid.

Summary of system sizing:

- Solar panel size: 12V, 2W × 1 solar PV panel
- Charge Controller size: 10A
- Battery size: 7Ah, 12V × 1 battery

3.3.5 Project Design and Installation

The project design and installation section outline the procedure for planning and implementing the system. It includes the selection of suitable components, the design of their cooperation, and ensuring of proper installation. This includes the selection of sensors, actuators, and energy-efficient components, in addition to ensuring the system operates effectively. This part emphasizes testing, calibration, and troubleshooting to make sure the system operates properly after installation.

Bamboo was selected as the building material due to its sustainability, durability, and environmentally favorable properties. Bamboo, as a renewable resource, presents a little environmental impact relative to conventional building materials, making it an optimal selection for eco-friendly projects. The unique durability, flexibility, and lightweight characteristics improve the system's overall efficiency and durability, while offering an ideally pleasing and efficient solution. Implementing bamboo not only fosters environmentally sustainable practices but also corresponds with the project's objective of advancing sustainable and innovative design. Figure 3.7 illustrates the bamboo cutting process, focusing each step of gathering and preparing bamboo for construction purposes.

Figure 3.7 Bamboo cutting and installation process

Following to the assembly and installation phaseas shows in Figure 3.8, the testing procedure follows thoroughly, making sure that all components of the Internet of Things (IoT)–based device for monitoring and controlling a chicken coop using photovoltaic solar energy function effectively and as designed. Figure 3.9 illustrates the completed configuration of the project, comprising three primary sections: one for accommodating the microcontroller and sensors, another for the installation of the solar-powered system, and a designated area for the setup of energy storage and related components.

Figure 3.8 Assembly process

Figure 3.9 Completed configuration of the project

3.3.6 Block Diagram of Overall System

To design a standalone photovoltaic (PV) solar-powered monitoring and control system for a chicken coop, a well-planned configuration is crucial to ensure uninterrupted power and efficient operation of all components. The system includes a photovoltaic solar panel as the principal energy source, a charge controller for managing power flow, a battery for energy storage, and an ESP32 module working as the main controller. These components function effectively to energise the sensors, relays, and actuators, providing the system ideal for renewable or remote environments. This design ensures continuous operation while utilising renewable energy, significantly reducing environmental effect and operating costs.

At the core of the system is the ESP32 module, a versatile microcontroller with built-in Wi-Fi capabilities, which acts as the brain of the setup. It processes sensor input and controls relay output, automating environmental control within the chicken coop. The DHT22 sensor, known for its accuracy, continuously monitors temperature and humidity levels, providing critical data to maintain a comfortable and healthy environment for poultry. Through monitoring of the environment, the ESP32 can engage fans or a heat lamp via the relays as necessary. For instance, when the temperature exceeds a specific threshold, the system autonomously activates the fans to reduce the temperature and ensure enough ventilation.

The MQ-2 gas sensor is included to identify hazardous gases, like smoke, propane, methane, and other gaseous substances that may risk the health and safety of the poultry. After detecting hazardous gas concentrations, the ESP32 activates the fans to improve air circulation and release the gases. Alerts can be dispatched to the farmer via a connected mobile or web application, facilitating prompt action against any threats. This early warning system not only improves animal safety but also reduces the probability of major incidents such as fires or toxic exposure.

The relays are crucial components in the system, working as switches to regulate external equipment such as fans and heat lamps. Upon activation by the ESP32, the relays provide the efficient operation of these devices to stabilise the coop's environment. For example, in cold situations, the ESP32 can autonomously activate the heat lamp to sustain a warm and comfortable temperature for the chickens. This degree of automation reduces the necessity of constant human supervision while simultaneously safeguarding the chickens' health, which is crucial for their welfare and production.

A crucial aspect of the system is its capacity to gather and archive real-time environmental data in a database. The ESP32 transmits data, encompassing temperature, humidity, and gas concentration measurements, to a central database for further evaluation. This information is available through a mobile or online application, allowing farmers to remotely observe the conditions within the chicken coop at any moment. The program is engineered for user-friendliness, offering a clear visualisation of the data and providing manual system control as required. Notifications and alarms can be dispatched via the application to notify users of any anomalous conditions, facilitating prompt action when necessary.

This IoT-driven solution, totally reliant on renewable energy, provides a sustainable and effective method for regulating the ambient conditions of a chicken coop. The device utilises solar energy, functioning autonomously from grid power, rendering it suitable for rural or distant agricultural environments. Furthermore, the incorporation of sensors and automation improves animal welfare by sustaining a healthy habitat and reducing manual labour for the farmer. The capacity to monitor and control the system remotely introduces an extra dimension of ease, facilitating effective farm management and improving output.

In summary, the integration of solar energy, sophisticated IoT technology, and automated control systems renders this approach both economically viable and ecologically sustainable for poultry management. Figure 3.9 presents a comprehensive overview of the block diagram for the development of an Internet of Things (IoT)-based device designed for monitoring and controlling a chicken coop utilising photovoltaic solar technology, highlighting its components and operational flow.

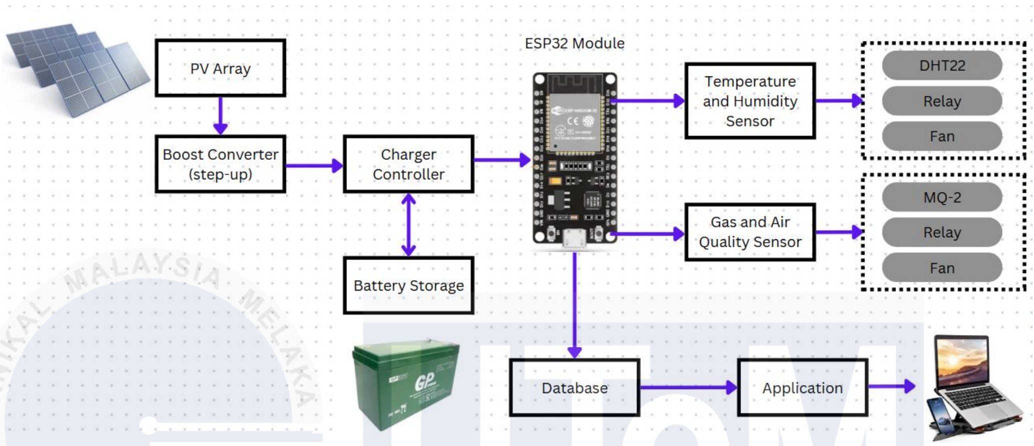


Figure 3.10 Block diagram of the project

3.4 Experiment Setup for Case A, Case B and Case C

The experimental setup evaluates the functionality and reliability of the IoT-based chicken coop monitoring and control system across three separate cases, each addressing a crucial part of the project to guarantee its overall efficiency and effectiveness.

The first case, Power Management, illustrates the system's ability to function self-sufficiently from the main power grid with renewable energy sources. A photovoltaic (PV) solar panel captures solar energy, which is managed by a charge controller to avoid overcharging of the 12V rechargeable battery. This battery provides reliable power to the ESP32 microprocessor, sensors, and actuators, ensuring continuous operation even under low light settings, including cloudy days or nights. This experiment studies the effectiveness of solar energy in sustainably powering IoT devices and analyses the battery's capacity to sustain steady operation in off-grid conditions.

The second case, Environmental Monitoring and Control, ensures optimal living conditions within the poultry enclosure. The DHT22 sensor measures temperature and humidity, whereas the MQ-2 sensor identifies hazardous gases, including smoke, propane, and methane. The ESP32 processes sensor data, activating relays to automate environmental controls. For instance, if the temperature above the limit, the system engages fans to cool the coop, and when the temperature lowers excessively, it activates a heat lamp to preserve warmth. After detection of harmful gas levels, the fans improving ventilation to ensure safety. This case study illustrates the system's capacity to automatically react to environmental fluctuations, ensuring a secure and comfortable habitat for chickens with minimal human oversight.

The third case, Data Monitoring and Remote Access, highlights the IoT capabilities of the system by concentrating on real-time data monitoring and remote management. The ESP32 transmits sensor information for temperature, humidity, and gas levels to the Blynk platform using Wi-Fi. The Blynk app enables users to visualise real-time data and receive notifications when conditions go outside permitted parameters. For instance, if the temperature rises excessively, a notification is dispatched to the user's smartphone, offering prompt intervention. The application facilitates remote operation of devices such as fans and heat lamps, offering flexibility and convenience for farmers who are not on-site. This case demonstrates the project's capacity to equip farmers with contemporary tools for the efficient and effective management of their poultry enclosures. Table 3.2 shows the summarizes the focus and key functionalities tested in each case.

Table 3.2 Summarizes the focus and key functionalities tested in each case

Cases	Focus	Key Functionalities	Mode
Case 1	Power Management	Evaluate the use of solar energy and battery	Operates for 3 days to assess uninterrupted

		storage to power the system sustainably.	functionality during daytime and nighttime.
Case 2	Environmental Monitoring and Control	Test automated controls for temperature, humidity, and gas levels using sensors and relays.	1 day operates continuously to monitor and control the environment under varying conditions.
Case 3	Data Monitoring and Remote Access	Validate real-time data transmission, alerts, and remote control via the Blynk platform.	24 hours of real-time monitoring and control simulation via the Blynk app

3.5 Summary

This chapter outlines the process to develop an IoT-based system to monitor and regulate the environment within chicken coops, utilising solar energy as its power source. It outlines the selection and integration of essential hardware components, including photovoltaic solar panels, charge controllers, batteries, the ESP32 microprocessor, and sensors such as the DHT22 for temperature and humidity and the MQ-2 for gas detection. Relays are utilised to automatically regulate fans and heat lamps, consequently maintaining optimal environmental conditions. This chapter clarify the utilisation of software tools such as the Arduino IDE for programming the ESP32, as well as the role of the Blynk platform in enabling real-time data monitoring and control via mobile or web applications. Diagrams and flowcharts explain the system architecture and operational processes. This methodology combines renewable energy with IoT technology to develop an efficient, sustainable, and automated system for maintaining chicken coops.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter provides a detailed summary of the anticipated outcomes from the project, focusing on two main components: the electrical energy produced by the photovoltaic (PV) solar generator and the effectiveness of the IoT-based device for monitoring and controlling a chicken coop. This study assesses how well the solar panels convert sunlight into electrical energy while taking a number of variables like location and weather into consideration. The objective is to ensure a consistent supply of electricity for the Internet of Things system, which has features like temperature control, and security measures to keep the chickens safe.

Practical applications and simulations using Proteus 8 Professional software are an example of preliminary results. These simulations help identify future difficulties and increase system reliability by projecting how the PV solar generator and the IoT-based gadget would work under different situations. To construct a sustainable and effective chicken coop management system, this chapter summarizes the integration of modern IoT solutions with renewable energy. The simulations provide valuable insights that inform future development and optimization of the system.

4.2 Data Collection

The data collecting approach for this project was carried out to assess the effectiveness and reliability of the IoT-based chicken coop monitoring and control system. Figure 4.1 illustrates the real-time voltage and current measurements produced by the photovoltaic solar panel and stored in the 12V battery, acquired by digital multimeters and power meters during the research for Case 1. Figure 4.2 depicts the environmental data obtained in Case 2, including temperature and humidity measurements from the DHT22 sensor, along hazardous gases, including smoke and methane, identified by the MQ-2 sensor. The ESP32 microcontroller processed these readings to automate the regulation of fans and heat lights. Figure 4.3 illustrates the IoT capabilities evaluated in Case 3, wherein sensor data was transmitted to the Blynk platform for continuous monitoring and remote accessibility. Alerts activated when environmental parameters surpassed specified limits, and remote actuator control was effectively demonstrated. The gathered data confirms the system's efficacy in sustainable energy utilisation, environmental regulation, and remote oversight.

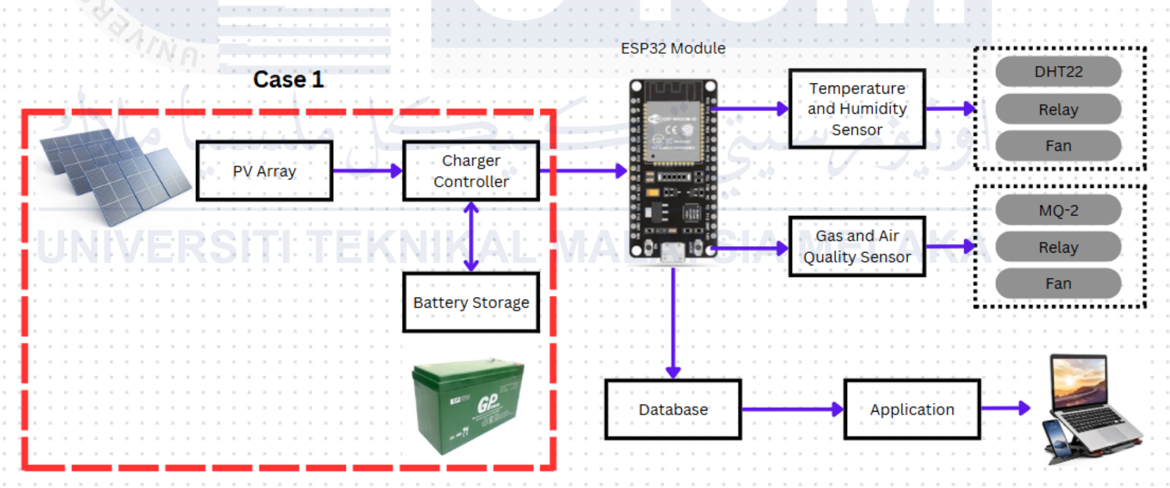


Figure 4.1 Case 1

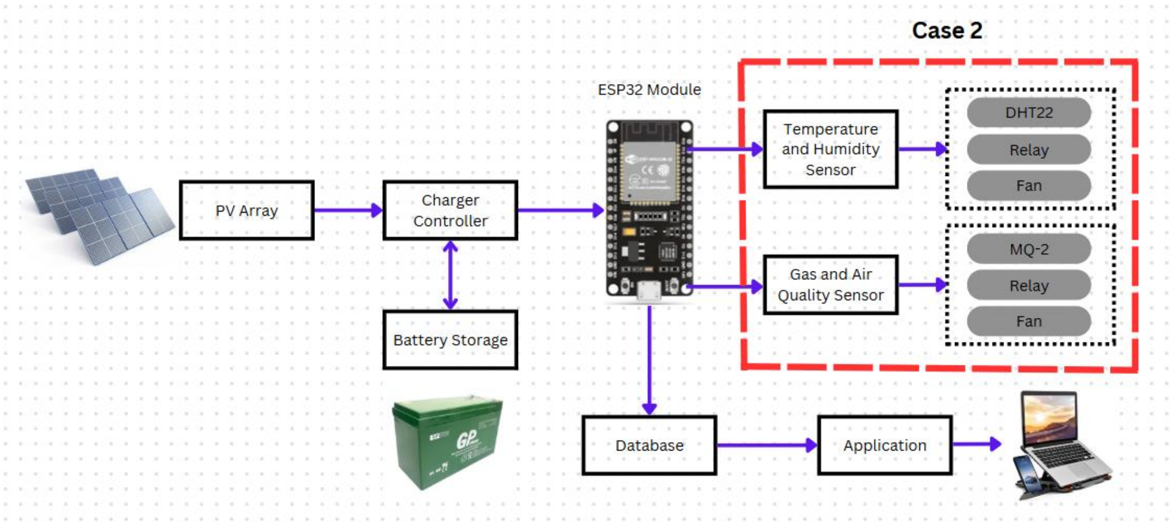


Figure 4.2 Case 2

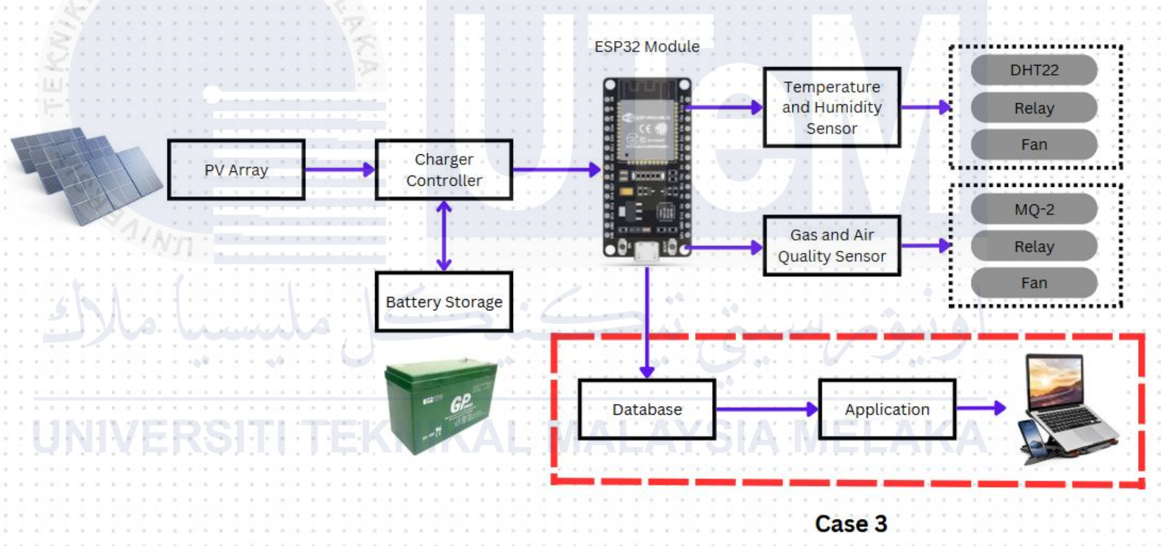


Figure 4.3 Case 3

4.2.1 Case 1 : Solar Energy System Input and Output Analysis for Daytime Performance Evaluation

Case 1 concentrates on assessing the utilisation of solar energy and battery storage for sustainable system power. The system functions for three days to evaluate its continuous performance both day and night, employing the solar panel to charge the battery by day and depending on battery storage to work at night. Data is gathered on the voltage and current produced by the photovoltaic solar panel, along with the battery's charge and discharge cycles, to verify the system's capacity for continuous operation without external power sources. This assessment offers insights into the efficacy of the solar energy system, the capability of the battery storage, and the comprehensive performance of the system in real-world scenarios. The objective is to ascertain that the system can sustain optimal performance, particularly in regulating energy requirements during nighttime when solar energy is not accessible.

4.2.1.1 Input data for Case 1

The data that was successfully gathered for the Case 1 experiment for input analysis, which was carried out at 5/11/2024 from 8.00 am in the morning to 5.00 pm in the evening untill 7/11/2024, is represented in Table 4.1.

Table 4.1 Input data for Case 1

5/11/2024				
Time	**Solar voltage, V**	**Solar current, A**	**Power, W**	**Remark**
8.00 am	7.00	0.20	1.40	Sunny
9.00 am	6.80	0.18	1.22	Sunny
10.00 am	6.98	0.19	1.32	Sunny
11.00 am	6.65	0.16	1.06	Sunny
12.00 pm	6.30	0.14	0.882	Sunny
1.00 pm	6.22	0.14	0.87	Sunny
2.00 pm	6.21	0.13	0.81	Sunny
3.00 pm	5.83	0.11	0.64	Cloudy
4.00 pm	5.00	0.10	0.5	Coudy

5.00 pm	5.3	0.12	0.636	Coudy
6/11/2024				
Time	**Solar voltage, V**	**Solar current, A**	**Power, W**	**Remark**
8.00 am	7.00	0.20	1.4	Sunny
9.00 am	6.90	0.18	1.24	Sunny
10.00 am	6.98	0.19	1.33	Sunny
11.00 am	6.75	0.17	1.15	Sunny
12.00 pm	6.30	0.14	0.88	Sunny
1.00 pm	6.22	0.14	0.87	Sunny
2.00 pm	6.20	0.13	0.80	Sunny
3.00 pm	5.93	0.11	0.65	Cloudy
4.00 pm	5.30	0.12	0.64	Coudy
5.00 pm	5.30	0.12	0.64	Coudy
7/11/2024				
Time	**Solar voltage, V**	**Solar current, A**	**Power, W**	**Remark**
8.00 am	5.98	0.08	0.48	Sunny
9.00 am	6.20	0.13	0.81	Sunny
10.00 am	6.21	0.13	0.81	Sunny
11.00 am	6.20	0.13	0.81	Sunny
12.00 pm	6.19	0.12	0.74	Sunny
1.00 pm	6.16	0.12	0.74	Sunny
2.00 pm	6.07	0.10	0.60	Sunny

3.00 pm	5.51	0.10	0.55	Cloudy
4.00 pm	5.20	0.10	0.52	Coudy
5.00 pm	5.20	0.10	0.52	Coudy

Figures 4.4, Figure 4.5, and Figure 4.6 present graphs illustrating a comprehensive analysis of the variations in voltage (V), current (A), and power generated by the solar panel over three consecutive days: 5/11/2024, 6/11/2024, and 7/11/2024. Each line on the graphs represents one of the electrical parameters, highlighting their relative changes throughout each day. The data provides valuable insights into the solar panel's behavior during this period, showcasing distinct patterns and trends such as peak performance times, consistency in power generation, and potential anomalies. These visualizations clearly depict the electrical characteristics and their evolution over the three days, offering a detailed understanding of the solar panel's daily performance.

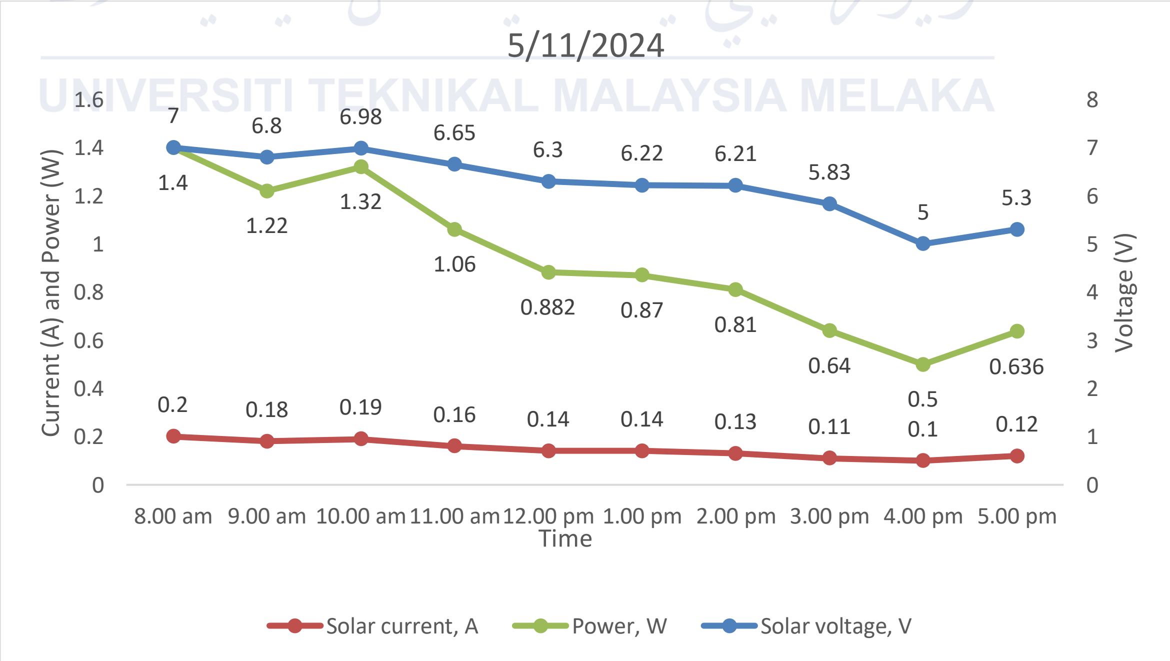


Figure 4.4 Graft Voltage (V), Current (A) and Power vs Time from solar panel on the date 5/11/2024

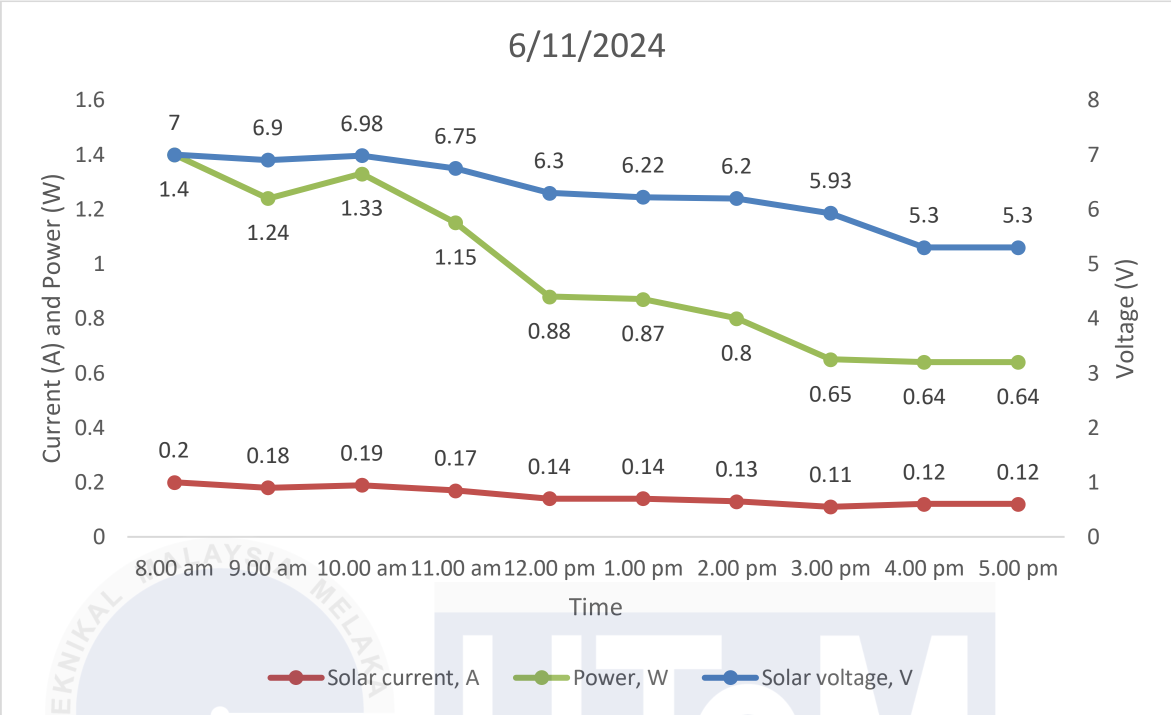


Figure 4.5 Graft Voltage (V), Current (A) and Power vs Time from solar panel on the date 6/11/2024

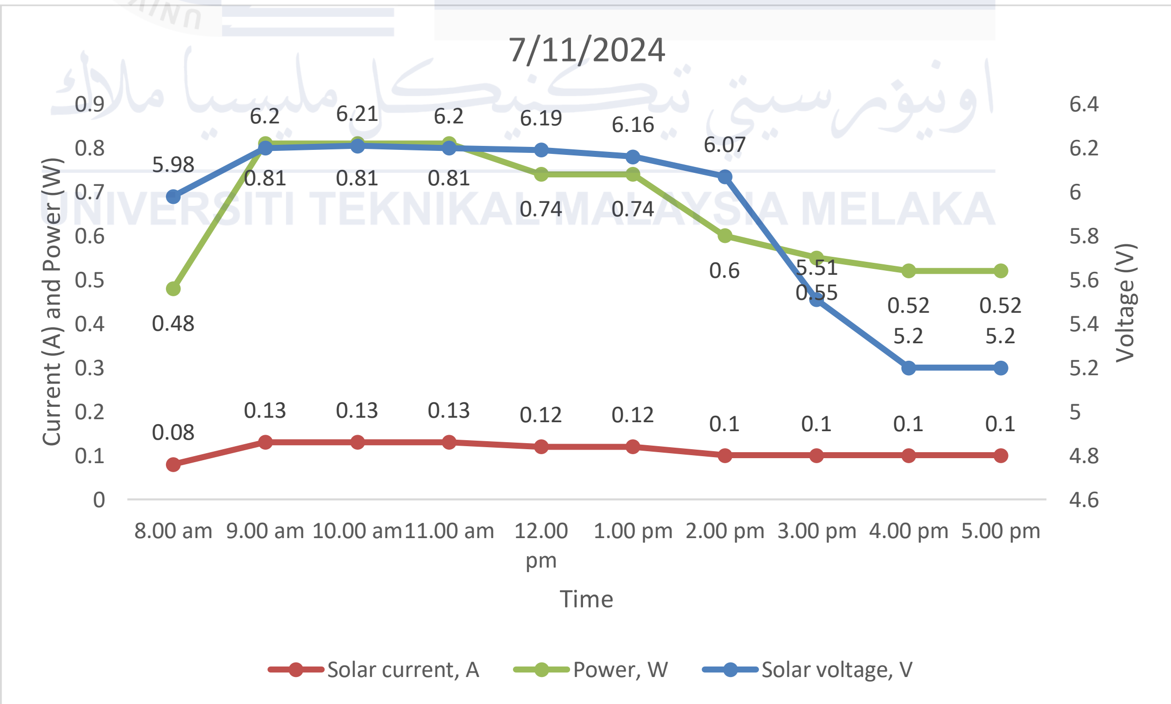


Figure 4.6 Graft Voltage (V), Current (A) and Power vs Time from solar panel on the date 7/11/2024

4.2.1.2 Output data for Case 1

The data has been gathered satisfactorily for the Case A. The data depicted in Table 4.2 and Table 4.3 illustrates an output analysis experiment that spanned the time period from 8.00 am in morning time to 5.00 pm in the evening at the same day as input data at 5/11/2024 until 7/11/2024. Table 4.2 shows output data that was collected.

Table 4.2 Output data for Case 1

5/11/2024				
Time	**Battery voltage,V**	**Battery Current, A**	**Power, W**	**Remark**
8.00 am	12.11	0.36	4.36	Sunny
9.00 am	12.11	0.37	4.48	Sunny
10.00 am	12.12	0.36	4.36	Sunny
11.00 am	12.13	0.37	4.49	Sunny
12.00 pm	12.14	0.37	4.49	Sunny
1.00 pm	12.14	0.38	4.61	Sunny
2.00 pm	12.15	0.37	4.49	Sunny
3.00 pm	12.16	0.36	4.38	Cloudy
4.00 pm	12.16	0.36	4.38	Coudy
5.00 pm	12.16	0.36	4.38	Coudy
6/11/2024				
Time	**Battery voltage,V**	**Battery Current, A**	**Power, W**	**Remark**
8.00 am	12.17	0.36	4.38	Sunny
9.00 am	12.17	0.37	4.50	Sunny

10.00 am	12.18	0.37	4.50	Sunny
11.00 am	12.18	0.36	4.38	Sunny
12.00 pm	12.19	0.35	4.27	Sunny
1.00 pm	12.20	0.35	4.27	Sunny
2.00 pm	12.21	0.36	4.39	Sunny
3.00 pm	12.21	0.36	4.39	Sunny
4.00 pm	12.22	0.37	4.52	Sunny
5.00 pm	12.24	0.36	4.41	Sunny
7/11/2024				
Time	**Battery voltage,V**	**Battery Current, A**	**Power, W**	**Remark**
8.00 am	12.32	0.35	4.31	Sunny
9.00 am	12.50	0.35	4.38	Suuny
10.00 am	12.73	0.36	4.58	Sunny
11.00 am	12.81	0.37	4.74	Sunny
12.00 pm	12.86	0.37	4.76	Sunny
1.00 pm	12.97	0.37	4.80	Sunny
2.00 pm	13.00	0.37	4.81	Sunny
3.00 pm	13.01	0.37	4.81	Cloudy
4.00 pm	13.01	0.37	4.81	Cloudy
5.00 pm	12.96	0.38	4.92	Cloudy

Figure 4.7, Figure 4.8 and Figure 4.9 shows the graph illustrates a comprehensive analysis of the variations in voltage, current, and power over the course of three consecutive days: 5/11/2024, 6/11/2024, and 7/11/2024. The electrical parameters are represented by

each line on the graph, which illustrates their relative changes throughout the day. Insights into the system's behaviour during this period are provided by the data, which shows distinct patterns and trends, including optimum performance times, consistency in readings, and potential abnormalities. The electrical characteristics and their evolution over the course of three days are clearly illustrated in this visualisation.

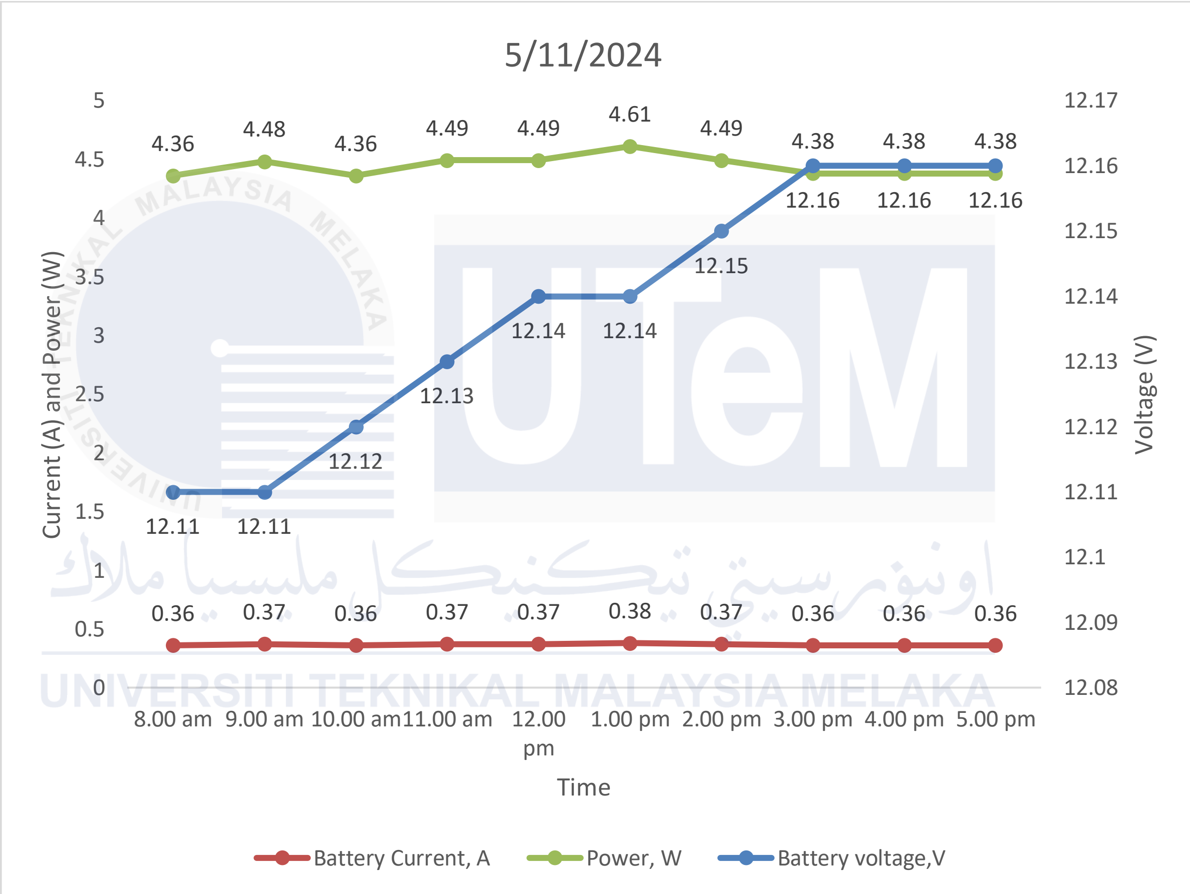


Figure 4.7 Graft Voltage (V), Current (A) and Power vs Time for battery on the date 5/11/2024

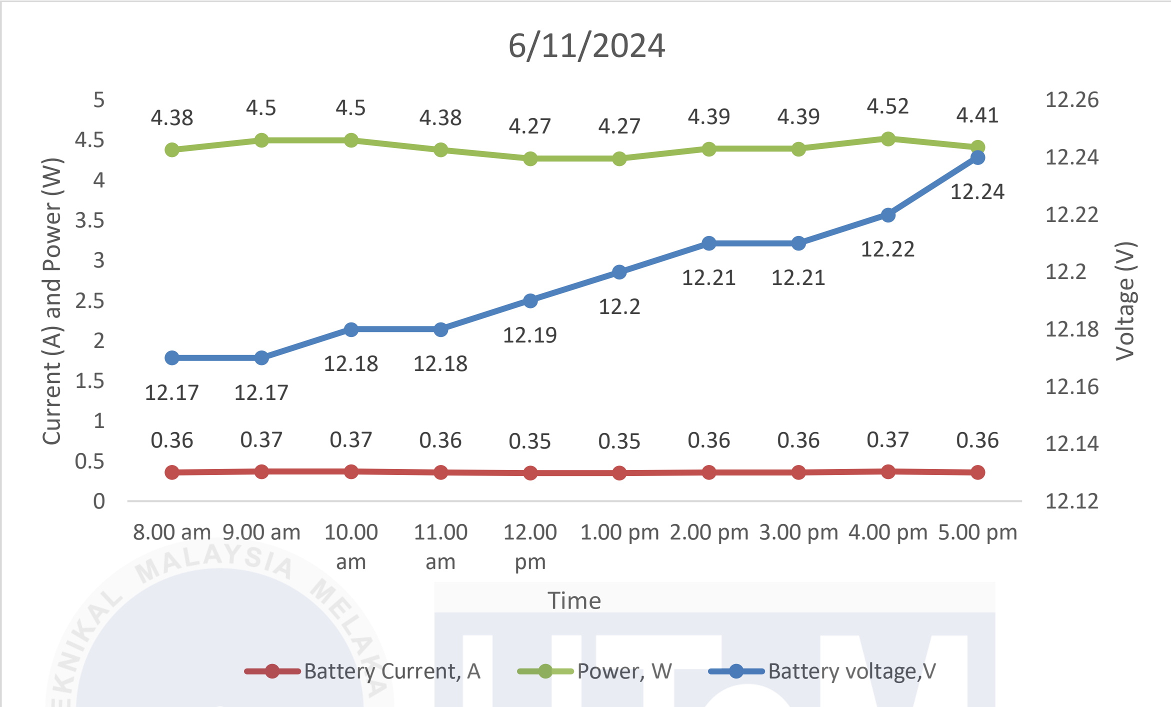


Figure 4.8 Graft Voltage (V), Current (A) and Power vs Time for battery on the date 6/11/2024

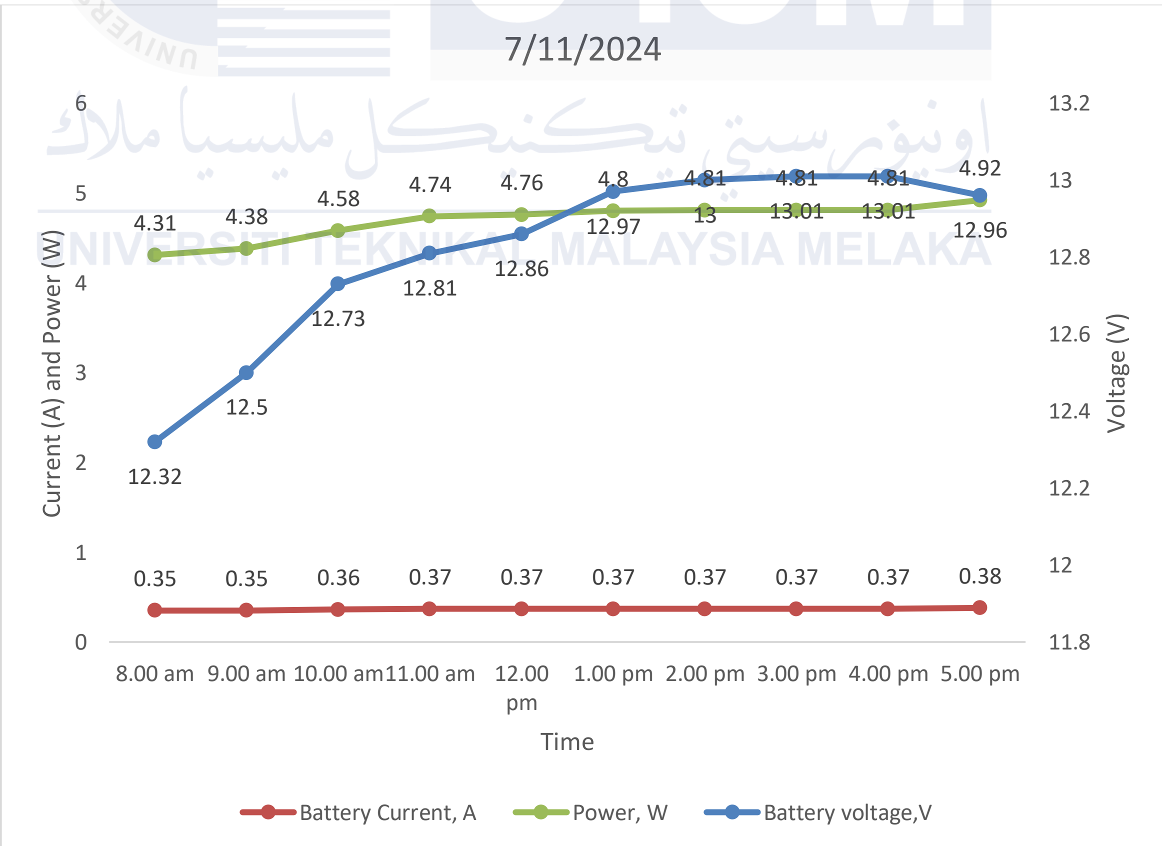


Figure 4.9 Graft Voltage (V), Current (A) and Power vs Time for battery on the date 7/11/2024

4.2.2 Case 2 : Environmental Data Analysis Using Temperature, Humidity, and Gas Sensors

Case 2 focusses the analysis of environmental monitoring and control components of the system, employing real-time data to sustain ideal conditions within the chicken coop. The system acquires environmental data, encompassing temperature, humidity, and gas concentrations (such as smoke or methane) using sensors such as the DHT22 and MQ-2. The ESP32 microcontroller processes this data, activating automated management of devices like fans and heat lamps to manage the environment. The system's effectiveness is evaluated by examining its capacity to adapt to variations in environmental conditions, guaranteeing that the coop stays within optimal parameters for avian health and wellbeing. This scenario illustrates the system's ability to autonomously monitor and control the environment without remote access, therefore providing efficient operation in sustaining a comfortable and secure environment for the chickens.

4.2.2.1 Temperature and Humidity (DHT22) analysis

The DHT22 analyze temperature and humidity data collected at 29/12/2024. The sensor provides measurements in Temperature (°C) and Humidity (%), with data collected over a 24-hour period at 1-hour intervals. Table 4.3 shows data collected temperature and humidity.

Table 4.3 Data collected for temperature and humidity for Case 2

Time	Temperature (°C)	Humidity (%)	Status
12.00 am	30.00	79.50	Normal
1.00 am	29.90	79.50	Normal
2.00 am	29.50	80.20	Normal

3.00 am	29.70	79.30	Normal
4.00 am	29.90	79.50	Normal
5.00 am	29.60	80.50	Normal
6.00 am	30.00	78.80	Normal
7.00 am	30.00	79.00	Normal
8.00 am	30.40	80.40	Normal
9.00 am	30.80	77.90	Normal
10.00 am	31.00	76.70	Normal
11.00 am	31.50	76.60	Normal
12.00 pm	31.10	76.70	Normal
1.00 pm	31.10	76.70	Normal
2.00 pm	32.00	76.30	Normal
3.00 pm	31.80	74.2	Normal
4.00 pm	31.40	76.7	Normal
5.00 pm	31.50	73.30	Normal
6.00 pm	32.00	75.20	Normal
7.00 pm	32.00	75.50	Normal
8.00 pm	30.00	69.20	Normal
9.00 pm	29.90	86.20	Normal
10.00 pm	29.90	86.20	Normal
11.00 pm	22.00	50.00	Cold

An intentional temperature disturbance was observed at 11:00 PM, which was deliberately executed by utilising ice in a tumbler to manipulate the DHT22 sensor's readings, data has been recorded in the table. The recorded temperature values experienced a substantial decrease because of the located cooling effect caused by the ice's positioning in close proximity to the sensor. The immediate abnormality in the data strongly indicates external influence is the cause, rather than natural environmental changes. The figured response of the DHT22, a highly sensitive sensor noted for its precision in detecting temperature fluctuations, is consistent with the rapid decrease in temperature. This incident emphasises the necessity of vigilant surveillance to identify and resolve intentional attempts to disrupt sensor functionality, thereby ensuring the integrity and reliability of environmental data that is collected. Figure 4.10 shows the ice's positioning in close proximity to the sensor DHT22 and Figure 4.11 shows the result after sensor detect temperature lower the range, heat lamp turninig on. Next, Figure 4.12 shows the graft DHT22 sensor graft.

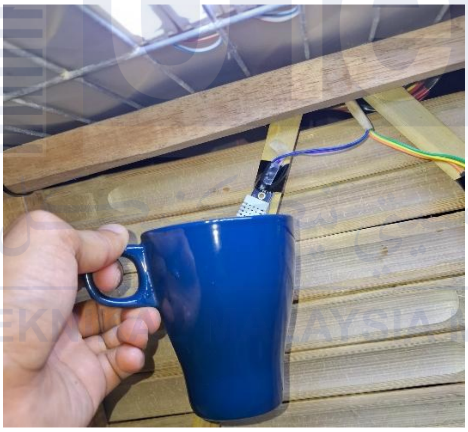


Figure 4.10 The ice's positioning in close proximity to the sensor DHT22

Figure 4.11 Heat lamp turning on

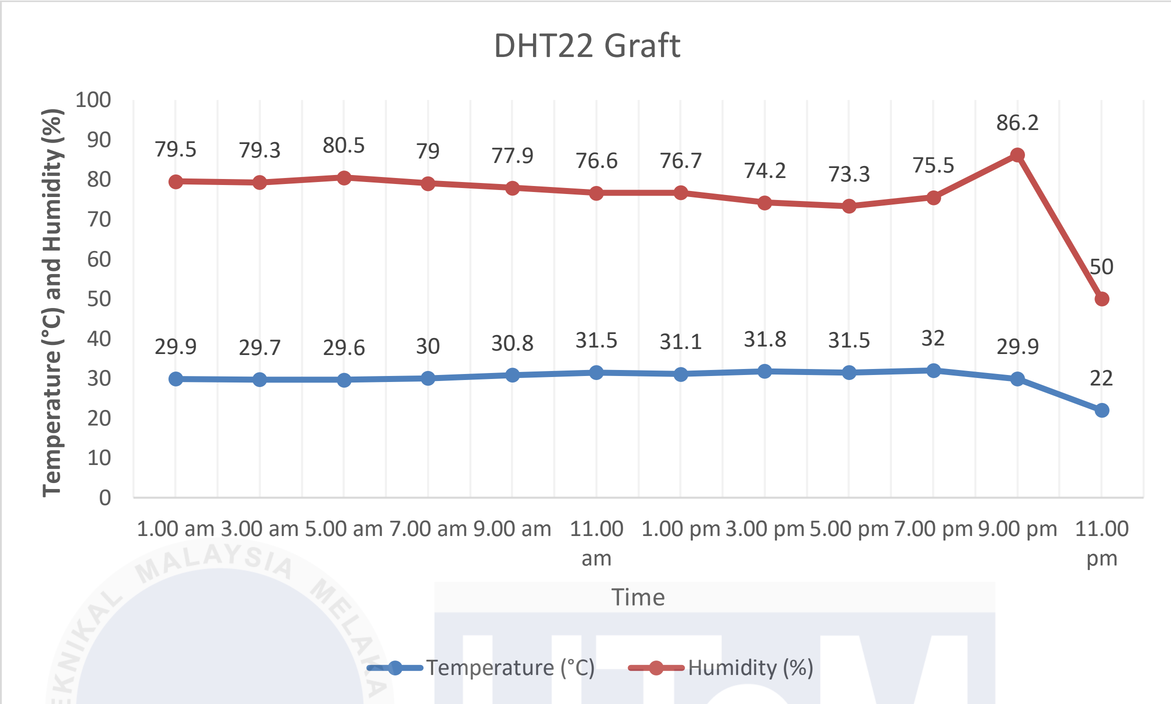


Figure 4.12 DHT22 sensor graft

For chickens aged 14 to 20 days, it is essential to maintain specific environmental conditions to support their growth and health. Humidity must be regulated between 60% and 85%. Humidity levels below 60% might result in dryness and stress in chicks, whilst levels above 85% may induce respiratory problems and promote bacterial proliferation. Therefore, the system must regulate and modify humidity levels throughout the day, employing devices such as humidifiers or dehumidifiers to sustain optimal conditions.

Temperature regulation is similarly crucial for immature chicks. The optimal temperature range for chicks in this age category is between 22°C and 35°C. Should the temperature drop below 22°C, the chicks may suffer from heatstroke, resulting in weakness and slower growth. If the temperature above 35°C, it may induce heat stress, potentially impacting their feeding behaviour and overall growth rate. Consequently, the system must include cooling mechanisms to reduce temperatures during peak heat and heating systems to maintain warmth during the colder early morning or nighttime periods.

To ensure the welfare of the chicks, the environmental management system must be adaptive, able to react to adjustments in temperature and humidity immediately. By continuously observing these factors, the system can engage cooling or heating mechanisms if required, guaranteeing that both temperature and humidity stay within optimal levels. This precise regulation will reduce stress, enhance growth conditions, and improve the overall health and productivity of the chickens during this crucial developmental phase.

4.2.2.2 Gas and Smoke (MQ2) analysis

The MQ-2 sensor was installed in the poultry cage for monitoring air quality, focussing on the detection of smoke and methane levels. The sensor provides measurements in parts per million (ppm), with data collected over a 24-hour period at 1-hour intervals. Table 4.4 shows data collected for gas and smoke in (ppm).

Table 4.4 Data collected for gas and smoke for Case 2

Time	Gas and Smoke (ppm)	Status
12.00 am	362	Normal
1.00 am	357	Normal
2.00 am	298	Normal
3.00 am	200	Normal
4.00 am	316	Normal
5.00 am	343	Normal
6.00 am	365	Normal
7.00 am	365	Normal
8.00 am	367	Normal
9.00 am	383	Normal

10.00 am	367	Normal
11.00 am	402	Normal
12.00 pm	443	Normal
1.00 pm	490	Normal
2.00 pm	336	Normal
3.00 pm	323	Normal
4.00 pm	2645	Butane gas/Abnormal gas
5.00 pm	343	Normal
6.00 pm	337	Normal
7.00 pm	356	Normal
8.00 pm	359	Normal
9.00 pm	343	Normal
10.00 pm	300	Normal
11.00 pm	293	Normal

The MQ2 sensor detected an abnormal increase in gas concentration at precisely 4:00 PM, which implies the presence of flammable gases in the monitored environment. Upon further examination, it appears that this anomaly was the result of an intentional attempt to tamper with the gas readings, potentially by releasing butane gas in close proximity to the sensor or using a gas lighter. This inference is strongly supported by the sudden increase in data values, as such elevated measurements typically occur only when the sensor detects a high concentration of flammable gases, which is consistent with the characteristics of butane or lighter emissions. The MQ2 sensor's responsiveness and sensitivity to gas changes in its environment are emphasised by this incident. Figure 4.13 shows an attempted tampering done by using a gas lighter. Figure 4.14 shows result after abnormal gas detected the exhaust fan running. Last part for Case 2, Figure 4.15 shows the Graft for MQ-2 sensor.

Figure 4.13 Butane gas is directed to the mq2 sensor

Figure 4.14 The exhaust fan running

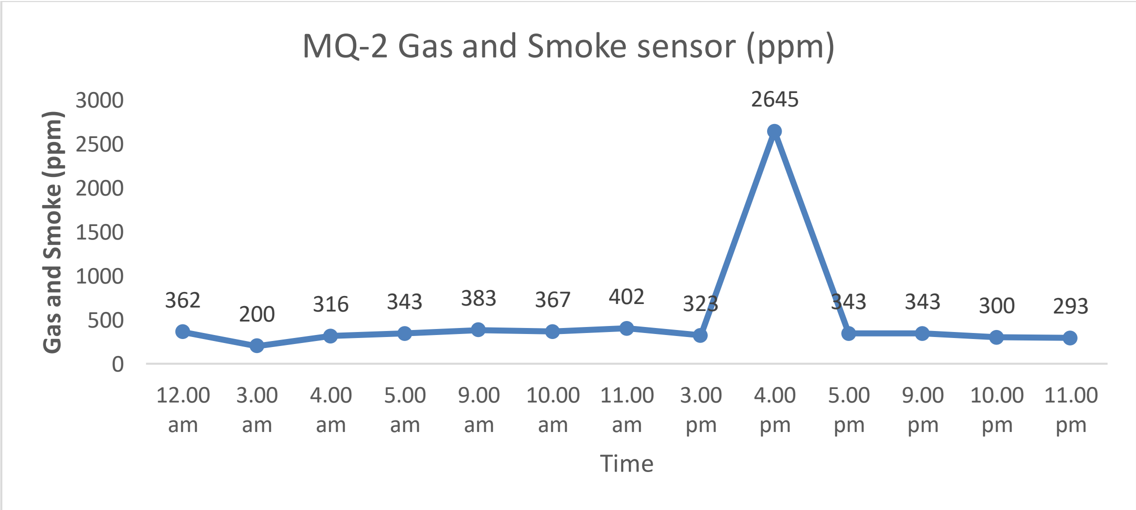


Figure 4.15 Graft for MQ-2 sensor

4.2.3 Case 3 : IoT-Based Remote Monitoring and Control System Evaluation

In Case 3, the system was designed to enable effective data monitoring and remote access by providing real-time sensor readings to the Blynk platform. This system allows users to monitor environmental parameters and identify problems, such as variations in temperature or humidity, providing prompt action to sustain healthy conditions. The system also offers remote control functionalities for essential components, such as fans and heat lamps, allowing users to set up quick modifications as required. The integration of real-time monitoring and control improves system responsiveness and ensures an environment that is stable and secure for the chicken coop.

4.2.3.1 Blynk Application for Monitor and Control system

Blynk system transmits real-time sensor readings to the Blynk platform via a web interface and mobile app for efficient data monitoring and remote access. The Blynk web platform displays real-time environmental data like temperature, gas levels, and exhaust fan and heat lamp condition. Based on Figure 4.15, Figure 4.16, Figure 4.17 and Figure 4.18 shows Blynk web console in fours condition like normal condition, Temperature and Humidity over range, Abnormal Gas detected and Temperature and Humidity bellow range. This interface shows system operation, allowing users to monitor and identify issues.

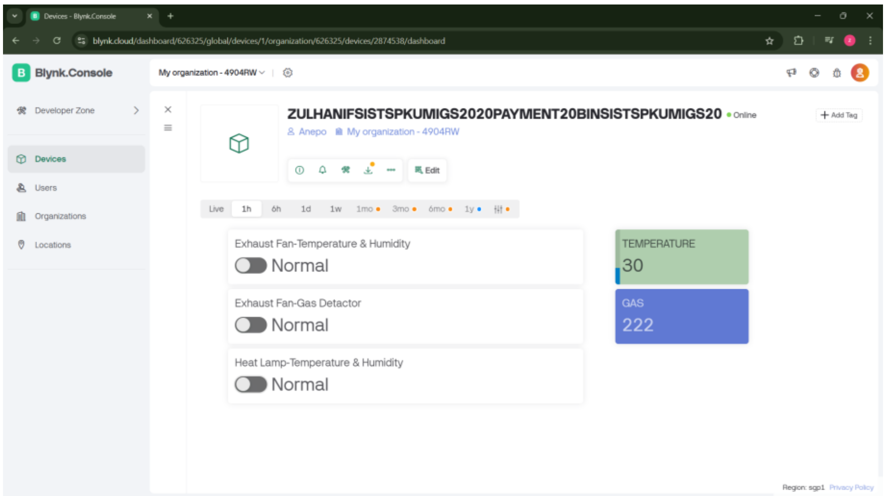


Figure 4.16 Blynk web console in Normal condition

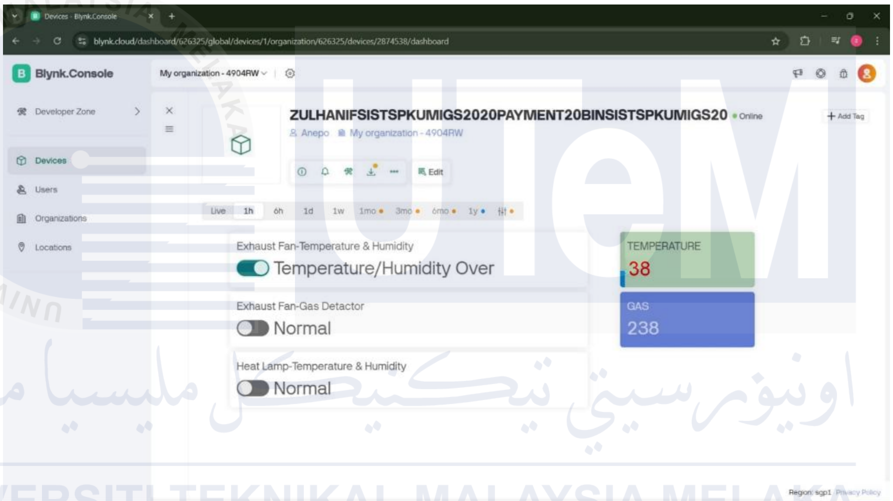


Figure 4.17 Blynk web console in Temperature and Humidity over range

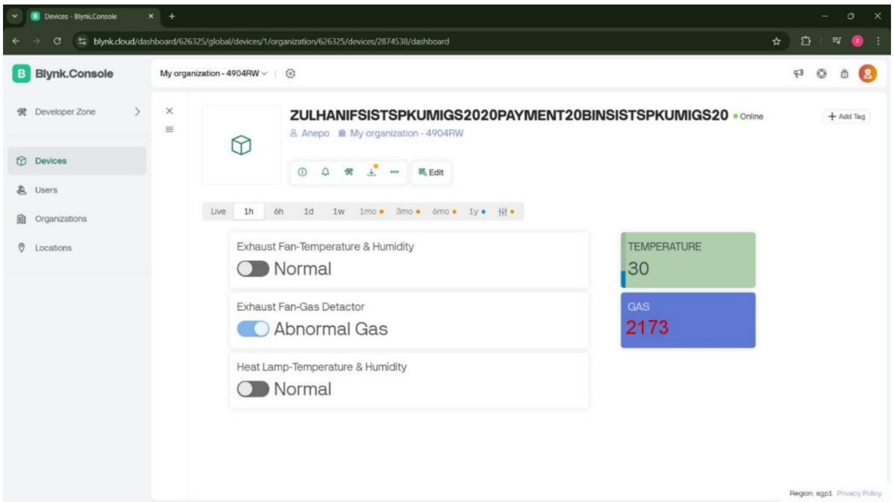


Figure 4.18 Blynk web console in Abnormal Gas detected

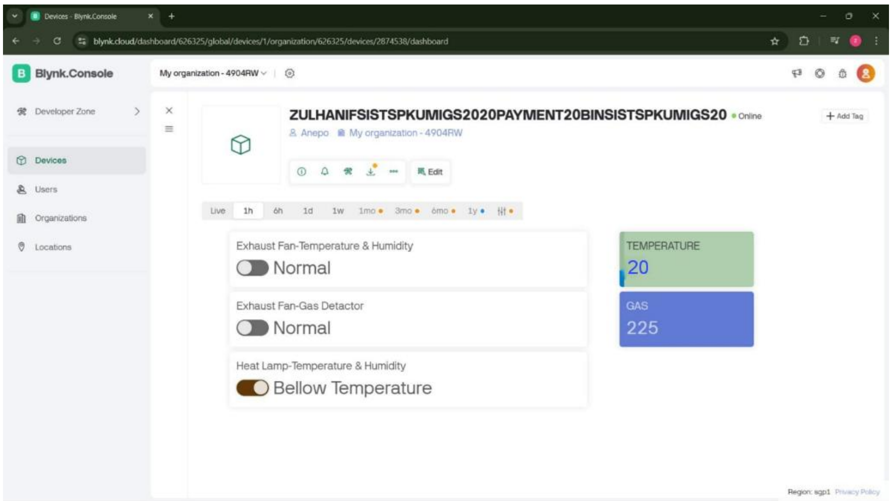


Figure 4.19 Blynk web console Temperature bellow range

Regarding constantly on the move monitoring, the mobile app interface duplicates the web platform in a smaller version. It displays temperature, gas levels, exhaust fan and heat lamp status in real time. The picture for Figure 4.18, Figure 4.19, Figure 4.20 and Figure 4.21 show Blynk mobile application in fours condition like normal condition, Temperature and Humidity over range, Abnormal Gas detected and Temperature and Humidity bellow range. Users can remotely monitor and adjust chicken coop environmental conditions to maximise safety and efficiency with both platforms.

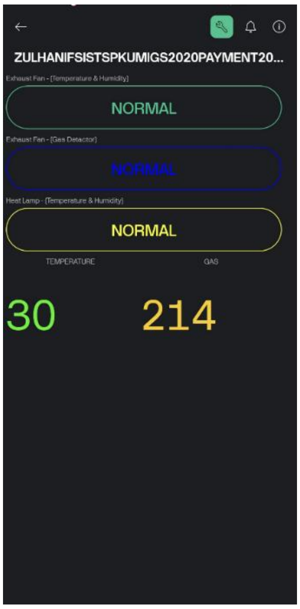


Figure 4.20 Blynk mobile application in Normal condition

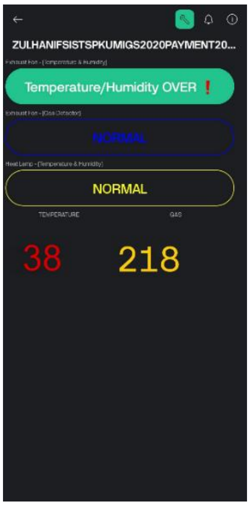


Figure 4.21 Blynk mobile application Temperature and Humidity over range

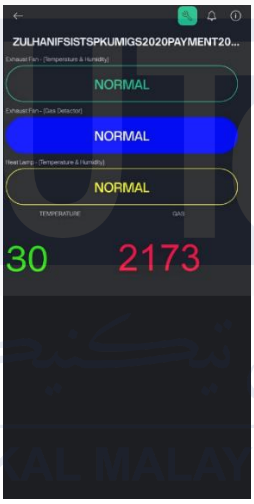


Figure 4.22 Blynk mobile application Abnormal Gas detected

Figure 4.23 Blynk mobile application Temperature bellow range

4.3 Summary

This chapter discusses the integration of an Internet of Things (IoT)-based chicken coop monitoring and control system powered by a photovoltaic (PV) solar generator. It underlines the system's advantages in monitoring environmental conditions and the solar panels' effectiveness in ensuring a consistent power supply. An exhaust fan, a heat lamp, a MQ-2 gas sensor, a DHT-22 temperature and humidity sensor, and an ESP32 module comprise the system. The system's performance is remotely monitored using the Blynk platform, which displays important data on a mobile application. The exhaust fan and heat lamp are regulated by the system to ensure that the optimal conditions are maintained in response to changes in gas levels and temperature. The objective of the initiative is to provide stable electricity supply and effective environmental management, while simultaneously identifying potential issues and managing further improvements through real-time monitoring and control.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the Development of an Internet of Things (IoT) – Based Device for Monitoring and Controlling a Chicken Coop An innovation technology called Photovoltaic Solar uses renewable energy to improve the environmental conditions in chicken coops. The photovoltaic solar power system and the Internet of Things-based monitoring and control system make up the two primary parts of this system. When there is sunlight, the photovoltaic solar system uses that energy to create electricity that powers the control and monitoring equipment and charges the battery bank. The battery the banks stored energy powers the system when sunlight is not available. By employing sensors to continuously measure temperature, humidity, and ammonia levels, the Internet of Things-based system offers an improved method for conventional chicken coop management. The technique places a high value on sustaining the ideal conditions for the chickens, improving both their health and output. This project contributes to sustainable agriculture by reducing energy consumption, minimizing environmental impact, and promoting animal welfare through efficient and automated monitoring and control.

5.2 Revisit the objective

This section will evaluate all objectives achieved for the project entitled Development of an Internet of Things (IoT)–Based Device for Monitoring and Controlling a Chicken Coop Using Photovoltaic Solar Power.

First, the objective to design an IoT-based device to monitor and control the chicken coop using the ESP32 module microprocessor has been achieved. A functioning device was created to facilitate real-time monitoring and regulation of the coop environment. The system includes sensors for temperature and humidity, automated ventilation controls, and real-time data streaming through a mobile application. The streamlined and intuitive design guarantees it satisfies the requirements of poultry growers while providing versatility for diverse coop layouts. This achievement aligns with SDG 9 (Industry, Innovation, and Infrastructure) by promoting innovation in agricultural practices and enhancing infrastructure with IoT technologies.

Second, the objective to develop the proposed prototype powered by a photovoltaic (PV) solar system has been achieved. The device was effectively integrated with solar panels and a battery storage system, guaranteeing continuous functioning during nighttime or low sunlight circumstances. The hardware and software were adeptly integrated to develop an energy-efficient and sustainable solution that corresponds with the project's renewable energy objectives. This supports SDG 7 (Affordable and Clean Energy) by utilizing renewable energy sources and SDG 13 (Climate Action) by reducing reliance on non-renewable energy.

Finally, the objective to evaluate the performance of the IoT-based device for monitoring and controlling the chicken coop has been achieved. The system exhibited precise environmental monitoring, exact control mechanisms, and dependable performance across various conditions. The results validate the device's efficacy and use as a novel method for managing chicken coops. The effective execution advances SDG 12 (Responsible Consumption and Production) by advocating for sustainable agricultural practices.

Overall, the project achieves its goals by delivering a dependable, sustainable, and IoT-enabled system tailored to enhance poultry farming while utilizing solar power efficiently. The combination of IoT and solar technology supports worldwide initiatives for achieving the SDGs via innovation, sustainability, and improved resource management.

5.3 Future Works

Future improvements can be made to the IoT-based chicken coop monitoring and control system as follows:

a) Incorporating a More Advanced Solar Charge Controller. To optimize the energy efficiency of the system, a more advanced solar charge controller can be implemented, such as the Victron Energy SmartSolar MPPT 100/30. This would enhance the system’s capability to charge the battery bank more efficiently, ensuring a more reliable and consistent power supply to the IoT monitoring and control components.

b) Enhancing IoT Integration for Improved Data Collection and Analysis. By expanding the IoT integration, the system can include more advanced data recording techniques for environmental monitoring and control. This could involve systematically capturing and archiving data related to temperature, humidity, gas levels, and battery status, allowing for more comprehensive analysis and predictive maintenance. Utilizing cloud-based storage and advanced data analytics tools will enable farmers to access actionable insights from the system more easily.

c) Integration of Automated Feeding and Drinking Control System. A key area of development is the addition of an automated feeding and drinking control system. IoT sensors will be used to track the levels of food and water, automatically dispensing them based on preset thresholds. This feature would be linked to the existing environmental monitoring system, adjusting feeding schedules based on real-time conditions like temperature, humidity, and ammonia levels, to optimize resource use and maintain the chickens' health.

d) Improving System Efficiency with Renewable Energy. To further enhance the system's sustainability, it would be beneficial to incorporate an energy-efficient power management solution that ensures the photovoltaic system operates optimally even under varying environmental conditions. By enhancing the energy capture and storage processes, the system would achieve greater autonomy, ensuring minimal reliance on external power sources.

e) Developing a Hybrid Monitoring System. In order to enhance the robustness of the system, a hybrid model combining solar power with wind or micro-hydro generation can be considered. This would provide a more consistent energy supply by utilizing multiple renewable energy sources, especially in areas with fluctuating sunlight. The integration of backup energy systems could ensure uninterrupted operation, even in adverse weather conditions.

These future works will contribute to creating a more autonomous, efficient, and sustainable IoT-based solution for poultry management, ensuring optimal conditions for the chickens while reducing energy consumption and improving overall system performance.

5.4 Potential of commercialization

The integration of an Internet of Things (IoT)-based monitoring and control system for chicken coops, powered by a photovoltaic (PV) solar system, offers a strong commercial opportunity, particularly in regions focusing on sustainable agriculture and renewable energy. This system provides a valuable, automated, energy-efficient, and environmentally sustainable alternative for regulating conditions in chicken coops. It contributes in reducing energy use, improving farm operations, and growing animal wellbeing. There is a chance to make money by licensing the technology and collaborating with private enterprises, agritech firms, and agricultural associations. It is crucial to ensure that commercialisation initiatives are aligned with environmental sustainability and animal welfare. This approach emphasises eco-friendly, scalable solutions that generate a successful business model while positively impacting the agriculture sector, promoting sustainable farming methods, and helping the environment and rural people.

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APPENDICES

Appendix A   Full coding in NodeMCU ESP32 module

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File Edit Sketch Tools Help

ESP32 Dev Module

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```
#define BLYNK_TEMPLATE_ID "TMPL6dfC-RdES"
#define BLYNK_TEMPLATE_NAME "MONITOR AND CONTROL CHICKEN COOP PV SOLAR"
#define BLYNK_AUTH_TOKEN "07MTrWaDF-K-OCbjmZcMyqj7D8uaQTIM"

#include <Adafruit_Sensor.h>
#include <DHT.h>
#include <WiFi.h>
#include <BlynkSimpleEsp32.h>
#include <EEPROM.h>

// DHT Sensor Settings
#define DHTPIN 4          // GPIO pin connected to the DHT22
#define DHTTYPE DHT22     // Specify the DHT sensor type
DHT dht(DHTPIN, DHTTYPE);

// Relay and MQ2 Sensor Settings
#define RELAY1_PIN 5          // GPIO pin for Relay 1 (temperature & humidity)
#define RELAY2_PIN 18         // GPIO pin for Relay 2 (gas detection)
#define RELAY3_PIN 19         // GPIO pin for Relay 3 (temperature ≤ 22.1°C)
#define MQ2_PIN 36            // GPIO pin connected to MQ2 sensor's analog output
#define GAS_THRESHOLD 1500    // Abnormal gas threshold value

// WiFi Credentials
char ssid[] = "Anepo";         // Replace with your WiFi SSID
char pass[] = "anepo1998";     // Replace with your WiFi Password

// Relay state variables
int relay1State = 0;  // Relay 1 (V0): 0 = OFF, 1 = ON
int relay2State = 0;  // Relay 2 (V1): 0 = OFF, 1 = ON
int relay3State = 0;  // Relay 3 (V2): 0 = OFF, 1 = ON

void setup() {
  // Initialize Serial Monitor
  Serial.begin(115200);
  dht.begin();  // Initialize the DHT sensor
```


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ESP32 Dev Module
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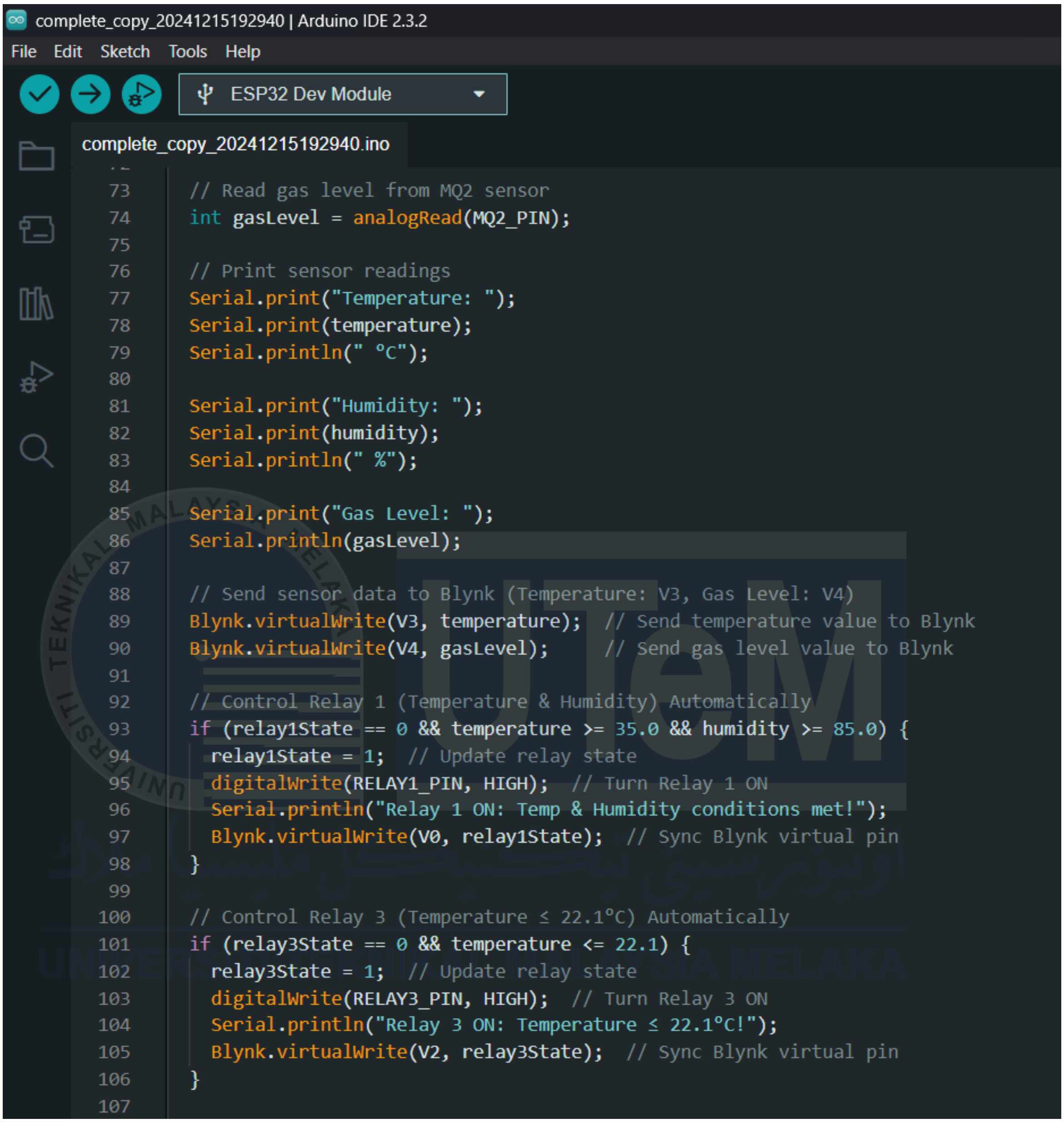
// Initialize relays as outputs
pinMode(RELAY1_PIN, OUTPUT);
pinMode(RELAY2_PIN, OUTPUT);
pinMode(RELAY3_PIN, OUTPUT);
// Set all relays to OFF initially
digitalWrite(RELAY1_PIN, LOW);
digitalWrite(RELAY2_PIN, LOW);
digitalWrite(RELAY3_PIN, LOW);
// Initialize EEPROM (store relay state in EEPROM memory)
EEPROM.begin(512); // Initialize EEPROM with a size of 512 bytes
relay2State = EEPROM.read(0); // Read relay2 state from EEPROM
digitalWrite(RELAY2_PIN, relay2State); // Set Relay 2 to stored state
// Connect to Blynk
Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
Serial.println("System Initialized and Blynk Connected.");
}
void loop() {
Blynk.run(); // Run Blynk
// Wait a few seconds between measurements
delay(2000);
// Read DHT sensor values
float humidity = dht.readHumidity();
float temperature = dht.readTemperature();
// Check if the readings are valid
if (isnan(humidity) || isnan(temperature)) {
Serial.println("Failed to read from DHT sensor!");
return;
}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ESP32 Dev Module
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// Read gas level from MQ2 sensor
int gasLevel = analogRead(MQ2_PIN);
// Print sensor readings
Serial.print("Temperature: ");
Serial.print(temperature);
Serial.println(" °C");
Serial.print("Humidity: ");
Serial.print(humidity);
Serial.println(" %");
Serial.print("Gas Level: ");
Serial.println(gasLevel);
// Send sensor data to Blynk (Temperature: V3, Gas Level: V4)
Blynk.virtualWrite(V3, temperature); // Send temperature value to Blynk
Blynk.virtualWrite(V4, gasLevel); // Send gas level value to Blynk
// Control Relay 1 (Temperature & Humidity) Automatically
if (relay1State == 0 && temperature >= 35.0 && humidity >= 85.0) {
relay1State = 1; // Update relay state
digitalWrite(RELAY1_PIN, HIGH); // Turn Relay 1 ON
Serial.println("Relay 1 ON: Temp & Humidity conditions met!");
Blynk.virtualWrite(V0, relay1State); // Sync Blynk virtual pin
}
// Control Relay 3 (Temperature ≤ 22.1°C) Automatically
if (relay3State == 0 && temperature <= 22.1) {
relay3State = 1; // Update relay state
digitalWrite(RELAY3_PIN, HIGH); // Turn Relay 3 ON
Serial.println("Relay 3 ON: Temperature ≤ 22.1°C!");
Blynk.virtualWrite(V2, relay3State); // Sync Blynk virtual pin
}

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File Edit Sketch Tools Help

ESP32 Dev Module

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```
  // Control Relay 2 (Gas Detection) Automatically or Manually
  if (gasLevel >= GAS_THRESHOLD && relay2State == 0) {
    relay2State = 1;  // Update relay state
    digitalWrite(RELAY2_PIN, HIGH);  // Turn Relay 2 ON (Gas detected)
    Serial.println("Relay 2 ON: Abnormal gas detected!");
    Blynk.virtualWrite(V1, relay2State);  // Sync Blynk virtual pin
    EEPROM.write(0, relay2State);  // Store the relay state in EEPROM
    EEPROM.commit();  // Commit the change to EEPROM
  }
  else if (gasLevel < GAS_THRESHOLD && relay2State == 1) {
    relay2State = 0;  // Update relay state
    digitalWrite(RELAY2_PIN, LOW);  // Turn Relay 2 OFF (Gas levels normal)
    Serial.println("Relay 2 OFF: Gas levels normal.");
    Blynk.virtualWrite(V1, relay2State);  // Sync Blynk virtual pin
    EEPROM.write(0, relay2State);  // Store the relay state in EEPROM
    EEPROM.commit();  // Commit the change to EEPROM
  }
}

// Blynk control for Relay 1 (V0) - Manually control from Blynk App
BLYNK_WRITE(V0) {
  relay1State = param.asInt();  // Get value from Blynk
  digitalWrite(RELAY1_PIN, relay1State);
  Serial.print("Relay 1 manually set to: ");
  Serial.println(relay1State ? "ON" : "OFF");
}

// Blynk control for Relay 2 (V1) - Manually control from Blynk App
BLYNK_WRITE(V1) {
  relay2State = param.asInt();  // Get value from Blynk
  digitalWrite(RELAY2_PIN, relay2State);  // Manually control Relay 2
  Serial.print("Relay 2 manually set to: ");
  Serial.println(relay2State ? "ON" : "OFF");
  EEPROM.write(0, relay2State);  // Store the relay state in EEPROM
  EEPROM.commit();  // Commit the change to EEPROM
}
```

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ESP32 Dev Module

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```
  // Control Relay 2 (Gas Detection) Automatically or Manually
  if (gasLevel >= GAS_THRESHOLD && relay2State == 0) {
    relay2State = 1;  // Update relay state
    digitalWrite(RELAY2_PIN, HIGH);  // Turn Relay 2 ON (Gas detected)
    Serial.println("Relay 2 ON: Abnormal gas detected!");
    Blynk.virtualWrite(V1, relay2State);  // Sync Blynk virtual pin
    EEPROM.write(0, relay2State);  // Store the relay state in EEPROM
    EEPROM.commit();  // Commit the change to EEPROM
  }
  else if (gasLevel < GAS_THRESHOLD && relay2State == 1) {
    relay2State = 0;  // Update relay state
    digitalWrite(RELAY2_PIN, LOW);  // Turn Relay 2 OFF (Gas levels normal)
    Serial.println("Relay 2 OFF: Gas levels normal.");
    Blynk.virtualWrite(V1, relay2State);  // Sync Blynk virtual pin
    EEPROM.write(0, relay2State);  // Store the relay state in EEPROM
    EEPROM.commit();  // Commit the change to EEPROM
  }
}

// Blynk control for Relay 1 (V0) - Manually control from Blynk App
BLYNK_WRITE(V0) {
  relay1State = param.asInt();  // Get value from Blynk
  digitalWrite(RELAY1_PIN, relay1State);
  Serial.print("Relay 1 manually set to: ");
  Serial.println(relay1State ? "ON" : "OFF");
}

// Blynk control for Relay 2 (V1) - Manually control from Blynk App
BLYNK_WRITE(V1) {
  relay2State = param.asInt();  // Get value from Blynk
  digitalWrite(RELAY2_PIN, relay2State);  // Manually control Relay 2
  Serial.print("Relay 2 manually set to: ");
  Serial.println(relay2State ? "ON" : "OFF");
  EEPROM.write(0, relay2State);  // Store the relay state in EEPROM
  EEPROM.commit();  // Commit the change to EEPROM
}
```

```

// Blynk control for Relay 3 (V2) - Manually control from Blynk App
BLYNK_WRITE(V2) {
  relay3State = param.asInt();  // Get value from Blynk
  digitalWrite(RELAY3_PIN, relay3State);
  Serial.print("Relay 3 manually set to: ");
  Serial.println(relay3State ? "ON" : "OFF");
}

```