SIDDAGANGA INSTITUTE OF TECHNOLOGY, TUMAKURU-572103

(An Autonomous Institute under Visvesvaraya Technological University, Belagavi)

Project Report on

"DESIGN AND DEVELOPMENT OF A SMART LOW COST SOLAR-OPERATED HYDROPONICS FODDER SYSTEM"

submitted in partial fulfillment of the requirement for the completion of V semester of

BACHELOR OF ENGINEERING

in

ELECTRONICS & COMMUNICATION ENGINEERING

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

CERTIFICATE

Certified that the mini project work entitled "DESIGN AND DEVELOPMENT OF A SMART LOW COST SOLAR-OPERATED HYDROPONICS FODDER SYSTEM" is a bonafide work carried out by ANJALI S (1SI23EC003), CHANDANA B S (1SI23EC022), DHANUSH N (1SI23EC035) and H PARIMALA (1SI23EC043) in partial fulfillment for the completion of V Semester of Bachelor of Engineering in Electronics & Communication Engineering from Siddaganga Institute of Technology, an autonomous institute under Visvesvaraya Technological University, Belagavi during the academic year 2025-26. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the department library. The Mini project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering degree.

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Course Outcomes

CO1: To identify a problem through literature survey and knowledge of contemporary engineering technology.
CO2: To consolidate the literature search to identify issues/gaps and formulate the engineering problem
CO3: To prepare project schedule for the identified design methodology and engage in budget analysis, and share responsibility for every member in the team
CO4: To provide sustainable engineering solution considering health, safety, legal, cultural issues and also demonstrate concern for environment
CO5: To identify and apply the mathematical concepts, science concepts, engineering and management concepts necessary to implement the identified engineering problem
CO6: To select the engineering tools/components required to implement the proposed solution for the identified engineering problem
CO7: To analyze, design, and implement optimal design solution, interpret results of experiments and draw valid conclusion
CO8: To demonstrate effective written communication through the project report, the one-page poster presentation, and preparation of the video about the project and the four page IEEE/Springer/ paper format of the work
CO9: To engage in effective oral communication through power point presentation and demonstration of the project work
CO10:To demonstrate compliance to the prescribed standards/ safety norms and abide by the norms of professional ethics
CO11: To perform in the team, contribute to the team and mentor/lead the team
Attainment level: - 1: Slight (low) 2: Moderate (medium) 3: Substantial (high)
POs: PO1: Engineering Knowledge, PO2: Problem analysis, PO3: Design/Development of solutions, PO4: Conduct investigations of complex problems, PO5: Modern tool usage, PO6: Engineer and the world, PO7: Ethics, PO8: Individual and collaborative team work, PO9: Communication, PO10: Project management and finance, PO11: Lifelong learning

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO-1											3		3
CO-2		3										3	
CO-3											3		3
CO-4						3	3						3
CO-5	3	3										3	
CO-6					3								3
CO-7			3	3								3	
CO-8										3			3
CO-9										3			3
CO-10								3					3
CO-11									3				3
Average	3	3	3	3	3	3	3	3	3	3	3	3	3

Abstract

The rising demand for livestock feed, combined with the limitations of traditional fodder cultivation such as the need for large land areas, continuous labor, and favorable weather poses major challenges for small and rural farmers. Conventional fodder farming typically requires 8–10 m^2 of land and consumes up to 80–90 liters of water per kilogram of fodder and requires about 3 months of growth, making it resource-intensive and unsustainable in regions facing land and water scarcity. These constraints often result in irregular and inconsistent fodder production, especially during dry or off-season periods.

To address these issues, this project focuses on the design and development of a smart, solar-operated hydroponic fodder system, which is a soilless cultivation technique that enables consistent, year-round fodder production within 8 days of growth. The system requires only 1–1.5 m^2 of space and uses up to 80%–90% less water than traditional methods, making it highly efficient and sustainable.

The system utilizes an ESP32 microcontroller integrated with DHT11 sensors to monitor temperature and humidity in real time. Based on these readings, the ESP32 controls actuators such as a relay, water pump to maintain optimal growing conditions. The microcontroller is powered through a solar panel and battery setup, ensuring energy-efficient. Additionally, through the ESP32's built-in Wi-Fi capability, system status are communicated to a Telegram bot for remote monitoring and alerts on the farmer's mobile device. The entire system is programmed using the Arduino IDE, integrating sensors, actuators, and a solar-assisted power supply to create an automated, reliable, and eco-friendly hydroponic fodder growing solution.

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Chapter 1

Introduction

Livestock farming depends heavily on the continuous availability of nutritious green fodder. However, conventional fodder cultivation requires large land areas, a constant water supply, and favorable climatic conditions, making it unsustainable for small and rural farmers. Traditional systems consume nearly 80–90 litres of water per kilogram of fodder and occupy around 8–10 m^2 of land, which often leads to inconsistent production, especially in regions facing water shortages and land constraints.

To overcome these limitations, hydroponic fodder cultivation provides an innovative and sustainable solution. It is a soilless technique that grows plants using a water instead of soil, thereby saving up to 80%–90% of water and requiring only 1–1.5 m^2 of space for small-scale fodder production . This makes the approach ideal for resource-limited and off-grid rural environments.

Table 1.1: Comparison of Traditional and Hydroponic Fodder Cultivation

Parameter	**Traditional Fodder**	**Hydroponic Fodder**
Land Required	8–10 m^2 per kg	1–1.5 m^2 per kg
Growth Time	60–70 days	7–10 days
Water Consumption	80–90 L/kg fodder	8–10 L/kg fodder
Soil Requirement	Soil required	No soil required
Fertilizers	Required	Not required
Climate Dependency	Highly dependent on weather and rainfall	Grown in controlled environment

Comparison of Traditional and Hydroponics Fodder Cultivation is shows in Table 1.1 Hydroponic fodder production is an efficient alternative to conventional fodder cultivation as it enables controlled environmental conditions and rapid plant growth. Maintaining temperatures around 25–30 °C and relative humidity levels of 65–78% ensures healthy and consistent fodder development. Hydroponic systems typically use about 1 kg of seeds per tray, with germination occurring within 24–36 hours. Fodder can be harvested within 7–8 days, producing nutritionally rich feed for livestock.

1.1 Motivation

Fodder production plays a vital role in livestock farming, as the quality and availability of green feed directly affect animal health and overall productivity. Traditional methods of cultivating fodder demand large areas of land, consume significant amounts of water, and depend heavily on seasonal conditions. These limitations make conventional fodder cultivation less suitable for small and marginal farmers who often face constraints in land, labor, and environmental stability. As a result, there is a growing need for more efficient, year-round, and low-maintenance alternatives for producing fresh fodder.

Hydroponic fodder cultivation provides a practical alternative by eliminating the need for soil and relying on controlled moisture through simple water-misting. Seeds can be grown in a compact space of about 1–1.5 m^2, enabling farmers to produce sufficient fodder even in areas where land availability is minimal, achieving up to 99.97% land savings compared to traditional methods. Additionally, hydroponic systems use 80–90% less water, making them highly suitable for rural and off-grid regions where water scarcity is a major concern.

1.2 Objectives

- To integrate temperature and humidity sensors for monitoring and maintaining optimal growth conditions.
- To automate system operations (pump and misting) using sensor feedback for efficient fodder production.
- To monitor system performance remotely by sending sensor data through a Telegram bot.

1.3 Organisation of the report

The Report is organized into seven chapters. The objectives and motivation of the project are outlined in Chapter 1.Literature Survey that presents a through overview of previous research on similar projects in Chapter 2. The project's system overview and block diagram of the project is found in Chapter 3. System hardware that includes all hardware components is discussed in Chapter 4. The software implementation of the system is included in Chapter 5. The results and findings are found in Chapter 6. Conclusions of the project is included in Chapter 7.

Chapter 2

Literature Survey

Hydroponic fodder and smart farming systems have evolved steadily over the past two decades. Earlier works focused on understanding basic plant responses, whereas recent research has expanded into automation, renewable energy, IoT control. The following review summarizes these contributions

Different hydroponic fodder production systems used for livestock feeding were reviewed, as reported by R. Sneath and F. McIntosh et al. [1]. The study explained the basic working principle of growing fodder without soil using controlled water and nutrients. It highlighted rapid growth cycles of 7–10 days with high biomass yield. The review also discussed advantages such as reduced land and water usage. However, it noted that system cost and energy consumption are key challenges in large-scale adoption.

The production methods and nutritional benefits of hydroponic green fodder for livestock were examined, reported by P.K. Naik et al. [2]. The study reported improved digestibility, higher nutrient availability, and enhanced growth performance in livestock. The system was shown to require significantly less land and water compared to conventional fodder cultivation. It was particularly suitable for drought-prone and fodder-scarce regions. Overall, the findings confirmed hydroponic fodder as an efficient and sustainable feeding alternative.

A smart hydroponic farming system powered by renewable energy sources was developed to support sustainable agriculture, as presented by H. Kim et al. [3]. The system continuously monitored temperature, humidity, and water levels using sensors. Automated control mechanisms maintained optimal growing conditions throughout the cultivation cycle. The use of renewable energy significantly reduced dependence on grid power and lowered operational costs. The study demonstrated the feasibility of efficient, sustainable, and year-round hydroponic farming.

M.B. Fernandes et al. investigated optimization techniques for hydroponic greenhouse cultivation using controlled environmental parameters [4]. Their study demonstrated that maintaining a stable temperature of around 27°C and relative humidity close to 65% inside the hydroponic chamber supports healthy plant growth. The use of sensor feedback and automated pump control ensured that water was supplied only when required, resulting in improved efficiency and reduced energy consumption.

R. Uchiyama et al. developed a weather-forecast-based solar-powered hydroponic cultivation system to improve energy efficiency and crop reliability [5]. The system utilized weather prediction data to manage solar power generation and schedule irrigation and nutrient supply. By forecasting variations in sunlight and climate conditions, energy utilization was optimized and power wastage was reduced. Automated control mechanisms helped maintain stable growing conditions under changing weather. The study demonstrated the effectiveness of combining weather forecasting with solar-operated hydroponic systems for sustainable farming.

An AI-based solar-sharing smart lighting system was developed to enhance lighting efficiency in hydroponic cultivation. M. Bernardo et al. [6] proposed an intelligent method to distribute available solar energy for controlling artificial lighting based on plant requirements. Machine learning algorithms were used to optimize light intensity and exposure duration, ensuring healthy plant growth. This approach reduced overall energy consumption and decreased dependence on grid electricity. The study demonstrated improved sustainability and energy efficiency in smart hydroponic systems.

Z. Zakaria et al. developed a cloud-powered platform to evaluate and manage energy usage in hydroponic systems. The platform collected operational and power-consumption data and analyzed it remotely using cloud services [7]. Real-time analytics helped identify energy inefficiencies and optimize system performance. The approach supported better decision-making for renewable energy integration. The study highlighted the role of cloud computing in improving the energy efficiency of smart hydroponic farming systems.

A solar-integrated hydroponic greenhouse designed for semi-arid regions was developed, as reported by S. Bezari et al. [8]. The system combined solar power with automated controls for irrigation, cooling, and environmental monitoring. It optimized water and energy usage while maintaining ideal growing conditions. The approach reduced reliance on conventional energy and conserved land and water resources. The study demonstrated sustainable and efficient hydroponic cultivation suitable for challenging climates.

An MPPT-enabled solar tracking array specifically for hydroponic applications was developed, as presented by C.C. Kang et al. [9]. The system combined maximum power point tracking with automated solar tracking to maximize energy harvesting. Real-time control ensured efficient power delivery to pumps and control units. The design improved overall energy efficiency under varying sunlight conditions. The study demonstrated reliable and sustainable power support for solar-operated hydroponic systems.

M. Balah et al. developed a solar-powered hydroponic system for microgreens to enable sustainable small-scale cultivation [10]. The system integrated solar energy with automated irrigation and nutrient management. Real-time monitoring ensured optimal growth conditions for microgreens. Energy efficiency was improved by relying primarily on renewable solar power. The study demonstrated that solar-powered hydroponics can support high-quality, resource-efficient microgreen production.

2.1 Summary of Literature Survey

The reviewed literature highlights significant advancements in hydroponic fodder and smart hydroponic farming systems, particularly through the integration of automation, renewable energy, and intelligent control techniques. Early studies focused on understanding basic hydroponic principles and fodder growth cycles, demonstrating rapid biomass production within short durations of 7–10 days while significantly reducing land and water usage. Subsequent research emphasized the nutritional benefits of hydroponic green fodder, reporting improved digestibility, higher nutrient availability, and enhanced livestock performance compared to conventional fodder cultivation. Studies have demonstrated that sensor-based monitoring and automated control of environmental parameters such as temperature, humidity help maintain optimal growth conditions, improve resource efficiency, and reduce manual intervention. The integration of solar energy significantly reduces dependence on grid power and operating costs, making such systems suitable for off-grid and rural areas. Advanced techniques including weather forecasting, cloud computing, machine learning, AI-based lighting, and MPPT-enabled solar tracking further enhance energy efficiency and system sustainability. Overall, the literature confirms that the integration of automation and renewable energy with hydroponic systems enables efficient, reliable, and low-cost fodder production.

Chapter 3

System Overview

The hydroponic fodder system automate the monitoring and control of essential environmental parameters required for healthy fodder growth. The system continuously tracks temperature, humidity sensors, while the microcontroller automatically manages misting and watering cycles to maintain optimal conditions. IoT connectivity enables real-time monitoring through a mobile application, ensuring efficient, reliable, and low-maintenance fodder production.

3.1 System Block Diagram

The block diagram (Figure 3.1) represents the working of the Smart Solar-Operated Hydroponic Fodder System. The system is designed to automate the monitoring and control of environmental parameters such as temperature and humidity, ensuring ideal growing conditions for hydroponic fodder.

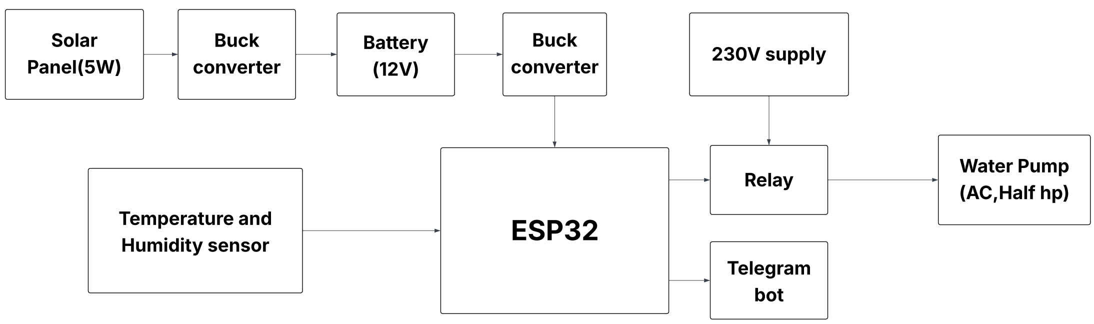

Figure 3.1: Block diagram of the hydroponic system

The system begins with a 5W solar panel, which serves as the primary power source. The energy from the solar panel is regulated by a buck converter to charge a 12V battery. This battery stores energy for continuous operation, especially during low sunlight or nighttime conditions. Another buck converter steps down the 12V supply from the battery to a stable voltage suitable for powering the ESP32 microcontroller.

The DHT11 temperature and humidity sensor is connected to the ESP32 to measure the real-time environmental conditions inside the hydroponic chamber. The sensor readings are continuously monitored by the ESP32, which processes the data and decides whether the system conditions are within the desired thresholds.

When the temperature exceeds the preset limit or humidity drops below the threshold, the ESP32 sends a control signal to the relay module. The relay acts as a switch to activate the AC water pump ($\frac{1}{2}$ HP), which provides misting or watering to maintain optimal moisture and temperature. The relay ensures isolation between the low-voltage control circuit and the high-voltage AC power circuit for safe operation.

The system also includes a Telegram bot interface, connected via the ESP32's built-in Wi-Fi. It allows the system to send live updates and alerts to the farmer's mobile device, keeping them informed of environmental changes and system actions.

Overall, the system integrates renewable solar energy, real-time sensing, and automated control to create a sustainable and efficient solution for continuous fodder production with minimal human intervention.

Chapter 4

System Hardware

The system hardware includes the microcontroller, sensors, and supporting modules that help in collecting data, processing it, and performing the required actions. Each component plays its own role, and together they ensure the system operates reliably and efficiently. This section explains the hardware used and how it supports the overall functioning of the project.

4.1 ESP32

The ESP32 (Figure 4.1) is a low-cost, low-power microcontroller developed by Espressif Systems. It comes with built-in Wi-Fi and Bluetooth, multiple GPIO pins, and advanced peripherals, making it ideal for smart automation projects such as the smart solar-operated hydroponic fodder system.

In this project, the ESP32 microcontroller serves as the central control unit responsible for processing sensor data and operating the water pump. The DHT11 sensor's data pin is connected to GPIO 4 of the ESP32, enabling real-time acquisition of temperature and humidity readings. The relay module, which controls the AC water pump, is interfaced with GPIO 15, allowing the ESP32 to automatically switch the pump ON or OFF based on environmental conditions. The board is powered through the 3V3 (3.3V) input pin, supplied from a regulated DC output of the buck converter, while the GND pin provides a common ground connection shared with all system components.

The ESP32 operates at an internal voltage of 3.3 volts, derived from the 3.3V input through its onboard voltage regulator. During normal operation, it draws a current of approximately 100 to 160 milliamperes (mA), with peak consumption reaching up to 250 mA during processing or peripheral activity. This low current requirement makes the ESP32 highly energy-efficient, which is advantageous for solar-powered applications like hydroponic system. The overall power consumption of the controller remains below 0.5 watts, ensuring minimal energy usage while maintaining reliable automation and sensing performance.

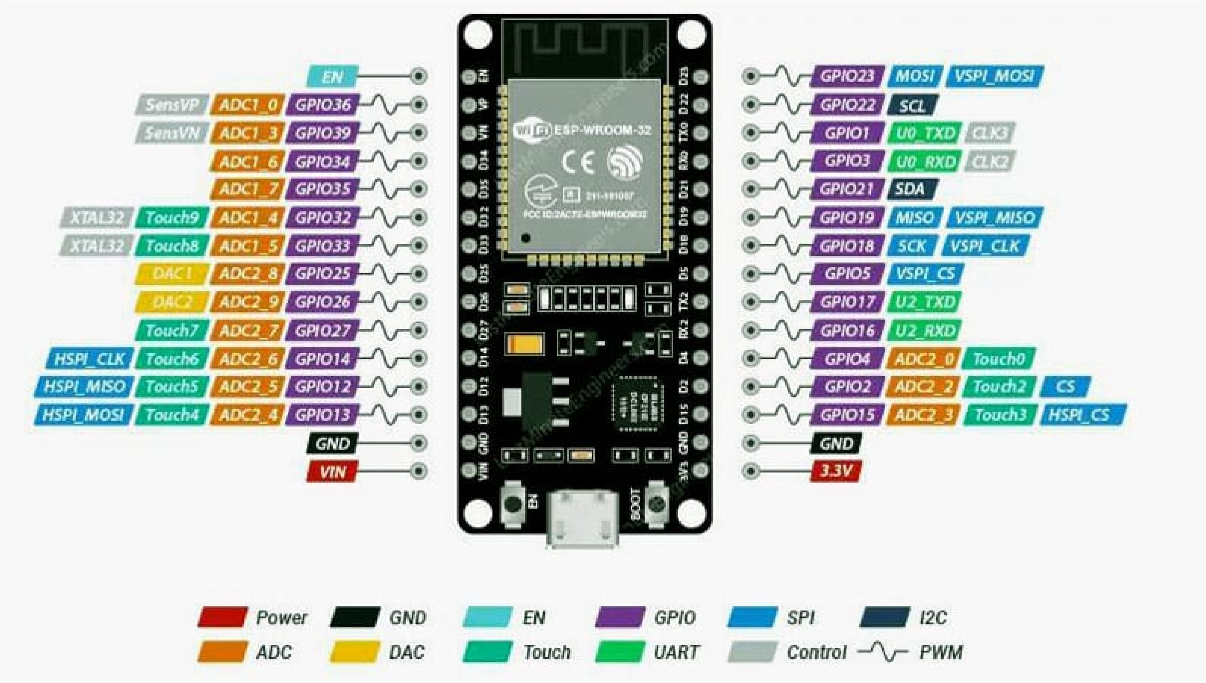

Figure 4.1: ESP32 development board

Hardware Specifications:

- **Operating Voltage:** 3.3 V DC
- **Input Voltage (3V3):** 3.3 V (regulated via buck converter)
- **Current Consumption:** 80–250 mA
- **GPIO Pins:** 30 (configurable as input/output)
- **Analog Inputs (ADC):** 12-bit ADC on multiple pins
- **PWM Channels:** Up to 16
- **Flash Memory:** 4 MB
- **SRAM:** 520 KB
- **Operating Temperature:** –40°C to +85°C
- **DHT11 Sensor (Data Pin): GPIO 4**
- **Relay Module: GPIO 15**
- **Power Input: 3V3 (3.3 V)** pin.

4.2 Solar Photovoltaic (PV) Panel

The solar panel (Figure 4.2) serves as the primary renewable power source for the smart solar-operated hydroponic fodder system.The 5W solar panel produces an output voltage of approximately 18V DC under standard sunlight conditions. This voltage is regulated by a buck converter, which steps it down to 12V DC to safely charge the 12V rechargeable battery. The stored energy is then used to supply 3.3V DC to the ESP32 controller, DHT11 sensor, and relay module through a secondary buck converter.

The ESP32 and sensor section consume around 100–160 mA of current during operation, while the relay circuit draws an additional small amount of current when activated. The water pump, rated at 0.5 HP (370 W), is powered directly by the 230V AC mains supply and is not connected to the solar system. It is automatically switched ON or OFF by the relay, which receives a control signal from the ESP32.

This configuration ensures that the control and sensing parts are solar-powered and energy-efficient, while the high-power water pump operates reliably using external AC supply, achieving a balanced and sustainable system design.

Figure 4.2: Solar Photovoltaic (PV) panel

4.3 DHT11 Temperature and Humidity Sensor

The DHT11 (Figure 4.3) is a low-cost, reliable digital sensor used for measuring temperature and relative humidity in the environment.The sensor continuously monitors the chamber environment and sends data to the ESP32 microcontroller.The DHT11 consists of two key components-a capacitive humidity sensing element and an NTC thermistor for temperature measurement. These components are integrated with an internal 8-bit microcontroller that processes the analog readings and converts them into a digital signal. This allows the sensor to communicate directly with the ESP32 using a single data pin, simplifying the overall circuit design. In the hydroponic fodder system, the DHT11 is powered through the 3.3-5V supply pin of the ESP32, and its data pin is connected to GPIO 4. The sensor draws less than 2.5 mA of current during operation, which is extremely low, making it highly energy-efficient for solar-based systems. The sensor continuously sends digital data to the ESP32 in a 40-bit format-16 bits for humidity, 16 bits for temperature, and 8 bits for checksum (error detection). Based on these readings, the ESP32 compares the values with preset threshold levels and decides whether to activate or deactivate the water pump via the relay module.The DHT11 maintains stable temperature and humidity inside the hydroponic chamber, ensuring healthy and rapid fodder growth.

Figure 4.3: Temperature and Humidity Sensor

Hardware Specifications:

- **Operating Voltage:** 3.3 V - 5.0 V DC
- **Operating Current:** less than 2.5 mA
- **Range:** Temperature-0°C – 50°C and Humidity-20% – 90% RH
- **Output Type:** Digital (single-wire serial)

4.4 AC Water Pump

The water pump (Figure 4.4) is one of the key components of the smart solar-operated hydroponic fodder system. Its primary function is to circulate water throughout the hydroponic chamber, ensuring the fodder receives adequate moisture for proper growth.
In this project, the AC water pump operates directly from the 230V AC mains supply, as its power requirement is too high for solar operation. The pump typically draws 1.5 to 2.0 amperes of current during normal operation, corresponding to a power consumption of approximately 350 to 400 watts. The pump is not continuously running,it is activated only when the temperature or humidity level drops below a predefined threshold detected by the DHT11 sensor.
The ESP32 microcontroller does not power the pump directly; instead, it sends a control signal to the relay module, which acts as an electronic switch between the microcontroller and the AC power line. When triggered, the relay closes the circuit, allowing current to flow to the pump. Once the desired humidity or temperature level is reached, the relay opens, cutting off power to the pump.
This approach improves the overall efficiency and dependability of the hydroponic system. It ensures uniform water circulation across all trays, promoting faster and healthier fodder growth. The automatic control mechanism reduces human effort and minimizes water wastage. As a result, the system operates smoothly with consistent performance and reliable output.

Figure 4.4: AC Water Pump

4.5 Buck Converter

Buck converters (Figure 4.5) play a key role in regulating voltage levels for the system. They step down higher DC voltages to safer and usable levels required by different components.

- First Buck Converter

Input: Around 18V DC coming from the solar panel
Output: 12V DC
Role: This converter prepares the solar power for charging the 12V battery and running any devices that operate directly at 12 volts. It ensures stable and controlled charging without overloading the battery.

- Second Buck Converter

Input: 12V DC from the battery
Output: 5V DC
Role: This converter provides a stable 5 V supply for low-voltage electronics such as the ESP32 controller and the DHT11 sensor. It ensures a steady and regulated voltage, protecting sensitive components and enabling reliable operation of the control and monitoring system.

Figure 4.5: Buck Converter

Chapter 5

System Software

This chapter describes the Software requirements,Flowchart, and Algorithm used for the implementation of the Smart Solar-Operated Hydroponic Fodder System.

5.1 Software Requirements

Programming, debugging, and executing the automation system require both application-level and embedded-level resources. The Arduino Integrated Development Environment (IDE) is used to develop and upload the control program to the ESP32 microcontroller. The Arduino IDE provides a user-friendly interface that allows code compilation, debugging, and serial monitoring to ensure correct system operation.

The software continuously reads data from the DHT11 sensor, compares the measured values with the predefined threshold levels, and then controls the relay module connected to the AC water pump. When environmental parameters go beyond the desired range, the program automatically triggers the pump and misting system to restore proper conditions. The system then returns to a monitoring mode once ideal conditions are achieved.

Software Requirements

- Arduino IDE for programming and uploading code to the ESP32 microcontroller.
- ESP32 board package installed in Arduino IDE (via ESP32 board manager).

Required libraries such as:

- **WiFi.h Library** – provides Wi-Fi connectivity to the ESP32 for establishing network communication.
- **WiFiClientSecure.h Library** – enables secure HTTPS communication between the ESP32 and Telegram servers for sending updates and alerts.
- **DHT.h Library** – used for interfacing with the DHT11 sensor to measure real-time temperature and humidity values.

- **Arduino Core Library** – provides essential functions for pin control, timing, and communication between ESP32 and connected hardware components.
- **String and Serial Libraries (Built-in)** – used for handling text data, debugging, and displaying sensor readings via the serial monitor.

5.2 Flowchart

The Flowchart (Figure 5.1) represents the operational workflow of the Smart Solar-Operated Hydroponic Fodder System. The system is designed to automate the process of maintaining optimal environmental conditions—specifically temperature and humidity—required for the consistent growth of fodder. The workflow begins when the system is powered on, and the ESP32 microcontroller loads the control program. Once initialized, the ESP32 starts collecting real-time data from the DHT11 temperature and humidity sensor, which continuously measures the surrounding environmental parameters inside the hydroponic chamber.

After the data is acquired, the ESP32 compares the measured temperature and humidity with the predefined threshold values set for ideal fodder growth. If the temperature is below the threshold or the humidity is above the threshold, the system interprets this as a favorable condition for fodder development. In this case, the system simply monitors the existing conditions without activating the misting or water pump units. However, if the temperature exceeds the upper limit or the humidity falls below the required range, the ESP32 sends a control signal to the relay module, which in turn activates the water pump and misting system. This action bringing the environment back to the optimal range for plant growth.

Once the environmental parameters are stabilized, the system automatically switches off the pump and misting units to conserve energy and water. The updated temperature and humidity data are then transmitted to the ESP32, which further sends this information to the Telegram bot for remote monitoring. This feature allows the farmer or user to receive live updates regarding the environmental conditions of the hydroponic chamber without needing to be physically present.

This automated loop continues indefinitely, ensuring that the internal environment remains favorable for the continuous production of nutritious green fodder. The process significantly reduces human labor, prevents resource wastage, and maintains a balanced ecosystem inside the growth chamber. The combination of real-time sensing, automatic control, and remote data communication enables the system to operate efficiently and sustainably, making it highly suitable for small-scale farmers, especially in rural and off-grid areas.

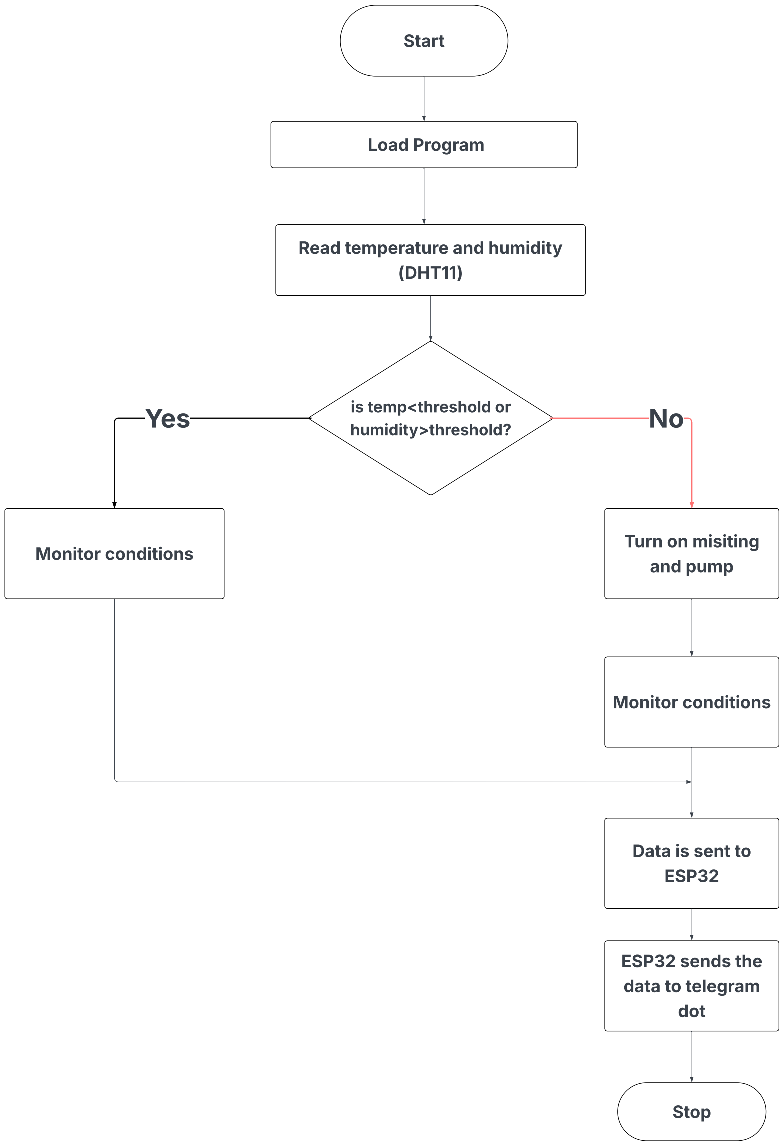

Figure 5.1: Flowchart

5.3 Algorithm

The following algorithm describes the logical sequence followed by the system for automated hydroponic fodder growth.

1. Start the system.
2. Load the program and initialize all components, including the microcontroller, DHT11 temperature and humidity sensor, relay module, and ESP32 Wi-Fi module.
3. Read the temperature and humidity values from the DHT11 sensor.
4. Compare the sensed values with predefined threshold limits (Temperature = 30°C, Humidity = 75%).
5. If the temperature is within the limit and humidity is sufficient, continue monitoring the environmental conditions.
6. If the temperature exceeds the threshold or humidity falls below the threshold, turn ON the relay-controlled misting system and water pump.
7. Run the water pump for a fixed duration to restore optimal environmental conditions.
8. Turn OFF the water pump after the required duration.
9. Send the temperature, humidity, and system status data to the ESP32 module.
10. ESP32 transmits the data to the Telegram bot for remote monitoring.
11. Repeat the monitoring and control process continuously for automated operation.
12. Stop the system (only when power is turned OFF).

This algorithm ensures that the system maintains ideal moisture stable environmental conditions, and provides real-time wireless monitoring without requiring human intervention.

Chapter 6

Results

The system performed effectively and achieved all of its intended Objectives, showing stable and dependable operation during testing. Each major feature such as automated control, accurate sensor measurements, and smooth data communication worked as expected. Overall, the results indicate that the system functions well in real-world conditions and offers a solid base for future enhancements or scaling.

1. Automatic water pumping achieved: The water pump successfully operates automatically based on sensor inputs, ensuring proper moisture levels without manual control.

2. Fodder growth has been successfully achieved confirming that the system operates effectively under the implemented conditions.

3. Mobile application integration implemented enabling monitoring of system parameters.

6.1 Experimental Result

Figure 6.1 shows hydroponic fodder system was arranged using eight trays, placed as four trays in each row across two rows to ensure uniform layout. The tray dimensions of $22 \times 16 \times 2.5$ inches provided sufficient surface area for even seed spreading and effective moisture retention during germination. The shallow depth supported proper aeration and prevented water stagnation. Across the various growth stages, the seeds exhibited consistent sprouting and strong root development in all trays. Uniform shoot emergence was observed due to equal watering and controlled environmental conditions. The arrangement allowed synchronized growth across both rows with minimal variation between trays. By the final stage, dense green fodder mats had formed, indicating healthy fodder production. The results confirm that the selected tray layout and dimensions were appropriate for achieving rapid and uniform hydroponic fodder growth.

Figure 6.1: Front view of the model

Figure 6.2 shows the stages of hydroponic fodder growth, starting from seed soaking and germination to dense, fully developed green fodder.

Seed Soaking (Pre-Germination): Before placing the seeds in trays, they are soaked in clean water for approximately **8–12 hours**. This soaking process activates germination by softening the seed coat and initiating metabolic activity inside the seed.

Day 1 – Initial Germination (Figure 6.1 (a)): On the first day, the soaked seeds are spread evenly in the trays. Initial germination begins, and small white sprouts start emerging from the seeds, indicating successful activation.

Day 2 – Early Sprouting (Figure 6.1 (b)): By the second day, sprouts become more visible and uniform across the tray. Root hairs start developing, and moisture is maintained through periodic misting.

Day 3 – Root Development (Figure 6.1 (c)): Roots grow longer and begin forming a thin root mat. Small green shoots start appearing above the seeds, showing healthy early-stage growth.

Day 4 – Shoot Emergence (Figure 6.1 (d)): Green shoots increase in height and density. Root interlinking improves, providing better support and stability to the fodder mat.

Day 5–6 – Rapid Vegetative Growth: During this stage, leaves grow rapidly and turn brighter green due to active photosynthesis. The root mat becomes thicker, enhancing water and nutrient absorption.

Day 7 – Dense Green Fodder (Figure 6.1 (e)): By the seventh day, the fodder reaches a harvestable stage. Dense green shoots and a well-developed root mat are observed, indicating high nutritional value.

Day 8 – Fully Mature Fodder (Figure 6.1 (f)): Between the eighth and tenth day, the fodder achieves full maturity with uniform growth across all trays. At this stage, the fodder is rich in moisture, protein, and enzymes, making it suitable for livestock feeding.

Overall, the uniform growth observed across all trays confirms that the automated misting system and environmental control conditions were effective throughout the cultivation period.

The system produces adequate biomass such that one fully grown hydroponic fodder tray per day is sufficient to feed one cattle, ensuring fresh and nutritious fodder supply.

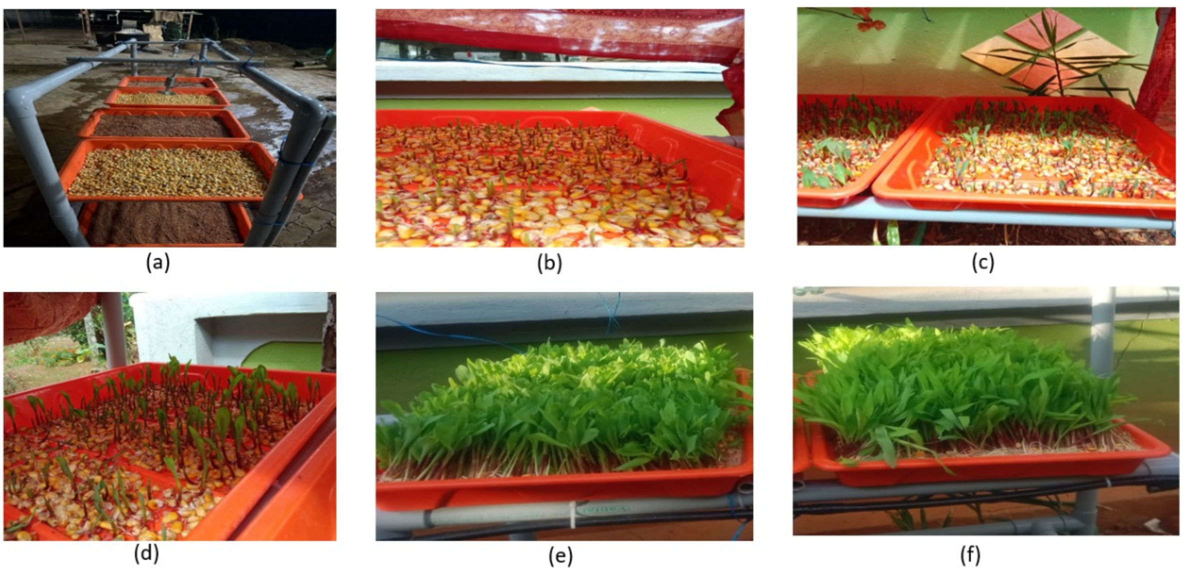

Figure 6.2: Stages of hydroponics fodder growth.
(a) first day growth, (b) second day growth, (c) third day growth,
(d) fourth day growth, (e) seventh day growth, (f) eighth day growth

Figure 6.3 shows the Telegram bot notifications generated by the ESP32-based control system, displaying real-time temperature and humidity readings along with the motor status. The notifications indicate automatic control actions such as motor ON/OFF operation, manual override commands, and periodic sensor updates, enabling effective remote monitoring of the hydroponic chamber.

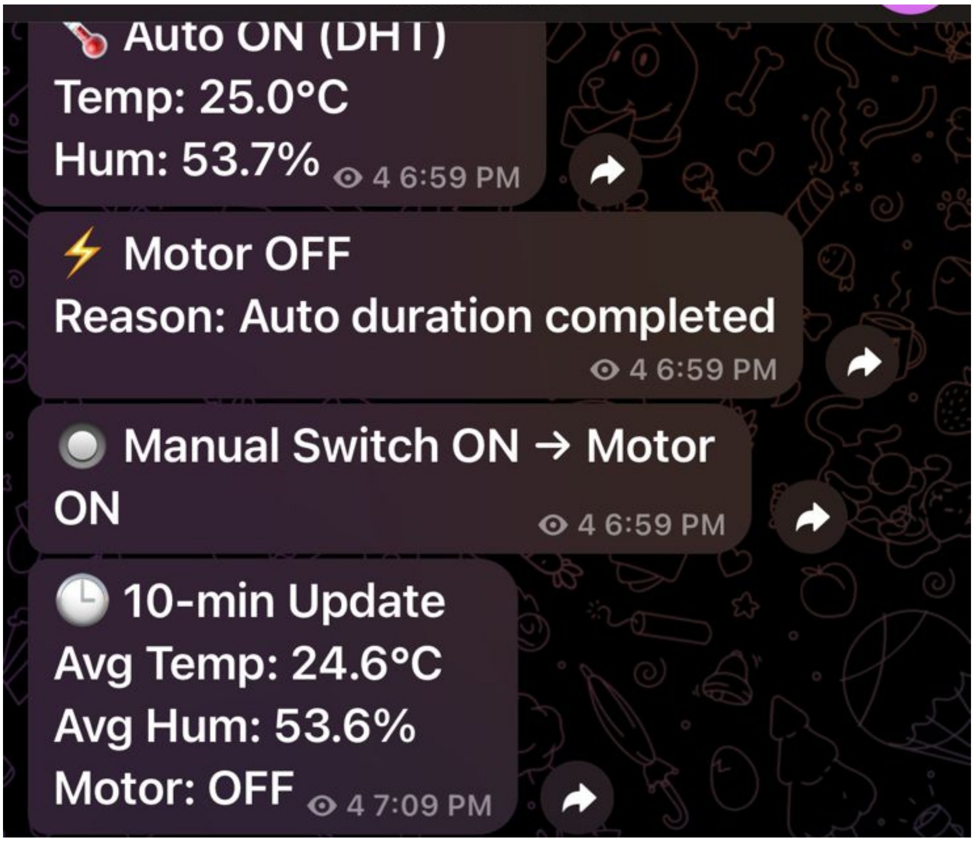

Figure 6.3: Telegram bot notifications displaying sensor readings and motor status

Figure 6.4 shows the automatic sensor reading received through the Telegram bot, indicating a temperature of 25.0 °C and a relative humidity of 53.7 % inside the hydroponic chamber. Since the humidity level is below the preset threshold, the control system initiates the misting operation to increase moisture and maintain optimal growth conditions.

Figure 6.4: Telegram bot notification when motor is ON

Figure 6.5 shows the Telegram bot notification indicating that the water pump is automatically switched OFF after the predefined misting duration is completed, ensuring controlled water usage and preventing over-watering inside the hydroponic chamber.

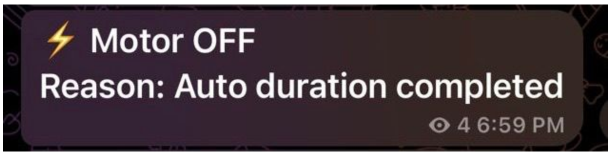

Figure 6.5: Telegram bot notification when motor is OFF

Figure 6.6 illustrates the Telegram bot notification generated when the motor is manually switched ON, allowing the user to override the automatic control during maintenance or special operating conditions.

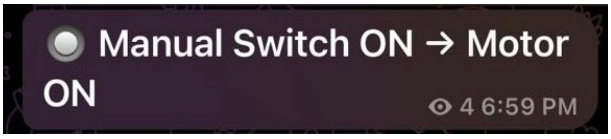

Figure 6.6: Telegram bot notification when the switch is manually ON

Chapter 7

Conclusion

The Smart Low-Cost Solar-Operated Hydroponic Fodder System integrates automation, renewable energy, and environmental sensing to provide an efficient and sustainable method for growing livestock fodder throughout the year. The system employs the ESP32 microcontroller as its core, which interfaces with sensors and actuators to continuously monitor and control environmental parameters such as temperature and humidity. By automating the misting and watering process through real-time sensor data, the system ensures optimal growth conditions while minimizing manual labor and resource usage.

The inclusion of the DHT11 temperature and humidity sensor enables accurate environmental monitoring, while the relay-controlled AC water pump regulates water flow based on threshold conditions. The solar power supply combined with a battery backup ensures continuous operation even in areas with limited electricity access, making the system particularly suitable for rural and off-grid applications. Additionally, the use of the Telegram bot allows real-time alerts and remote supervision, providing farmers with instant updates on system performance and environmental changes.

Extensive testing of the system demonstrated reliable and consistent operation, with significant reductions in both land usage and water consumption compared to traditional fodder cultivation. The automated control process not only improves the efficiency of fodder production but also ensures the availability of nutrient-rich, fresh green feed for livestock regardless of climatic conditions.

Bibliography

[1] R. Sneath and F. McIntosh, "Review of hydroponic fodder systems," *Queensland Government Technical Report*, vol. 2, no. 1, pp. 1–14, 2003.

[2] P. K. Naik, B. K. Swain, and N. P. Singh, "Production and utilization of hydroponic green fodder," *Indian Journal of Animal Nutrition*, vol. 31, no. 4, pp. 15–20, 2014.

[3] H. Kim, I. Kim, J.-W. Seo, and J. Ko, "Smart renewable-energy-powered hydroponic farming," *Renewable Agriculture and Food Systems*, vol. 12, no. 3, pp. 1–10, 2017.

[4] M. B. Fernandes, B. A. Costa, and J. M. Lemos, "Hydroponic greenhouse crop optimization," in *Proc. 13th APCA Int. Conf. Automatic Control and Soft Computing (CONTROLO)*, Ponta Delgada, Portugal, pp. 270–275, 2018.

[5] R. Uchiyama, "Weather-forecast-based solar-powered hydroponic cultivation system," *IEEE Journal of Emerging Agricultural Technologies*, vol. 1, no. 1, pp. 22–29, 2019.

[6] M. Bernardo, "AI-based solar-sharing smart lighting for hydroponics," *IEEE Transactions on Sustainable Computing*, vol. 7, no. 2, pp. 130–138, 2022.

[7] Z. Zakaria, "Cloud-powered energy evaluation platform for hydroponics," *Energy Informatics in Smart Agriculture*, vol. 2, no. 3, pp. 65–73, 2022.

[8] S. Bezari, "Solar-integrated hydroponic greenhouse for semi-arid regions," *Sustainable Agriculture Systems*, vol. 6, no. 2, pp. 50–58, 2023.

[9] C. C. Kang, "MPPT-enabled solar tracking array for hydroponics," *Renewable Energy Automation Journal*, vol. 4, no. 2, pp. 112–120, 2024.

[10] M. Balah, "Solar-powered hydroponic system for microgreens," *International Journal of Sustainable Agriculture*, vol. 11, no. 1, pp. 55–62, 2025.

[11] The Engineering Projects, *ESP32 Pinout, Datasheet, Features and Applications*, Available at: https://www.theengineeringprojects.com/2020/12/esp32-pinout-datasheet-features-applications.html, Accessed: 2025.

[12] Robu.in, *18V 20W 36-Cell Solar Panel (54 × 46 cm)*, Available at: https://robu.in/product/18v-20w-36-cell-solar-panel-54-x-46-cm/, Accessed: 2025.

[13] *Temperature and Humidity Sensor*, Available at: https://www.waveshare.com/temperature-humidity-sensor.htm, Accessed: 2025.

[14] Aqua Nature Online, *Brushless AC Submersible Water Pump (ACP-532)*, Available at: https://www.aquanatureonline.com/product/marine-aqua-brushless-frequency-conversion-ac-pumpwater-pumpsubmersible-pumpreturn-pumpcontrollable-pumpaquarium-pump-acp-532/, Accessed: 2025.

[15] ADIY Electronics, *LM2596 DC–DC Step-Down Buck Converter (5V)*, Available at: https://adiy.in/shop/lm2596-step-down-dc-dc-buck-converter-5v/, Accessed: 2025.

Appendices

Appendix A

Sustainable Development Goals addressed

#	SDG	Level
1	No Poverty	1
2	Zero Hunger	3
3	Good Health and Well-being	1
4	Quality education	1
5	Gender equality	1
6	Clean water and Sanitation	2
7	Affordable and Clean Energy	3
8	Decent work and Economic Growth	2
9	Industry, Innovation and Infrastructure	3
10	Reduced Inequalities	1
11	Sustainable cities and Communities	2
12	Responsible Consumption and production	3
13	Climate action	2
14	Life below water	1
15	Life on Land	3
16	Peace, Justice and Strong Institutions	1
17	Partnership's for the Goals	1

Levels: Poor:1, Good :2, Excellent:3

Appendix B

Self-Assesement of the Project

Table 2.1: PO and PSO Mapping

#	PO / PSO	Project Contribution	Level
1	Engineering Knowledge	Applies electronics and IoT basics.	3
2	Problem Analysis	Analyzes and automates process.	3
3	Design/Development of Solutions	Designs ESP32-based system.	3
4	Investigation of Complex Problems	Observes system conditions.	2
5	Modern Tool Usage	Uses Arduino and IoT tools.	3
6	Engineer and Society	Supports sustainable farming.	2
7	Ethics	Follows safe practices.	2
8	Individual and Team Work	Works individually and in team.	2
9	Communication	Communicates technical outcomes.	2
10	Project Management and Finance	Manages cost and resources.	2
11	Life-long Learning	Enhances IoT knowledge.	3
1	PSO1	Applies embedded systems skills.	3
2	PSO2	Implements automation solutions.	3

PSO1:Apply the concepts of electronic circuits and systems to analyses and design systems related to Microelectronics, Communication, Signal processing and Embedded systems for solving real world problems

PSO2:To identify problems in the area of communication and embedded systems and provide efficient solutions using modern tools/algorithms working in a team

Levels: Poor:1, Good :2, Excellent:3

Appendix C

Data Sheet of ESP32

Table 3.1: Technical Specifications of ESP32

Parameter	**Description**
Processor	Xtensa LX6 dual-core microcontroller, up to 240 MHz
Memory	520 KB SRAM
Flash Storage	4 MB Flash memory
Operating Voltage	3.3 V DC (not 5 V tolerant)
Current Consumption	80–250 mA (depending on load)
Wireless Connectivity	Wi-Fi (802.11 b/g/n, 2.4 GHz) and Bluetooth (BLE + Classic)
GPIO Pins	Up to 30 digital I/O pins
ADC & PWM	12-bit ADC channels and up to 16 PWM outputs
Communication Interfaces	UART, SPI, I^2C, CAN
Application in Project	Sensor monitoring, relay control, and wireless data transmission

Appendix D

Data Sheet of Solar Photovoltaic (PV) Panel

Table 4.1: Technical Specifications of Solar Photovoltaic (PV) Panel

Parameter	**Description**
Panel Type	Polycrystalline Solar PV Panel
Rated Power	5 W
Output Voltage	Approximately 18 V DC under standard sunlight conditions
Output Current	Approximately 0.27 A at peak power
Energy Source	Renewable solar energy
Voltage Regulation	Buck converter used to step down voltage to 12 V DC
Battery Charging	Charges a 12 V rechargeable battery
Application in Project	Supplies power to ESP32, DHT11 sensor, and relay control circuit
System Role	Enables off-grid and energy-efficient operation of the system

Appendix E

Data Sheet of DHT11 Sensor

Table 5.1: Technical Specifications of DHT11 Sensor

Parameter	**Description**
Sensor Type	Digital temperature and humidity sensor
Operating Voltage	3.3 V – 5.0 V DC
Operating Current	Less than 2.5 mA
Temperature Range	0°C to 50°C
Humidity Range	20% – 90% RH
Temperature Accuracy	$\pm 2C$
Humidity Accuracy	±5% RH
Output Type	Digital (single-wire serial communication)
Application in Project	Monitoring temperature and humidity for automatic pump control

Appendix F

Data Sheet of Buck Converter

Table 6.1: Technical Specifications of Buck Converter

Parameter	**Description**
Converter Type	DC–DC Buck (Step-Down) Converter
Input Voltage (Stage 1)	Around 18 V DC from solar panel
Output Voltage (Stage 1)	12 V DC for battery charging
Input Voltage (Stage 2)	12 V DC from battery
Output Voltage (Stage 2)	5 V DC for control electronics
Efficiency	High efficiency (typically 85–95%)
Application in Project	Voltage regulation for ESP32, DHT11 sensor, and relay module
System Role	Ensures stable and safe power supply to low-voltage components

Appendix G

Data Sheet of AC Water Pump

Table 7.1: Technical Specifications of AC Water Pump

Parameter	**Description**
Pump Type	AC Water Pump
Rated Power	0.5 HP
Supply Voltage	230 V AC
Current Consumption	Approximately 1.5–2.0 A during operation
Power Consumption	Around 350–400 W
Operating Mode	Intermittent (controlled through relay)
Control Method	Relay controlled by ESP32 microcontroller
Application in Project	Circulates water for misting and moisture control in fodder trays
System Role	Provides uniform water distribution for healthy fodder growth